

Relationship between Technological Advancement and Agricultural Production: Evidence from India

Chumki Handique



Abstract: Indian economy has more than 60% of the work force engaged in it and with the sectoral contribution of 17-18% to country's GDP in 2018-19. Despite such heavy dependence and high significance of the agricultural sector, per capita productivity in agriculture over the past few decades is less in comparison to the productivity in other sectors. Available statistics shows that agricultural production has rose marginally during the period of green revolution (starting in 1960s) which was driven by the technology revolution. Technology revolution here means- 'seed-fertiliser-water technology' or modern technology.

In the present study, a detailed time series analysis for a time period of 36 years (1981-2017) is made to study the impact of technology in production in both the short run and long run. Firstly, the present status of technology use is studied and secondly a crop-output model is considered depicting the role of technology in production of India. Here, the impact of technology is measured using variables such as gross irrigated area, Pesticide use, Synthetic nitrogen fertilizer (NPK) uses, use of improved seed varieties (HYVs) etc. and their impact upon agricultural production (food grains as well as non-food grains) is tested using various econometric tests such as Johansen Co-integration test, regression estimates etc. A composite index has been constructed using PCA method as a proxy to technology. To examine the linkage between technological advancement and agricultural production in India, we employed the Vector auto regression (VAR) model proposed by Sims. To draw inferences on the results of VAR, we also used forecast error variance decomposition (FEVD) which gives both short-run impact and long-run impact of each variable in explaining the forecast error variance of the dependent variable.

Keywords: role, technology, production, agriculture, green revolution,

I. INTRODUCTION

Agriculture and allied sector forms the bedrock of Indian economy. Existence of instability in the agricultural sector may adversely affect growth in production, investment, employment, consumption, and income distribution, which may impede the economic development and growth of the country (Abler et al., 1994; Eicher and Staatz, 1998).

Manuscript received on February 10, 2020.

Revised Manuscript received on February 20, 2020.

Manuscript published on March 30, 2020.

* Correspondence Author

Chumki Handique, Department of Economics, Dibrugarh University, Assam, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](http://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Since, majority of the Indian people live in village, agriculture continues to be the major economic activity in rural areas of India. Hence, factors contributing to agriculture production continue to remain vital for the developmental concerns of the Indian Economy. Despite concerted industrialization in the last six decades, agriculture has always been the back bone of the Indian economy and agricultures still occupies a place of pride in our country.

A. What is Agricultural Technology?

Agriculture technology means the application of techniques and tools to control growth and harvesting of animal and food products. It is the technological process used to create understanding of how equipment and structures, used together with people, soil, plants and animals and their products to use environment, to sustain and maintain a better standard of living and to promote economic growth. In India, after the onset of green revolution, a variety of crop improvement Programmes (a vital component of the modern agricultural technology) have been focusing on development of superior crop varieties. It has been observed that the crop (improved varieties) performed effectively only when used in combination with fertilizer, pesticides and water. Hence, the development of improved agricultural production also calls for the development of the agricultural input sector too.

B. Importance of technology in agriculture:

India's population has been increasing rapidly in the recent years leading to increased strains on our food supply and resources and thereby causing threats to food security. Between 1980 and 2000, population of developing countries increased by 39%, and income per-capita rose 45%, but the agricultural area grew by only 11% (Food and Agriculture Organization of the United Nations [FAO]). To feed our ballooning population, food production must increase by estimated 70% by driving agriculture production. The ability to add value to agricultural production via the application of scientific knowledge and techniques have always been the key forces behind agricultural growth in particular and economic growth in general. Benefits of technology use in agriculture includes-

1. Minimised use of water, fertilizer, and pesticides in the production process which in turn keeps food prices down.
2. Reduced negative impact of inputs on natural ecosystems.
3. Less runoff of chemicals into rivers and groundwater.
4. Greater efficiencies in production and lower cost of production.

5. Sustainable and safer growing conditions and safer foods as a result.

II. A REVIEW OF EMPIRICAL LITERATURE

Review of relevant literature particularly from the 1980s period has been done.

