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Influence of technologies on the growth rate of GDP from agriculture: A case study of sustaining economic growth of the agriculture sector in Bihar

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Abstract. The influence of agricultural technologies on the growth of agricultural value-added based on time series data of Bihar (India) over the period 1990–2016 has been examined in this paper. The technological progress appears to be a major determinant of boosting the potential productivity of land and affecting positively the economic growth. The results indicated that there are significant and certain benefits from the utilization of a system of technological innovations including mechanization, renewed capital stocks, as well as transfer of new knowledge to farmers' and permanent cropping practices. Farming practices involving crop rotation, multi-cropping, and agro forestry are recommended to sustain agricultural sustainability since they seem to be economically viable and environmentally friendly. It was found that technological innovations pertaining to soil conditions, irrigation systems and chemical fertilizers might be beneficial to agricultural production growth in the long-term when they are managed in accordance with soil characteristics and in a balanced way. The results also showed that the labour force, the forest area, the amount of credits to agriculture, and the amount of energy consumed to power irrigation are likely to be insignificant to boost directly the growth of agricultural value-added. Thus, it is recommended that Bihar makes a large scale investment in agricultural capital and carry on renewal at opportune moments so as to keep steady the positive trend of the agricultural growth over the years. The investment may be in terms of mechanized technologies, supporting infrastructure and appropriating the knowledge relating to their management; and adopting new farming technologies and practices involving crop rotation, multi-cropping and agro-forestry so as to sustain the growth of agricultural value added.

Keywords: Sustainable economic growth, agricultural technology, Cobb-Douglas production function

1. Introduction

The world is facing a key challenge to grow food sustainably to meet the demand of the growing population without degrading the natural resources base and the United Nations advocates the adoption of resource-conserving technologies and sustainable production practices in the agricultural field. In recent years, agricultural production increasingly depends on science and technology advances, farm infrastructures, fertilizers and pesticides use, planting structures for crops, water management and policy for agriculture development. Different input factors have different influences on agricultural production. For instance, while the Integrated Pest Management (IPM) seeks to use pesticides when other options are ineffective [1,6], the Integrated Nutrients Management (INM) recommends to balance both organic and inorganic fertilizers [5] for a green production. Actually, owing to some serious concerns, sustaining the agricultural production growth and yields requires nowadays the application of Fertilizer Best Management Practice [10] as a key technological innovation, in the regions that are highly dependent on agriculture and have substantial employment and income arising from subsistence farming.

Several classifications of technological innovations have been made to differentiate policies or modeling. One categorization distinguishes between technologies that are embodied (such as machines, fertilizers, and seeds) and those that are disembodied (e.g., integrated pest management schemes, a set of new practices) [4]. Another categorization distinguishes between neutral and non-neutral technologies: Harrod-neutral if the technology is labour-augmenting (i.e. helps labour); Solow-neutral if the technology is capital-augmenting. The technological progress function developed by Nicholas [9] measures technological progress as the rate of growth of labour productivity. So, a technological change may cause the production-possibility frontier to shift outward, allowing economic growth. In this context, Wang and Zhou [18], after measuring the contribution rate of scientific and technological progress, suggested that the sector of construction and industry should rely on technological progress so as to improve the international competitiveness and realize the sustainable development goal. Except for scientific and technological progress, a number of researches [11,13,16] turned the attention of government and practitioners towards agricultural technologies and practices concerns, and then, diverse mathematical models such as Cobb-Douglas production function, and Solow remaining value model [7,12,14,15], have been used to measure their contribution to agricultural production in the short and long terms. Kumar and Yadav [8] found that the yield response of grains (rice and wheat intercropped) to a direct Nitrogen (N) fertilizer supply would decline over a long period, and in contrast, the application of Phosphorus (P) and Potassium (K) would increase the grains yields. Moreover, a balanced dose of N-P-K is required to maintain durable soil fertility and raise grains yields. Obviously, the increase on crop yields also related to many other factors. Some researchers basically drew attention upon the impact of human capital investments and fixed capital stock investments on agricultural gross domestic product and some, investigated on the impact of irrigated land [2].

