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The Role of Information and Communication Technology (ICT) in Agriculture Productivity in India

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ABSTRACT

The study examined the role of ICT in agricultural productivity in India. It also analyzed the determinants of agricultural productivity. The causality test indicated the existence of long-run causality running from ICT and agricultural growth (AG) to economic growth. It showed bi-directional causality between agricultural growth and GDP. The long-run causality from ICT to AG was however uni-directional, implying the significance of ICT in agricultural growth. The determinants of agricultural productivity growth revealed increased machinery usage, investment in ICT, gross domestic capital formation and area under cultivation to be significantly contributing to increased productivity growth. The study suggests strengthening the effective implementation of ICT usage in Indian agriculture.

1. Introduction

Information communication technology assumes a vital role in the performance of all sectors of an economy. Information technology (IT) has emerged as a new factor of production. Modern agriculture has came to increasingly depend on information and communication technology, which includes information technology devices communication equipments and softwares. In developed nations, it has transformed the image of agriculture sector by raising efficiency in agricultural production, through its new information tools. Agricultural activities in these countries are based on web-linked database on different types of information, like climate, various Government schemes, price and demand information, and technical knowledge about farming (Rao 2007). It also has the potential to enhance the productivity and efficiency of agriculture sector, especially in developing countries.

India is mainly an agricultural economy, which plays a vital role in the socio-economic fabric of the country. She is the fourth largest exporter of agricultural commodities, accounting for 10 percent of the country's exports. The sector contributed nearly 14 percent of the Gross Domestic Production (GDP). The agriculture and allied sectors has increased the value added from 137.17 US billion dollar in the financial year 2007 to 259.23 US billion dollar in the financial year 2016, accounting for 89.01 percent growth over the eight years period (Central Statistical Organization 2016). Besides, Approximately 60 percent of the country's population depends on agriculture sector for their employment and livelihood.

Literature on the effects of ICT on agricultural growth has been mixed. Kramer and Dedrick (1994) found a positive relationship between IT investment and productivity growth inAsia Pacific countries for 1984-1990. Dewan and Kramu (1998) found that while IT investment was positively and significantly associated in developed countries, it was not significant in developing nations. Based on cross-country study, Pohjola (2000-02) reported a significant role played by ICT in economic growth of the developed countries. Timmer and Van (2008) observed investment in ICT to have significantly increased productivity, besides reducing transaction costs in developed countries. Ekanayake (2010) found agriculture production directed towards exports markets to be positively affected by investment in ICT sector. Erumban and Das (2015) concluded that the role of ICT investments was limited to the service sector, and was successful in raising the overall growth in India, but could not spread its spillover effects across the country. Against this backdrop, the objective of the present paper are:-

1. to examine the trends in ICT, agriculture growth and economic growth in India;
2. to analyze the casual relationship among ICT, agricultural growth and economic growth; and
3. to analyze the influence of ICT and other factors on agricultural productivity.

2. Method and Data

The data for the study are collected from the Department of Telecommunication and Planning Commission, government of India. The methodology adopted for studying the trends are simple averages, percentages, ratios, growth rates, diagrams and regression analysis. Cointegration and error correction model have been used for analyzing the casual relationship between ICT, agricultural share to GDP and economic growth in India. Investment in telecommunication industry and GDP at factor cost have been taken as the proxies for ICT and economic growth respectively.

The analysis is based on a system of equations, including the variables ICT, economic growth and agriculture share to GDP, all expressed in log form under the vector auto regression (VAR) model. The model is based on the following set of equations:-

$$\Delta LEG_t = \alpha_0 + Z_1 EC1_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta LEG_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta LAG_{t-i} + \sum_{i=1}^{p} \alpha_{3i} \Delta LICT_{t-i} + \varepsilon_{1t} \quad (1)$$

$$\Delta \text{LAG}_t = \beta_0 + Z_2 EC2_{t-1} + \sum_{i=1}^{p} \beta_{1i} \Delta LAG_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta LEG_{t-i} + \sum_{i=1}^{p} \beta_{3i} \Delta LICT_{t-i} + \varepsilon_{2t} \quad (2)$$

$$\Delta \text{LICT} = \gamma_0 + Z_3 EC3_{t-1} + \sum_{i=1}^{p} \gamma_{1i} \Delta LICT_{t-i} + \sum_{i=1}^{p} \gamma_{2i} \Delta LEG_{t-i} + \sum_{i=1}^{p} \gamma_{3i} \Delta LAG_{t-i} + \varepsilon_{3t} \quad (3)$$

where, z_1 , z_2 and z_3 are the coefficients of error-correction terms in the equations (1), (2) and (3) respectively. These coefficients are expected to capture the long-run causality among the variables LEG, LAG and LICT. Whereas, ΔLEG_{t-i} , ΔLAG_{t-i} and $\Delta LICT_{t-i}$ are expected to capture the short-run causality among the variables.