Darek Byerlee, (1987), in his paper, '*maintaining the Momentum in Post-Green Revolution Agriculture: A Micro-Level Perspective from Asia.*' Reviewed the opportunities that are present in the agricultural sector for rapid growth in productivity. His study was from a micro-level perspective in the post-green revolution era. In his paper, knowledge and skills of farmers have been considered as important determinants. Increased farmer-oriented research and development strategies, extension services and rural education is still found to be inadequate in many areas.

Gupta et al, (2003), in the paper titled, '*Sustainability of Post-Green Revolution Agriculture: The Rice-Wheat Cropping Systems of the Indo-Gangetic Plains and China*', focused on sustainable natural resource management problems of the rice-wheat system. They suggested several measures to harness the benefits of modern agriculture like- innovative technological options, farmer-participatory mode of research, dry seeding, intensification, and diversification etc.

Larson et. al (2004), examined the factors behind the instability in Indian agriculture in their study, '*Instability in Indian Agriculture-a challenge to Green Revolution technology*'. They studied the instability in the area, production and yield of major food crops of India from the time period 1950-1951 to 2001-2002 which they divided into pre and post- green revolution period. They used measures of dispersion and co-variances for testing crop instability. Results for most of the crops showed an increasing instability in both production and yield. However, green revolution has been successful in increasing the production of major crops in India. They concluded that although green revolution has increased production, but it came with the cost of greater instability in yield. This instability is caused by lack of access to improved seed varieties, fertilisers, farm management adoption etc. Pure stabilisation measures, diversification, crop insurance etc. were suggested as possible solutions to deal with the instability.

Douglas Gollin, et.al, (2015), in their study titled, '*Technology Adoption in Intensive Post-Green Revolution Systems*' tried to analyse the trend and pattern in technology adoption in the post-green revolution period. They also discussed about the role of technology in sustaining productivity growth in the intensive agricultural system in Asia. They choose the cereal-based agricultural system of Asian areas where the impact of green revolution was felt maximum. The results of their study revealed that improved crop management system along with fertiliser encouraged the productivity growth in the study areas. They observed through their study that the cost of agricultural labour has been ever increasing, further strengthening the demand for labour-saving technologies.

III. OBJECTIVES :

- i. To study the present status and growth performance of Indian agricultural sector.
- ii. To study the status of technology use in Indian agriculture.
- iii. To examine the relationship (short run and long run) between technology and agricultural production in India.

IV. METHODOLOGY AND DATA SOURCES:

A. Data Sources:

In this study, we used time-series secondary data (continuous) for the time period of 36 years i.e. from 1981 to 2017. The sources of collecting data are Directorate of Economics and Statistics (Ministry of Agriculture and Farmers Welfare), Government of India, The Fertiliser Association of India, and various other government publications and reports. The time-period is considered here after the onset of technology revolution in India. The post green revolution period i.e. from 1980s onwards depicts the emergence of technology revolution in India. Thus, considering data from this time period may be expected to make the impact analysis more suitable and accurate.

B. Analysis:

For analysing the research objectives, we incorporated both descriptive as well as statistical and econometric tools and techniques. For the first two objectives we employed statistical tools like figures and graphs along with the calculation of simple percentages, averages, growth rates and compound annual growth rates etc.

For the third objective, a technology index have been constructed using Principal Component Analysis (PCA). PCA is a statistical procedure used to convert a set of observations of possibly correlated variables into a set of values that are uncorrelated variables called principal components. PCA is done here by eigen value decomposition method and then a composite index has been constructed as a proxy of technology.