2. Purpose of the study

This paper proposes to study the influence of technologies in value addition that contribute towards compilation of the gross domestic product from agriculture especially in the backward regions with prominent subsistence farming to facilitate potential changes in the income structure. This background is made to examine the case of Bihar, one of the prominent states of India with 10.2% population, currently lying at the lower rung of the industrial development index (with 1.5 percent share in number of factories; 0.34 percent share in fixed capital; 0.58 percent share in working capital; 0.84 percent share in persons engaged; and 0.84 percent share in value of output to All India) as the contribution of the industrial sector to the state's GSDP stands at 19.0 percent in 2015-16, compared to the national average of 31.3 percent. It is highly dependent on agriculture, with substantial employment and income arising from subsistence farming. It is important to investigate how the range of agricultural technologies like mechanization, chemical technology, management practices and policies relating to cropping, as well as other agricultural infrastructures, could improve value addition to the gross domestic product besides the common factors of production (capital stock, labour force, land area). The main issues investigated are: How are agricultural technologies linked to the agricultural production growth and what association of agricultural technologies should be deployed for sustaining the growth of the agricultural gross domestic production in Bihar.

This study depends on the Cobb-Douglas (C-D) production function to determine the influence of agricultural technologies on the growth of agricultural value-added in Bihar (India) over the period 1990–2016. Then, an analysis is made of the response of agricultural value-added growth over time following technological innovations or shocks, and the corresponding findings are put forward.

3. Modeling and data description

3.1. Theoretical modeling

The mathematical equation estimated in this study, based on Cobb-Douglas (C-D) production function, may be written as:

$$Y = A_0 \exp(\delta t) \prod_{i=1}^{p} X^{\alpha_i} \tag{1}$$

where Y is the potential output or income value, A_0 is the level of the output at base period, exp represents the exponential function, δ is the parameter of technological progress, t indicates the time variable expressing the influence of technological progress, p is the number of factors of production, X is a matrix of factors

Table 1
Variable definitions and data sources

Variable	Definition	Sources
AGRIVA	Agricultural value-added (Rs million, value price 2011)	DES, Bihar, 2017
NETK	Net capital stocks value (Rs million, value price 2011)	Author estimate, 2017
MACHI	Number of machines (tractors, harvesters, threshers) used	DES, Bihar, 2017
CREDI	Amount of credits to agriculture (Rs million, value price 2011)	NABARD, 2017
ENERG	Amount of energy used to power irrigation, in Million Kwh	Govt. of Bihar, 2017
LABOR	Number of workers in agriculture sector	DES, Bihar, 2017
ALAND[1]	Land for arable land and permanent crops (area in hectare)	DES, Bihar, 2017
FORES	Land for planted and naturally regenerated forest (area in hectare)	DES, Bihar, 2017
IRRIG	Land equipped for irrigation (area in hectare)	DES, Bihar, 2017
FERTIL	Chemical fertilizers (nitrogen, phosphorus and potassium) consumed (quantity in tons)	DES, Bihar, 2017

of production and α_i is the parameter of ith factor of production.

It may be demonstrated that the α_i are the output or income elasticity coefficients. Thus, seeking the partial derivative on X in Eq. (1), we can get:

$$\frac{\partial Y}{\partial X_i} = \alpha_i \frac{Y}{X_i} \tag{2}$$

Hence,

$$\alpha_i = \frac{\partial Y}{\partial X_i} \times \frac{X_i}{Y} \tag{3}$$

X_i is the ith factor of production. The values of the α_i are obtained by applying the logarithm on both sides of Eq. (1). Thus, the basic specification is given as follows:

$$\ln(Y) = \ln(A_0) + \delta t + \sum_{i=1}^{p} \alpha_i \ln(X_i), \tag{4}$$

Where $\ln(Y)$ is the logarithm of the dependent variable. Moreover, the contribution rate in percentage of a factor of production to the growth of output or income may be calculated by the following equation.

$$E_{X_i} = \alpha_i \frac{g_{X_i}}{g_Y} x100 \tag{5}$$

where E_{X_i} and g_{X_i}, are respectively, the contribution rate and the average annual growth rate of the ith factor of production; and g_Y is the average annual growth rate of the output or income.

3.2. Data

The dataset supporting the conclusions of this article comprises of one endogeneous variable Agricultural value added and nine exogeneous variables:

1. Net capital stock;
2. Number of machines (tractors, harvesters, threshers) used;
3. Amount of credit to agriculture;
4. Energy used to power irrigation;
5. Number of workers in the agriculture sector;
6. Area of arable land and permanent crops;
7. Area on planted and naturally regenerated forest;
8. Area equipped for irrigation;
9. Amount of chemical fertilizers consumed.