Ordinary least square (OLS) multiple regression analysis has been adopted to estimate the influence of ICT and other factors on agricultural productivity. The first difference of the variables were taken. This is because all variables are I (1). The variables included in the regression model are growth rate of agricultural productivity, growth rate of investment in ICT, growth rate of net irrigated land, growth rate of gross domestic capital formation in agriculture sector, growth rate of agricultural machinery per 100 square kilometer of arable land, growth rate of area under cultivation and growth rate of value-added by labour. Growth rate of agricultural productivity is used as the dependent variable and the rest of the variables comprise the independent variables in the estimated multiple regression. To identify the influence of ICT and other factors on agricultural productivity, the following equation has been estimated:-

GAPDY = β_0 + β_1GRICT + β_2GIRLD + β_3GGDCF +β_4GMACH+ β_5GARCL+ β_6GVLAD + u

Where,

GAPDY = agricultural productivity growth rate;

GRICT = investment in ICT growth rate;

GIRLD = irrigated land growth rate;

GGDCF = gross domestic capital formation growth rate;

GMACH = machinery usage growth rate;

GARCL = area under cultivation growth rate;

GVLAD = value-added by labour growth rate;

u = error term; and

β = the slope coefficients.

Here, β is known as the regression coefficient, which is estimated using the principle of ordinary least squares.

3. Results and Discussion

Table-1 shows trends in GDP, share of agriculture in GDP and investment in telecommunication industry. The table shows that GDP of India increased from Rs. 789,506 crores in 1980 to Rs. 6,261,150 crores in 2015, rising at an average of Rs. 2709191.5 crores during the study period 1980 to 2015.GDP grew at an average growth rate of 30.13 percent during the same period. India's GDP growth rate increased continuously from 1990, 28.93 percent upto the 2010, 51.20 percent but decreased to 27.30 percent in 2015. The global economic slowdown in U.S.A which came in the same period may be reason for decline in GDP growth during the period 2010-15. The share of agriculture sector to GDP increased from Rs. 285,015 crores in 1980 to Rs. 872,624 crores in 2015, with moderate fluctuations upto 2005. It rose at an average growth rate of Rs. 15.21 percent during the study period 1980 to 2015. As regards investment in telecommunication sector, it increased from Rs. 1883 crores in 1980 to Rs. 45621 crores in 2015, rising at an average of Rs. 18267.875 crores during the period 1980 to 2015. Investment in telecommunication sector grew at an average of 52. 09 percent during the same period. The table-1 also shows that GDP of India during 1980-90 grew at an average growth rate of 19.98 percent during the period 1980-90. It increased from Rs. 3,160,261 crores in pre-1991 period to Rs. 18,513,271 crores in post-1990 with a significant average growth rate of 36.22 percent in the post-reforms period against the combined average growth rate of 34.43 percent. The share of agriculture sector to GDP increased from Rs. 10,16602 crores in pre-1991 period to Rs. 31,54807 crores in the post-1990, grew at an average growth rate of 17.06 percent in the post-reforms period against the combined average growth rate of 17.37 percent. Investment in telecommunication sector increased from Rs. 11,516 crores in pre-1991 period to Rs. 13,4627 crores in the post-1990 period, grew at an average of 49.11 percent in the post-reforms period against combined average growth rate of 59.53 percent.

Table-2 shows descriptive statistics of all variables in pre-1991, post-1990 and total study period (1980-2015). It is observed that the series of LEG, LAG and LICT are normally distributed in all three periods. This is confirmed by the Jarque-Bera statistics, which cannot reject the null hypothesis of normal distribution at one percent level of significance.

Table-3 gives information on ICT tools used in agricultural activities in India. The efficiency of the model has been tested for the presence of serial correlation and heteroscedaticity, besides normality of residuals. Breusch-Godfry serial correlation test has been used to verify the presence of serial correlation. The test shows no evidence of no serial correlation in the model. Further, the Auto Regressive Conditional Heteroscedaticity (ARCH) test indicates that there is no ARCH effect in the model. The normality of residuals is confirmed by the Jarque-Bera statistic. Therefore, the result holds that residuals are normally distributed.

Prior to performing the Cointegration test, test of order of integration for each variable using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests have been conducted. Their results are presented in table-4. The results show that the null hypothesis that there is presence of unit root is not rejected at the levels for all variables. However, the null hypothesis is rejected against the alternative hypothesis that there is presence of unit root, when the first difference of the variables are taken. Thus, the first difference of all variables are found to be stationary, and hence all the series are integrated of order one. The tests of unit root support the unit root hypothesis at one percent level of significance for all variables.