C. Selection of indicators:

Principal Component Analysis have been used to construct the technology index. The following seven indicators have been used for constructing the composite index –

Names	Indicators
X ₁	Net irrigated area (in '000 hectare)
X ₂	Area irrigated more than once (in '000 hectare)
X ₃	Consumption of pesticide (in '000 tonne)
X ₄	Synthetic nitrogen fertilizer (NPK) consumption (in '000 tonne)
X ₅	Use of improved seed varieties (HYVs) in '000 tonnes
X ₆	Use of tractors (in numbers)
X ₇	Use of power tillers (in numbers)
Source-author's	

Initially, the data were normalized using the following formula:

$$Z_i = X_i - /X_i$$

In the next step, we incorporated the indicators into the following formula for constructing the composite index-

$$\text{Technology Index} = Z_1 + Z_2 + Z_3 + \dots + Z_n$$

Where, Z1, Z2, Z3 and Zn are the normalised value of the seven different indicators mentioned above

C. Regression estimation:

To examine the relationship among technological advancement and agricultural production in India, we used the Vector auto regression (VAR) model proposed by Sims. Further, we also use forecast error variance decomposition (FEVD). FEVD result gives the forecast error variance of variables in a VAR model. It provides information about the relative importance of each explanatory variable in affecting the forecast error

variance of the dependent variable in both short run and long run.

D. Model Specification:

In our analysis, the VAR model is constructed in the following form:

$$X_t = \alpha_{1i} + \sum_{i=1}^n \beta_{1i} X_{t-i} + \sum_{i=1}^n \gamma_{1i} Y_{t-i} + u_{1t}$$

Where,

α_{1i} And α_{2i} represents the intercept terms.

β and γ shows the estimated coefficients; and n represents optimal lag order.

The dependent variable here is agricultural production and the explanatory variable is the composite index of technology.

V. RESENT STATUS OF INDIAN AGRICULTURE

Year	TABLE-1 GVA AT CURRENT PRICES			% share
	Entire economy	Agriculture, Forestry and Fishing		
2011-12	8,107	1,502		18.5
2012-13	9,203	1,675		18.2
2013-14	10,363	1,926		18.6
2014-15	11,504	2,094		18.2
2015-16	12,574	2,228		17.7
2016-17	13,936	2,496		17.9

Source: Central Statistics Office, (New Series)

Table 1 illustrates Gross Value Added (GVA) at current basic prices for agriculture, forestry and fishing, its percentage share and the GVA for the entire economy from 2011-12 to 2016-17. GVA of Agriculture, Forestry

and Fishing accounted for 17.9% at current basic prices for the year 2016-17. However, in the overall GVA of the country, the share of this sector has been showing a declining trend except for the years 2013-14 and 2016-17.

TABLE 2: PERCENTAGE GROWTH OF GVA (2011-12 PRICES)						
Sectors	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Agriculture, forestry & fishing.	1.5	5.6	-0.2	0.6	6.3	3.4
Crops	0.2	5.4	-3.7	-3.2	6.9	5.5
Livestock	5.2	5.6	7.4	7.9	6.5	2.9
Industry	0.2	5.9	1.9	1.8	1.3	5.7
Fishing & Aquaculture	4.9	7.2	7.5	10	6.1	5.9
GVA at basic prices	5.4	6.1	7.2	8.1	7.1	6.5

Source: Central Statistics Office, (New Series)

Table 2 illustrates Growth of Gross Value Added (GVA) in different agricultural sub-sectors from the year 2012-13 to 2017-18. The growth rate of GVA at constant basic prices was 6.5 per cent in 2017-18, as compared to 7.1 per cent in the corresponding period of previous year. In agriculture, forestry and fishing sector there was a high increase in the GVA from 1.5% in 2012-13 to 5.6% in 2013-14 followed by a drastic reduction to negative GVA of -0.2% in the next year. From 2015-16 onwards, growth in GVA took off for the next two years but reduced by 3% in the recent 2017-18. The overall trend was thus uneven over the past few decades. Similar pattern is observed in case of crops. GVA growth was marked by negative growth in 2013-14 and 2014-15 followed by rise