These variables comprise part of the official statistics compiled regularly by the various government agencies and were obtained from the Directorate of Economics and Statistics, Bihar and other related departments of the Bihar government/government of India. The modeling adopted is based on annual time series data for 27 years (1990–2016) on these ten variables, obtained from these sources. Table 1 provides variable definitions and data sources.

The data were examined for stationary of time trend with the null hypothesis of the Augmented Dickey-Fuller t-test:

H_0: $\theta = 0$ (i.e. the data need to be differenced to be stationary)
Versus the alternative hypothesis of
H_1: $\theta < 0$ (i.e. the data are stationary and do not need to be differenced)

And thereafter the data were processed through suitably developed R-Programming.

4. Descriptive statistics on variables

Data processed through the suitably developed R-Progamming is presented in Table 2. Table 2 pro-

[1]According to the FAO, "Arable land" refers to land producing crops requiring annual replanting or fallow land or pasture used for such crops within any five-year period" (multiple-cropped areas are counted only once). A briefer definition appearing in the Eurostat glossary similarly refers to actual, rather than potential use: land worked (ploughed or tilled) regularly, generally under a system of crop rotation. "Permanent cropland", meanwhile, refers to land producing crops which do not require annual replanting. It includes forested plantations used to harvest fruit but not tree farms or proper forests used for wood or timber.

Table 2
Descriptive statistics of variables

	LAGRIVA*	LNETK	LMACHI	LCREDI	LENERG	LLABOR	LALAND	LFORES	LIRRIG	LFERTIL
Mean	13.2247	13.2103	5.2640	8.3390	3.9335	7.3359	7.8468	8.5074	2.7103	9.1964
Median	13.2671	13.2306	5.2204	8.9860	3.9411	7.3524	7.9338	8.4992	2.6391	9.7549
Maximum	13.7350	13.3351	5.4553	10.4571	3.9411	7.5011	8.0709	8.6656	3.1355	10.9455
Minimum	12.5952	13.0656	5.0434	0.0000	3.9240	7.0475	7.4501	8.3689	2.3026	3.4965
Std.Dev	0.3452	0.1067	0.1264	2.1330	0.0086	0.1285	0.2152	0.0902	0.3711	1.8895
Skewness	0.3092	0.1577	0.0303	2.3479	0.2236	0.5237	0.8283	0.1196	0.0985	1.6399
Kurtosis	1.8479	1.2548	1.8422	9.6442	1.0500	2.3029	2.2204	1.8701	1.1836	4.8064
Jarque-Bera	1.9236	3.5383	1.5122	74.4700	4.5028	1.7808	3.7710	1.5008	3.7556	15.7729
Probability	0.3822	0.1705	0.4695	0.0000	0.1053	0.4105	0.1518	0.4729	0.1529	0.0004
Sum	357.068	356.679	142.128	225.152	106.204	198.070	211.863	229.699	73.178	248.304
Sum.Sq.Dev.	3.0989	0.2960	0.4154	118.2907	0.0019	0.4291	1.2037	0.2113	3.5804	92.8298
Observations	27	27	27	27	27	27	27	27	27	27

*Indicates the logarithm of AGRIVA and all other variables are described in logarithmic values as well.