Since the existence of unit root for all the variables is confirmed, the next step is to conduct Cointegration test. The Johanson Cointegration test results are presented in table-5. The results support the existence of two cointegrating equation, implying that the three variables ICT, agricultural share to GDP and economic growth are cointegrated. Thus, the test indicates that there exists a long-run relation between the variables, or that all the variables ICT, agricultural share to GDP and economic growth are moving together in the long-run.

According to Granger (1969), when time series X Granger-causes time series Y, past values of X can be used to forecast the future values of Y. Having confirmed the existence of long-run association among the variables, the next step is to find the causal relationship among the given variables. The presence of cointegration allows to use the Vector Error Correction Granger causality, which manifests both in the short-run as well as long-run causality. Table-6 presents the estimated results of Vector Error Correction model. It shows the error correction term for cointegrating equation with LEG, LICT and LAG as dependent variables. In the table error term with ICT (-0.429) as dependent variable is not significant. Therefore, it reveals that EG and AG does not cause ICT in the long-run. However, the long run coefficient with LEG (-0.338) and LAG (-0.752) as dependent variables are significant.

In sum, the first finding of the analysis is that there is long-run causality running from ICT and AG to economic growth (GDP). This finding is consistent with the theory on ICT and growth that ICT does lead to economic growth (Dewan and Kreamer 1998). The next finding of the analysis shows evidence of bi-directional causality between agricultural growth (AG) and GDP, which is also consistent with the findings reported in existing literature (Pohjola 2000). The third finding of the analysis indicates a uni-directional causality running from ICT to AG, implying that ICT is an important determinant of AG in India. However, the results reveal that there are no short-run causality among the variables. It also presents chi-square and probability in brackets for Granger Causality tests.

Table-7 reports the ordinary least square regression results of the agricultural productivity growth rate function. Growth rate of investment in ICT (GRICT) is positively and significantly related to agricultural productivity, indicating that a unit increase in investment in ICT significantly increases agricultural productivity by about 0.051 units. Dissemination of information through different ICT schemes have positive, but not strong bearing on agricultural productivity, as there are other hindrances to effective utilization of ICT potentials in the Indian context, like illiteracy, willingness to adopt new technology, easy accessibility, availability of relevant or localized contents in own languages, especially in the rural areas. Hence, there is still a long way to go to make the farmers understand and to motivate the importance of ICT usage in agriculture sector.

Machinery used per 100 square kilometer (GMACH) has the strongest and positive bearing on agricultural productivity. One unit increase in it significantly increases agricultural productivity by 54.443 units. Gross domestic capital formation (GGDCF) and area under cultivation (GARCL) in agriculture are also positively and significantly related to agricultural productivity, contributing to 0.011 and 0.132 units increase respectively.

The effects of change in net irrigated land (GIRLD) and value-added by labour (GVLAD) are positive, but not significant on agricultural productivity. The R^2 value implies that the included explanatory variables describe 87 per cent of the total variations in the dependent variable. The overall fitted model emerges statistically significant.

4. Conclusion

Cointegration and error correction mechanism were used to analyze the casual relationship among the ICT, AG and EG in India. The results of the multivariate cointegration suggested that the existence of a long-run causality, running from ICT and AG to economic growth (GDP). It showed evidence of bi-directional causality between agricultural growth (AG) and GDP, which is consistent with the existing literature (Pohjola 2000). The study also indicated uni-directional causality running from ICT to AG in the long-run. It implies that ICT is an important determinant of AG in India. Thus, the results support the evidence that ICT fuels economic growth in India.

Further, the influence of ICT and other factors on agricultural productivity were examined, using multiple regression model. The regression results suggested that changes in machinery usage, investment in ICT, gross domestic capital formation and area under cultivation exercise positive and significant impact on change in agricultural productivity, with change in machinery usage having a strong bearing on agricultural productivity in India.

In sum, the study indicates that there is still a long way to go to achieve effective diffusion of information and communication technology in the Indian agriculture sector.

Table 1: Trends in GDP, Share of Agriculture in GDP and Investment on Telecommunication Industry.

Year	GDP in Rs. Crores	Growth Rate (%)	Share of Agriculture Rs. Crores	Growth Rate (%)	Investment on Telecommunication in Rs. Crores	Growth Rate (%)
1980	798,506	-	285,015		1883	-
1985	1,013,866	26.98	333,616	17.06	3195	69.68
1990	1,347,889	32.95	397,971	19.30	6438	101.51
1995	1,737,741	28.93	447,127	12.36	11555	79.49
2000	2,342,774	34.82	522,755	16.92	15915	37.74
2005	3,253,073	38.86	594,487	13.73	25817	62.22
2010	4,918,533	51.20	717,814	20.75	35719	38.36
2015	6,261,150	27.30	872,624	21.57	45621	27.73
Period	GDP in Rs. Crores	Average Growth Rate (%)	Share of Agriculture Rs. Crores	Average Growth Rate (%)	Investment on Telecommunication in Rs. Crores	Average Growth Rate (%)
Pre 1991	3,160,261	19.98	10,16602	12.11	11,516	57.06
Post 1990	18,513,271	36.22	31,54807	17.06	13,4627	49.11
Combined	21,673,532	34.43	41,71409	17.37	14,6143	59.53

Source: Own calculations from Planning Commission Government of India data.