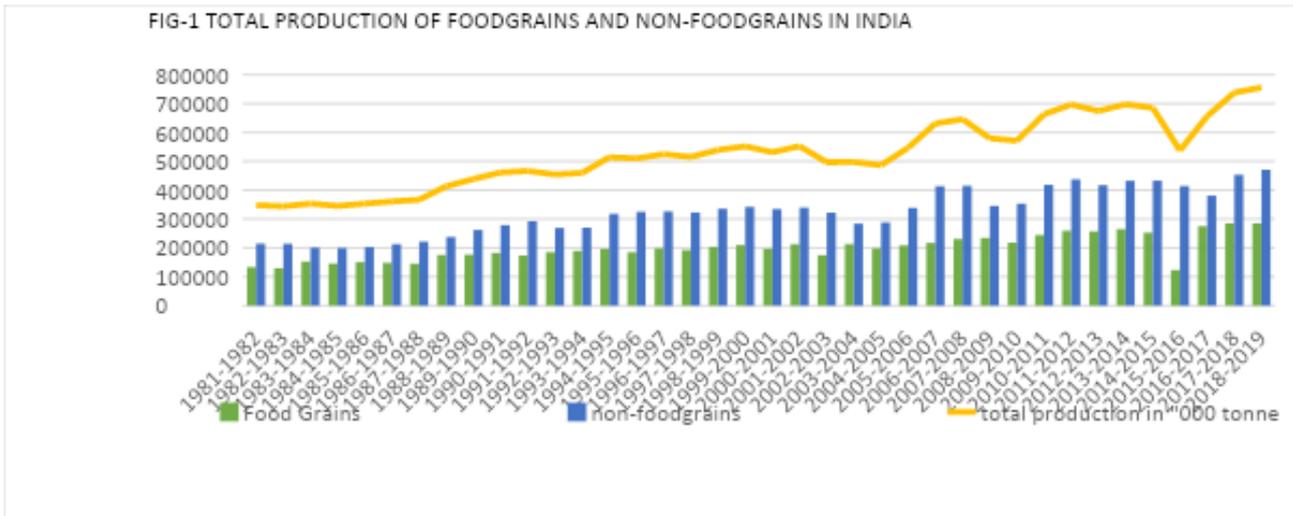
in GVA over the last two years. In case of forestry and logging, fishing and aquaculture, GVA contribution has shown an uneven pattern as well.

The major causes behind this uneven growth as found by many empirical studies are- low agricultural productivity in the respective years. Key issues likely to affect agricultural productivity include-decreasing sizes of agricultural land holdings, continued dependence on the monsoon, inadequate access to irrigation etc

Growth Performance Of Crop Output At National Level

This makes India one of the top producers of several food crops such as rice, wheat, sugarcane, cotton and pulses. It is the highest producer of milk and second highest producers of fruits and vegetables.





Source: Department of Agriculture, Cooperation &Farmer’s Welfare.

Figure-1 indicates the total production of food-grains and non- food-grains (in thousand tonnes) from the time period of 1981 to 2018. Total production has been increasing since 1980s except for the year 2005-06 and 2014-15 due to low productivity in these years

A. Compound annual Growth Rates of Area, Production and Yield of Principal Crops in India.

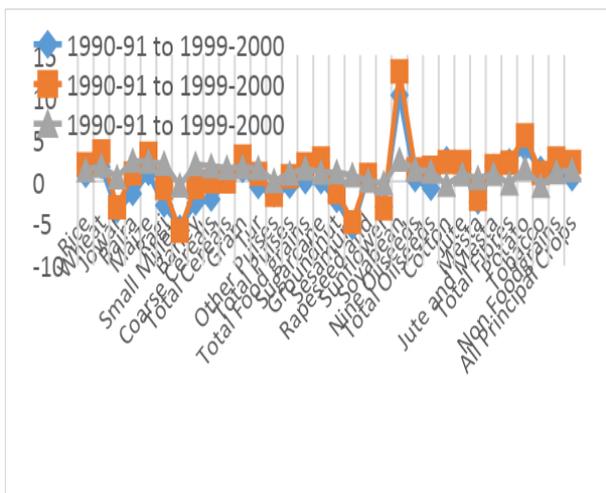


Fig-2 Cagr Of Area, Production And Yield Of Principal Crops In India (1990-2000)