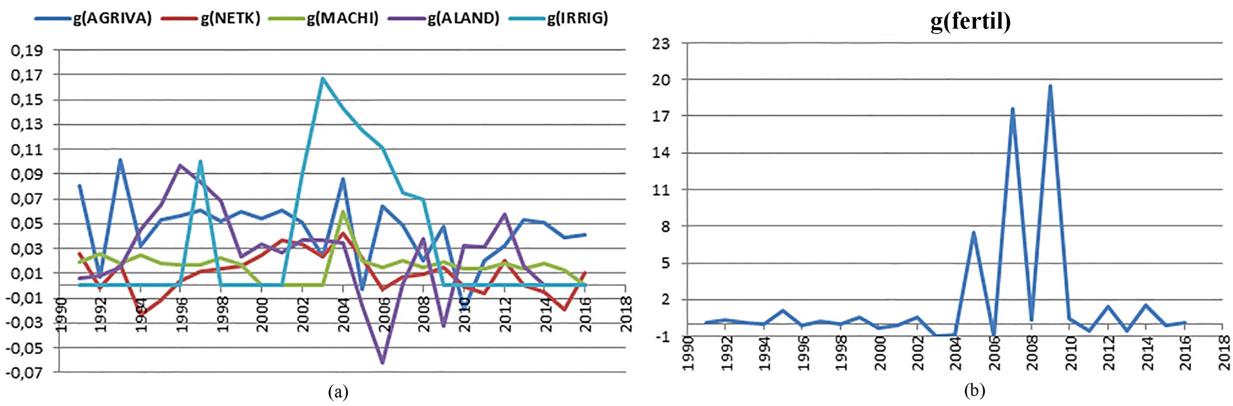

Fig. 1. a. Growth rate of AGRIVA; NETK; MACHI; ALAND; and IRRIG, b. Growth rate of FERTIL.

vides a description of variables (in logarithm) in terms of central tendency and dispersion. Over the period of study, the average value-added is about Rs 1322 billion, almost identical to the average value of net capital stocks. The discrepancy between the maximum and minimum values of each variable is likely to be insignificant except for *FERTIL* as it is shown in Fig. 1b. The statistics show with exception of *IRRIG* and *FORES* of which the mean values are greater than the Median values, that all other variables are negatively skewed. In addition, it is found that all variables show a leptokurtic tendency given that their kurtosis coefficients are positive. The statistics also inform about a normal distribution regarding all variables except *CREDI* and *FERTIL*.

Figure 1a and b describe the trend of the annual growth rate of variables and indicates that the evolvement of variables has not been steady over the study period. The trends depict serious fluctuations of the growth rate of agricultural technologies and as a result, an unstable growth rate of agricultural value-added. In 2005 and 2010 (Fig. 1a), the growth of agricultural value-added was negative, showing a certain drop in the value-added with a slight severity in 2010. The highest growth rate is about 16.5% (2003) and attained by *IRRIG* whereas the lowest growth rate is about −6% (2006) and attained by *ALAND*. Figure 1b presents information specific to the growth rate trend of chemical fertilizers uptake, of which the peak is attained at 19.42%. This evolvement raises some questions pertaining to the effect of chemical technologies on crop yields. However, studies have suggested that applying chemicals in a balanced ratio would be the best way to draw profit from these land-saving technologies [10].

Figure 1a shows trends of annual growth rates of agricultural value-added, net capital stocks, machinery, arable land and permanent crops, and area equipped for irrigation (1990–2016).

Figure 1b shows trend of annual growth rate of chemical fertilizers (1990–2016).

Figure 2 describes the linear relation between agricultural technologies and agricultural value-added. It indicates that the number of machines used, the number of hectares equipped for irrigation, and the num-

Table 3
The augmented Dickey-Fuller unit-root test on variables: results

Variables	Unit-root test in	ADF test statistic	Test critical values	Integration order
LAGRIVA	First difference, including intercept	−6.926025	−3.724070***	I(1)
LNETK	First difference, without intercept nor trend	−2.730906	−2.660720***	I(1)
LMACHI	First difference, including intercept	−4.067870	−3.724070***	I(1)
LCREDI	First difference, without intercept nor trend	−11.40214	−2.664853***	I(1)
LENERG	First difference, without intercept nor trend	−4.898979	−2.660720**	I(1)
LLABOR	First difference, including intercept and trend	−3.924902	−3.673616**	I(1)
LALAND	First difference, without intercept nor trend	−2.077273	−1.955020**	I(1)
LFORES	First difference, including intercept	−3.674498	−2.986225**	I(1)
LIRRIG	Second difference, without intercept nor trend	−5.234235	−2.664853***	I(2)
LFERTIL	First difference, without intercept nor trend	−6.700149	−2.660720***	I(1)

***Indicates significance at the 1% level. **Indicates significance at the 5% level. Source: Suitably developed programmes in R-Language.