Table: 2 Descriptive Statistics of key Variables: Pre 1991, Post 1991and Combined Periods

Pre 1991 Period			
Descriptive Statistics	LEG	LAG	LICT
M	13.839	12.718	8.210
M	13.829	12.713	8.083
Max.	14.114	12.894	8.807
Min.	13.590	12.560	7.540
Σ	0.172	0.108	0.403
m_3	0.173	0.241	0.192
m_4	1.890	2.014	2.058
J-B	0.618(0.74)	0.552(0.76)	0.473 (0.79)
Post 1991 Period			
Descriptive Statistics	LEG	LAG	LICT
M	14.860	13.251	9.865
M	14.798	13.234	9.944
Max.	15.649	13.679	10.728
Min.	14.114	12.874	8.746
Σ	0.5038	0.235	0.618
m_3	0.0953	0.178	-0.232
m_4	1.695	1.997	1.782
J-B	1.883(0.40)	1.228(0.55)	1.841(0.39)
Combined Period (1980-2015)			
Descriptive Statistics	LEG	LAG	LICT
M	14.569	13.099	9.391
M	14.519	13.123	9.360
Max.	15.649	13.610	10.728
Min.	13.591	12.561	7.541
Σ	0.182	0.324	0.957
m_3	0.182	0.054	-0.278
m_4	1.782	1.933	1.853
J-B	2.425(0.30)	1.724(0.42)	2.438(0.29)

Note: μ - mean; M – median; Max. – maximum; Min. – minimum; σ – standard deviation; m_3 - Skewness; m_4 - kurtosis; J-B – Jarque-Bera test for normality respectively; figures in parenthesis are respective p-value.

Table- 3: ICT Applications in Agricultural Activities

Sl. No.	ICT Tools	Activities
1	Internet and Broadband	Knowledge sharing, Social media, e-community, Market
2	Computers and Websites	Agriculture information and markets.
3	Sensor Networks	Real time information, Better data quantity and quality,
4	Satellite	Weather universal accessibility, Remote sensing
5	Data Storage and Analytics	Precision agriculture, Actionable knowledge.
6	Telephone	Interactive voice response
7	Broadcasting	Expertise sharing, Advisory
8	Mobile	Advisory, Sales, Banking, Networking.

Source: International Telecommunication Unit.

Table: 4 Unit Root Tests

Variables	ADF Levels	ADF First Difference	PP Levels	PP First Difference
LEG	-2.093	-4.359*	-1.800	-4.348*
LAG	-2.634	-9.881*	-4.497	-21.351*
LICT	-2.501	-6.944*	-2.522	-10.963*

Note: * indicate significant at one percent level.

Table: 5 Johanson Multivariate Cointegration Tests

Trace Test			
	Null Hypothesis	**Alternative**	**Trace Statistic**
	r = 0	**r > 0**	**(42.689)***
	r ≤ 1	**r > 1**	**(12.168)****
	r ≤ 2	**r > 2**	**(4.323)**
Maximum Eigen-value test			
	Null Hypothesis	**Alternative**	**Max-Eigen**
	r = 0	**r = 1**	**(30.521)***
	r = 1	**r = 2**	**(7.845)****
	r = 2	**r = 3**	**(4.323)**

Note:* and ** indicates significance at one and five percent level respectively.

Table: 6 VCEM Granger Causality Results

Dependent Variable	ΔLEG	ΔLAG	ΔLICT	Error Correction Term
ΔLEG	-	2.648 (0.266)	0.860 (0.651)	-0.338* (0.018)
ΔLAG	1.699 (0.428)	-	0.795 (0.671)	-0.752** (0.032)
ΔLICT	2.213 (0.330)	2.172 (0.337)	-	-0.429 (0.569)

* and ** indicates significant at 1 and 5 percent level respectively; and Numbers in the parentheses are P-values.

Table: 7 OLS Regression Results: Agricultural Productivity Function.

Sl. No.	Variables	Coefficients
1	Constant	104.083(17.48) *
2	GRICT	0.051(1.836)***
3	GIRLD	2.291(0.117)
4	GARCL	0.132(1.841)***
5	GVLAD	1.154(1.502)
6	GGDCF	0.011(7.251)*
7	GMACH	54.443(5.264)*
8	Adjusted-R^2	0.87
9	F-Value	38.160

Note: Brackets show t-value; and *, ** and *** indicate significance at 1, 5, and 10 percent levels respectively.

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