Figure 2 and 3 shows compound annual growth rate (CAGR) of area, production and yield of principal crops in India from 1990-2000 and 2000-2012 respectively. During this period, the CAGR in case of area under cultivation and production of crops shows similar trend. In case of soya bean and oilseeds, area and production were the highest during this period. But, during the period 2000-2012, the area production and yield of the principal crops in India showed a fluctuating trend. The area under many of the crops showed negative growth rate. Some of such crops are jowar, small millets, rapeseed and mustard and jute and soyabean. Productivity of Jute and mustard also showed negative growth during this period.

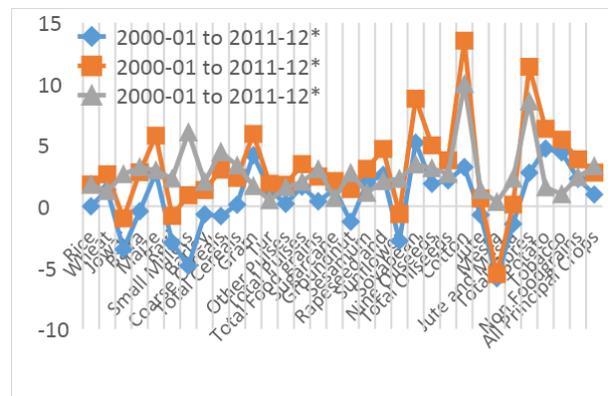
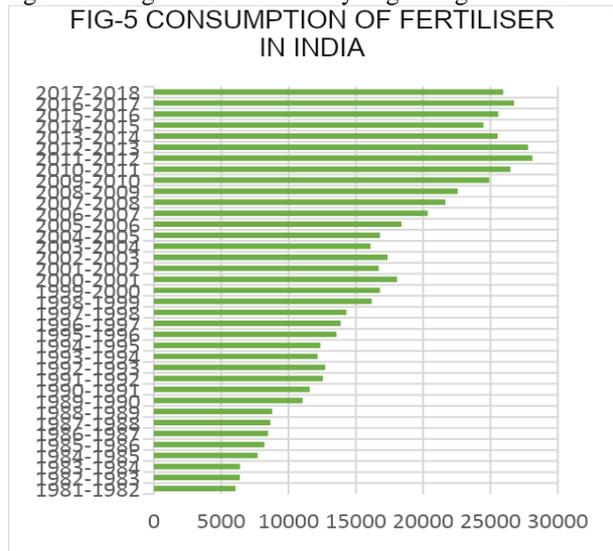


Fig-

3 Cagr Of Area, Production And Yield Of Principal Crops In India (2000-2012)

Source- Ministry of Agriculture, Cooperation & Farmers Welfare, advance Estimates.

All these trend reflect that in the post-green revolution period, the initial momentum of modern technology led agricultural growth were slowly beginning to decline to



Source-Ministry of Agriculture and Farmers Welfare, Government of India.

VI. STATUS OF TECHNOLOGY-USE IN INDIAN AGRICULTURE

Figure 4 and figure 5 shows the consumption of pesticides and fertilisers in India respectively. Consumption of pesticides in India has been increasing over the past few decades with the highest consumption in the years 1989 to 1993. Since then it showed a decreasing trend followed by a slow increase since 2010 onwards.