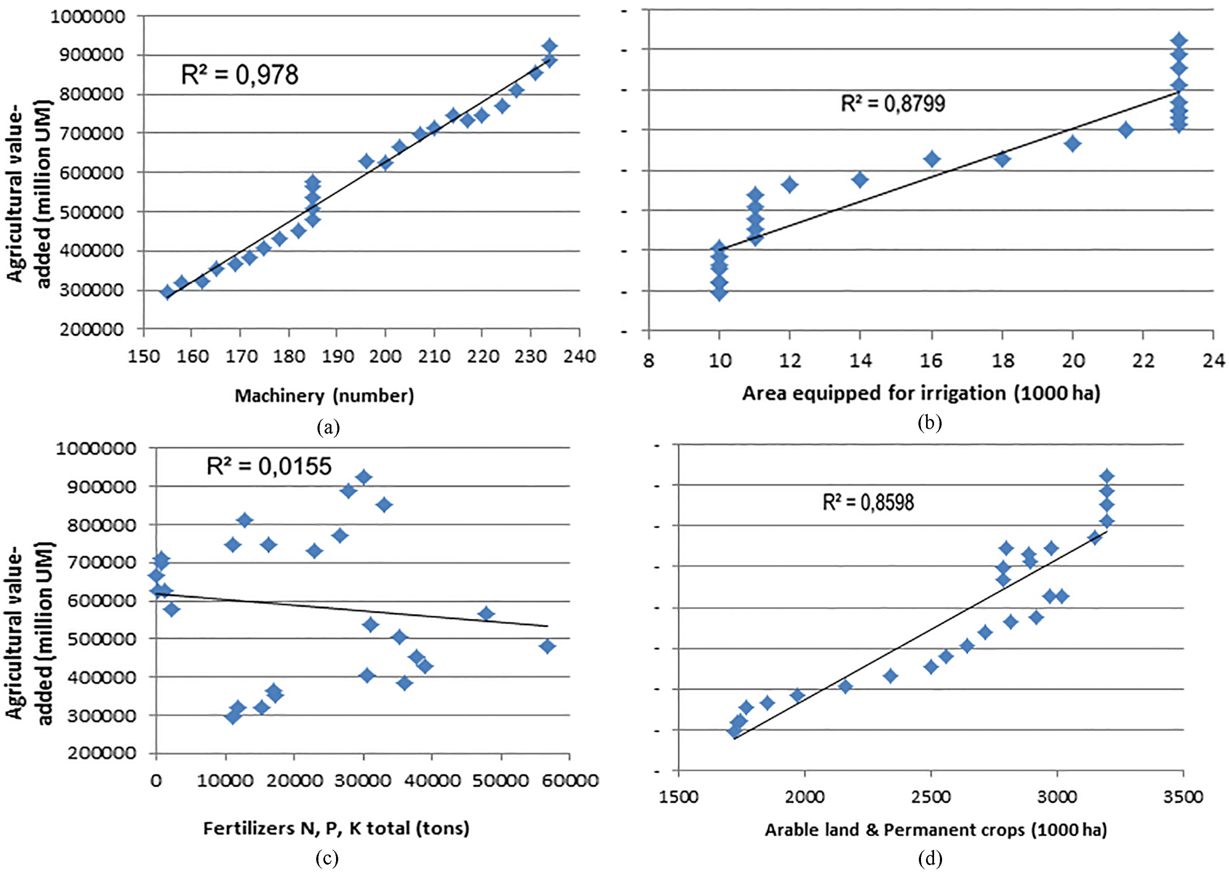

Fig. 2. a and b show relationship between agricultural value added and machinery and area equipped for irrigation. c and d show relationship between agricultural value added and fertilizers and arable land and permanent crops.

ber of hectares for arable land and permanent crops, are greatly related to the growth of agricultural value-added. Therefore, a linear model might explain correctly the relationship between the underlying variables, which may help to boost the growth of agricultural production in association with these underlying technologies. However, the agricultural gross domestic product is likely to be inexplicable by the amount of chemical fertilizers in terms of linear relation in this study.

Figure 2a shows relationship between machinery and agricultural value-added (1990–2016) and Fig. 2b relationship between area equipped for irrigation and agricultural value-added (1990–2016).