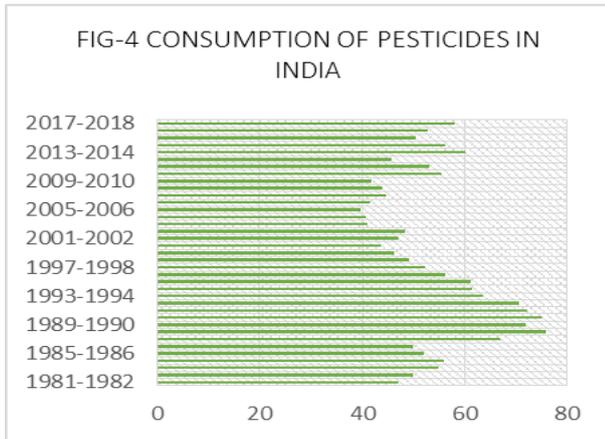
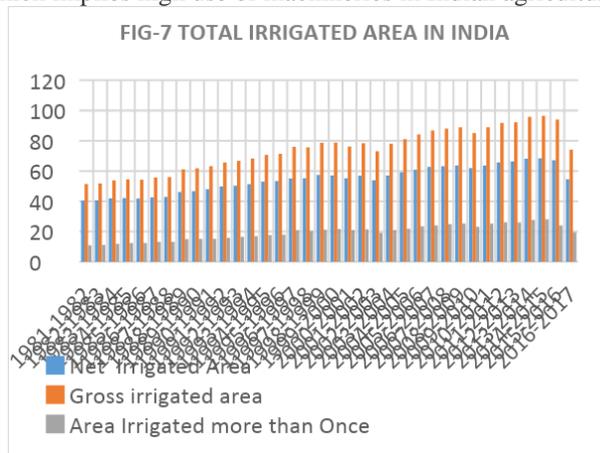


Figure 6 and figure 7 shows sale of tractors, power. The sale of tractors and power tillers are used here as proxies for use of power tillers and tractors in agriculture due to unavailability of data (marked by* and # signs in the figure to indicate unavailability of data). The figures 6 shows an increasing trend in sale i.e. use of tractors and power tillers which implies high use of machineries in Indian agriculture.



Source- Directorate of Economics and Statistics (Ministry of Agriculture and Farmers Welfare), Government of India.

The total irrigation (figure 7) also shows an increasing trend over the study period. In India the proportion of wheat area under irrigation grew from 33 per cent in 1961 to 75 per cent in 1988 as irrigation facilities became available on formerly rain fed land and as wheat substituted for other crops on irrigated land (Breylee, 1992).

VII. EMPIRICAL ANALYSIS

To construct the technology index we have used Principal Component Analysis in this study. For the composite index the following variables have been considered are net irrigated area, area irrigated more than once, consumption of pesticide, Synthetic nitrogen fertilizer (NPK) consumption, use of improved seed varieties (HYVs) etc. use of tractors, use of power-tillers and net sown area. As per the process,

we have select the two components which have eigen values more than 1; and we got two components for the analysis.

Table 3- The Score Of The Composite Index Of Technology

year	Techn ology index	year	Techno logy index	year	Techn ology index
1981	40.56	1993	44.35	2010	57.80
1982	41.07	1994	44.71	2006	55.84
1983	41.64	1996	45.40	2007	56.35
1984	41.73	1997	45.62	2008	56.74
1985	41.74	1998	45.92	2009	57.51
1986	41.88	1999	45.83	2011	57.76
1987	42.64	2000	45.53	2012	58
1988	43.11	2001	45.48	2013	57.89
1989	43.60	2002	45.71	2014	57.73
1990	43.99	2003	54.28	2015	57.90
1991	44.20	2004	54.82	2016	58.03
1992	44.31	2005	55.44	2017	57.95
1995	45.10				
Source- author's own computations					

Table 3 shows the composite scores of technology index for the study period i.e. from 1981 to 2017. The resultant composite index showed that the provision of technological facilities have been improved during the period of our analysis; as the score of the composite index has been improved over the years. The score of the composite index of technology used in agriculture is given in Table 3. The factor loadings of the included variables have been listed in table 4:

Table-4 Factor Loadings Of The Variables Included In The Study

variables	Factor loadings
Area irrigated more than once	0.982
Fertiliser consumption	0.971
Net irrigated area	0.967
HYV Seed usage	0.884
Use of Tractors	0.98
Use of Power-Tillers	0.985
Pesticide consumption	0.643
Source- author's computations	

To examine the linkage between technological advancement and agricultural production growth in India, we used the Vector auto regression (VAR) model proposed by Sims. We also use forecast error variance decomposition (FEVD) to draw inferences on the short run and long run effects. To represent production, in the model, we used total agricultural production (in current 000 tonnes) and composite index of technology as a proxy of technological advancement for the time period of 1981 to 2017.

VIII. INTERPRETATION OF THE REGRESSION RESULTS

1. The result of VAR model indicates that the agricultural production is significantly influenced from technological advancement in the longer period but it was highly absent in very short run.
2. In the short run, the FEVD that impact of technological advancement is highly absent for agricultural production. It means that the variable of technological advancement is highly exogenous for the short run. But, in the long run, the impact of technological advancement has increased as 21.24 % of forecast error in the agricultural production is explained by the variable of technological advancement in long run.

IX. CONCLUSION

This paper analysed the role and impact of technology in agriculture post 1980s and also studied the present status of Indian agriculture, performance of crop output, growth status of area, productivity and yield of major food grains and the status of technology use in Indian agriculture. The GVA in the agriculture sector is marked by uneven growth over the last few years. The causes behind this uneven growth is due to low agricultural productivity in the respective years. Key issues likely to affect productivity are- decreasing sizes of agricultural land holdings and lack of access to modern technology. Growth status of area, productivity and yield of major food grains showed even trend during the 90s but more fluctuating trends in the 2000s which shows declining impact of the technology-driven growth post-green revolution. Status of use of modern technology is however somewhat satisfactory as these variables showed a increasing trend, although slowly. To empirically test the magnitude of impact technology variables upon agricultural production, a technology index was constructed using PCA by incorporating the technology variables- net irrigated area, Pesticide consumption, Synthetic nitrogen fertilizer (NPK) consumption in terms of nutrients, use of improved seed varieties (HYVs), use of tractors, power-tillers into a composite technology index. Thereafter, to test the relationship between technological advancement and agricultural production growth in India, we used the Vector auto regression (VAR) model proposed by Sims. We also use forecast error variance decomposition. The results of this analysis indicate that that the agricultural production is significantly influenced from technological advancement in the longer period but it was highly absent in very short run. In the short run, the impact of technological advancement is highly absent for agricultural production. It means that the variable of However, in the long run, the impact of technological advancement has increased as 21.24 % of forecast error in the agricultural production is

explained by the variable of technological advancement in long run.

To summarize, given the significant impact of technology upon agricultural production, the instability in the sector is likely to be diminished through stabilisation policies that encourage farmer’s access to modern technology, shifting to micro-irrigation techniques to improve efficiency of water use, improving access to quality seeds by engaging with the private sector, mechanisation of agriculture, access to fertilisers and pesticides, accompanied by knowledge and technical skill of the farmers.

APPENDICES

Johansen co-integration test result:

Date: 12/17/19 Time: 21:39
 Sample (adjusted): 1984 2017
 Included observations: 34 after adjustments
 Trend assumption: Linear deterministic trend
 Series: LNPROD PC
 Lags interval (in first differences): 1 to 2
 Unrestricted Co-integration Rank Test (Trace)

Hypothesized	Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical
Value	Prob.**		
None	0.154901	6.165822	15.49471
0.6759			
At most 1		0.012961	0.443557
3.841466	0.5054		

Trace test indicates no co-integration at the 0.05 level
 * denotes rejection of the hypothesis at the 0.05 level
 **MacKinnon-Haug-Michelis (1999) p-values
 Unrestricted Cointegration Rank Test (Maximum Eigenvalue)
 Hypothesized Max-Eigen
 0.05
 No. of CE(s) Eigenvalue Statistic Critical
 Value Prob.**

None	0.154901		5.722264
14.26460			
At most 1		0.012961	0.443557
3.841466			

Max-eigenvalue test indicates no co integration at the 0.05 level
 * denotes rejection of the hypothesis at the 0.05 level
 **MacKinnon-Haug-Michelis (1999) p-values
 Series: LNPROD PC
 Lags interval (in first differences): 1 to 2

Unit root test result for the variables at first differencing

Null Hypothesis: D(LNPROD) has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=5)
 t-Statistic Prob.*
 Augmented Dickey-Fuller test statistic -5.469635
 0.0001
 Test critical values 1% level -3.639407
 5% level -2.951125
 10% level -2.614300

*MacKinnon (1996) one-sided p-values.