Finally Fig. 2c shows relationship between chemical fertilizers and agricultural value-added (1990–2016),

Table 4
Estimation of the growth of agricultural value-added

Variable	Sample $	
	Coefficient	S.E.
Constant	−103.5374**	34.48855
YEAR	0.041686***	0.011901
LNETK	0.586066**	0.203309
LMACHI	0.886031**	0.352736
LCREDI	0.003155	0.004138
LENERG	0.958764	1.200274
LLABOR	−0.029977	0.488572
LALAND	0.383954***	0.094556
LFORES	1.766482	1.259222
LIRRIG	−0.268012***	0.082152
LFERTIL	−0.004634*	0.002418
Dum1	0.079432***	0.015338
Dum2	−40.045332**	0.016504
AR(3)	−0.688183**	0.275643
Adjusted R^2	0.997	
F-statistic	800.48***	
Durbin-Watson stat (DW)	2.358	

Sample $: 1990–2016 ($N = 27$). ***Indicates significance at the 1% level. **Indicates significance at the 5% level. *Indicates significance at the 10% level. Source: Suitably developed programmes in R-Language.

whereas Fig. 2d shows relationship between arable land and permanent crops area and agricultural value-added (1990–2016).

5. Empirical results and discussion

5.1. Unit-root test on variables

It may be mentioned that log of the data was taken to avoid exponential trending before differencing. The Augmented Dickey-Fuller (ADF) tests in Table 3 show that the null hypothesis for each variable does have a unit-root at a level that cannot be rejected. While the endogeneous variable agricultural value added (LAGRIVA) and five exogeneous variables: net capital stock (LNETK); number of machines (LMACHI); amount of credit to agriculture (LCREDI); land equipped for irrigation (LIRRIG); and chemical fertilizer consumed (LFERTIL) could not be rejected even at the 1% level – the rest of the four exogeneous variables could not be rejected at the 5% level. Then, all these variables were converted into first difference or second difference (*LIRRIG*) for further analysis.

5.2. Estimation of parameters α_i

Based on Eq. (4), the growth of agricultural value-added is estimated as shown in Table 4, by running the relevant econometric model containing an autoregressive component. Moreover, two *dummy* variables (*Dum1, Dum2*) were introduced in order to capture respectively the impact of sectorial development policy and strategy and natural phenomena (e.g. flooding, precipitations). These variables influenced the growth of agricultural value-added since the null hypothesis that their coefficients are equal to zero cannot be accepted.

The regression model performs well, predicting 99% of the specified equation correctly. F-statistic was calculated to establish the causality between the growth of agricultural value-added and its determinant factors. All the diagnostic tests on the residuals coming from the long-run model estimation (serial correlation, heteroscedasticity, normality) are desirable.

5.3. Prediction of the growth of agricultural value-added

This section analyzes the gap between the forecasted value (*LAGRIVAF*) and the value of *LAGRIVA* estimated in Section 5.2 named actual value. The objective is to determine the goodness of fit of the estimated regression model. Figure 3a pertaining to the forecasted value indicates that the Root Mean Squared Error is set to only 1.146% and the curve of *LAGRIVAF* is passing through 95% the confidence interval. The Theil Inequality Coefficient shows a perfect fit as well. As a result, we may conclude that the forecasted and actual *LAGRIVA* are moving closely, and then, the predictive power of the estimated regression model is quite satisfactory. This can be observed in Fig. 3b where both *LAGRIVA* and *LAGRIVAF* are plotted together.

6. Impulse response of agricultural production growth

This section provides information on how agricultural value-added will further be reacting in the short, medium and long terms to a positive innovation or shock to an agricultural technology. Analysis and the graphical presentation of the shocks to the net capital stock (LNETK), number of machines (LMACHI), number of hectares of arable land and permanent crops (LALAND), number of hectares equipped for irrigation (LIRRIG), and number of tons for chemical fertilizer (LFERTIL) and their effect on the agricultural value added function was done using Cholesky

Table 5
Impulse response of agricultural value-added (1–10 years)

PERIOD	LAGRIVA	LNETK	LMACHI	LALAND	LIRRIG	LFERTIL
1	0.016548	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000938	0.001880	0.004575	0.003364	0.003025	0.006375
3	0.009523	0.000622	0.008313	0.003506	−0.001925	−3.58E-06
4	0.005766	0.001267	0.011745	0.010891	−0.001772	0.002663
5	0.000604	0.003451	0.007465	0.016807	−0.000977	0.003770
6	0.003461	0.005264	0.008238	0.018609	−0.005930	0.002293
7	0.000132	0.005264	0.008238	0.016867	−0.004091	0.001389
8	0.002821	0.002423	0.004726	0.012513	−0.004422	0.001753
9	0.004001	−5.71E-05	0.006643	0.009692	−0.003263	−0.000406
10	0.003092	−0.001353	0.006889	0.009398	−0.000784	0.001047