Result of VAR

Vector Autoregression Estimates

Date: 12/17/19 Time: 21:45

Sample (adjusted): 1983-2017

Included observations: 35 after adjustments

Standard errors in () & t-statistics in []

LNPROD	PC	
LNPROD(-1)	0.723107 (0.18164) [3.98104]	-4.030280 (3.44001) [-1.17157]
LNPROD(-2)	-0.66273 (0.16956) [-0.39085]	5.4355535 (3.21131) [1.69262]
PC(-1)	-0.000160 (0.00921) [-0.01736]	1.003768 (0.17445) [5.75390]
PC(-2)	0.010217 (0.000975) [1.04773]	-0.65963 (0.18468) [-0.35718]
C	4.039224 (1.40490) [2.87509]	-14.85470 (26.6073) [-0.55829]
R-squared	0.886256	0.957340
Adj. R-squared	0.871090	0.951652
Sum sq. resids	0.175299	62.87663
S.E. equation	0.076442	1.447718
F-statistic	58.43750	168.3087
Log likelihood	43.02779	-59.91481
Akaike AIC	-2.173017	3.709418
Schwarz SC	-1.950824	3.931610
Mean dependent	13.15730	49.61932
S.D. dependent	0.212905	6.584073

11. Singh, A. P. (2013). Strategies for Developing Agripreneurship among Farming Community in Uttar Pradesh, India, *Academica: An International Multidisciplinary Research Journal*, 3(11) 1- 12.

AUTHOR PROFILE



Chumki Handique has completed her M. Phil in the area of International trade from Dibrugarh University. She has received her Masters in Economics from Department of Economics, Dibrugarh University and her Bachelor's degree in Economics from Manohari Devi Kanoi's Girls College, Assam, India.

REFERENCES

- Alex, Lwakuba, (2011). A Review and Analysis of Policies on Farmers' Entrepreneurship Development, A publication of PELUM, Misereor, pp. 1-55.
- International Development: Vol. 4, No. 5, 477496 (1992).
- Fan, S. (1991). 'Effects of technological change and institutional reform on production growth in Chinese agriculture', *American Journal of Agricultural Economics*, 73, pp. 266-275.
- Food and Agriculture Organization of the United Nations. FAOSTAT data. Available at [http:// faostat.fao.org/](http://faostat.fao.org/), May 2005.
- Gollin, Douglas, Morris, Michael, Byerlee, Derek, (2015), *Technology Adoption In Intensive Post-Green Revolution Systems, Issues Facing Agricultural Technology Adoption in Developing Countries* (David Zilberman, University of California at Berkeley, Presiding), <http://ajae.oxfordjournals.org/>
<http://www.ibef.org/industry/agriculture-presentation>
<http://www.yourarticlelibrary.com/entrepreneurship/7-challenges-involved-in-developing-agripreneurship/41110/>.
- Ministry of Agriculture, various years (b). Department of Agriculture and Co-operation, Government of India. Agricultural statistics at a glance. Published by the Directorate of Economics and Statistics, New Delhi, India.
- Nandram, S. S. and Samson, K. J. (2000). Successful entrepreneurship: more a matter of character than of knowledge, (in Dutch with English summary). Nyenrode Centre for Entrepreneurship, Breukelen, the Netherlands, p. 242.
- Pray, C. E. and Ruttan, V. W. (1990). 'Science and technology policy: lesson from the agricultural sector in South and Southeast Asia'. In Evenson, R. E. and Ranis, G. (eds), *Science and Technology: Lessons for Development Policy*. Boulder: Westview Press
- Sagar, Vidya (1977). A Component Analysis of the Growth of Agricultural Productivity in Rajasthan: 1956-61 to 1969-74. *Indian Journal of Agricultural Economics*, 35 (2): 42-59.