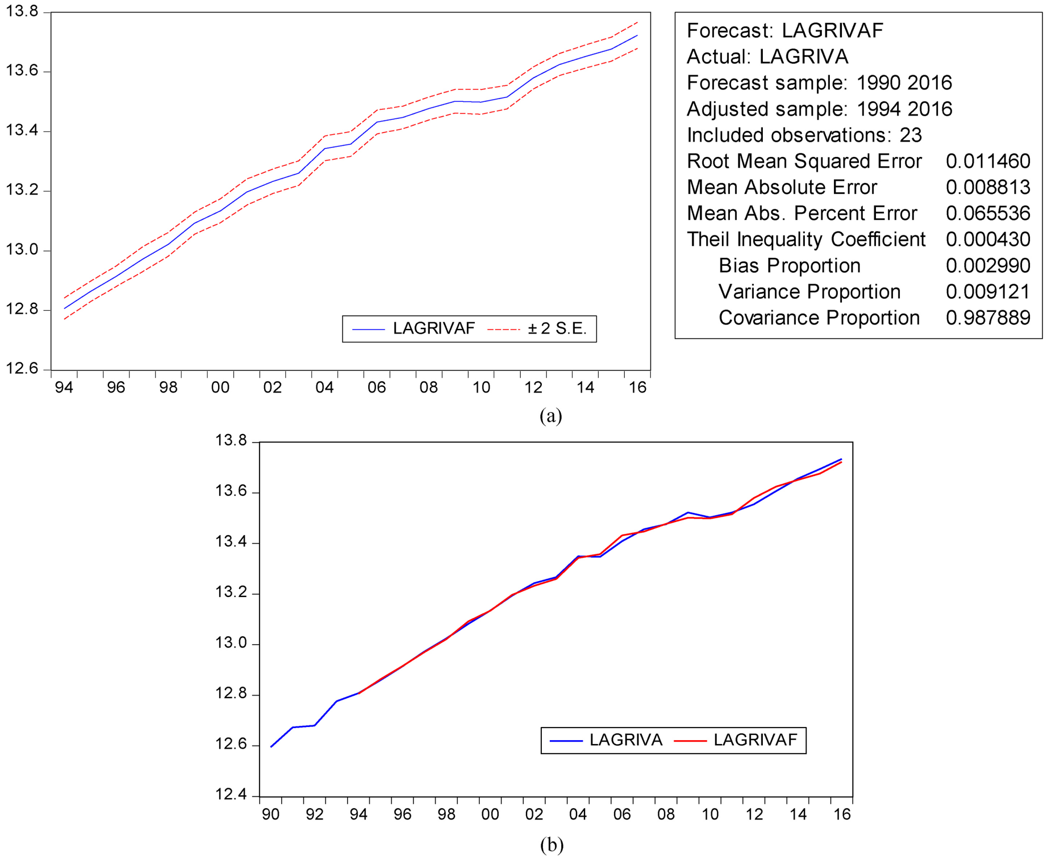

Fig. 3. a: Trend of forecasted growth of agricultural value-added (1990–2016). b: Gap between actual and forecasted growth of agricultural value-added (1990–2016). Source: Suitably developed programmes in R-Language.

(d.f. Adjusted) innovation with suitably developed R-Programming. The response is presented in Table 5.

It is found that today's innovation to machinery (LMACHI) and arable land and permanent crops area (LALAND) in Bihar is continuously positive for the ten years (depicted in Fig. 4c and d) and may be affecting positively and steadily the growth of agricultural value-added within 10 years (long term). Therefore, the goal of sustainable agriculture should rely on mechanized technologies and farming practices involving multi-cropping and agro-forestry.

The growth of agricultural value-added in Bihar responding positively to a net capital stocks (LNETK) are positive for the first 8 years, but turning negative in the ninth and tenth years (depicted in Fig. 4b) which implies that in the short and medium terms (1–8 years) it may be positively affecting the growth of agricultural value added, but it may be declining and turning into

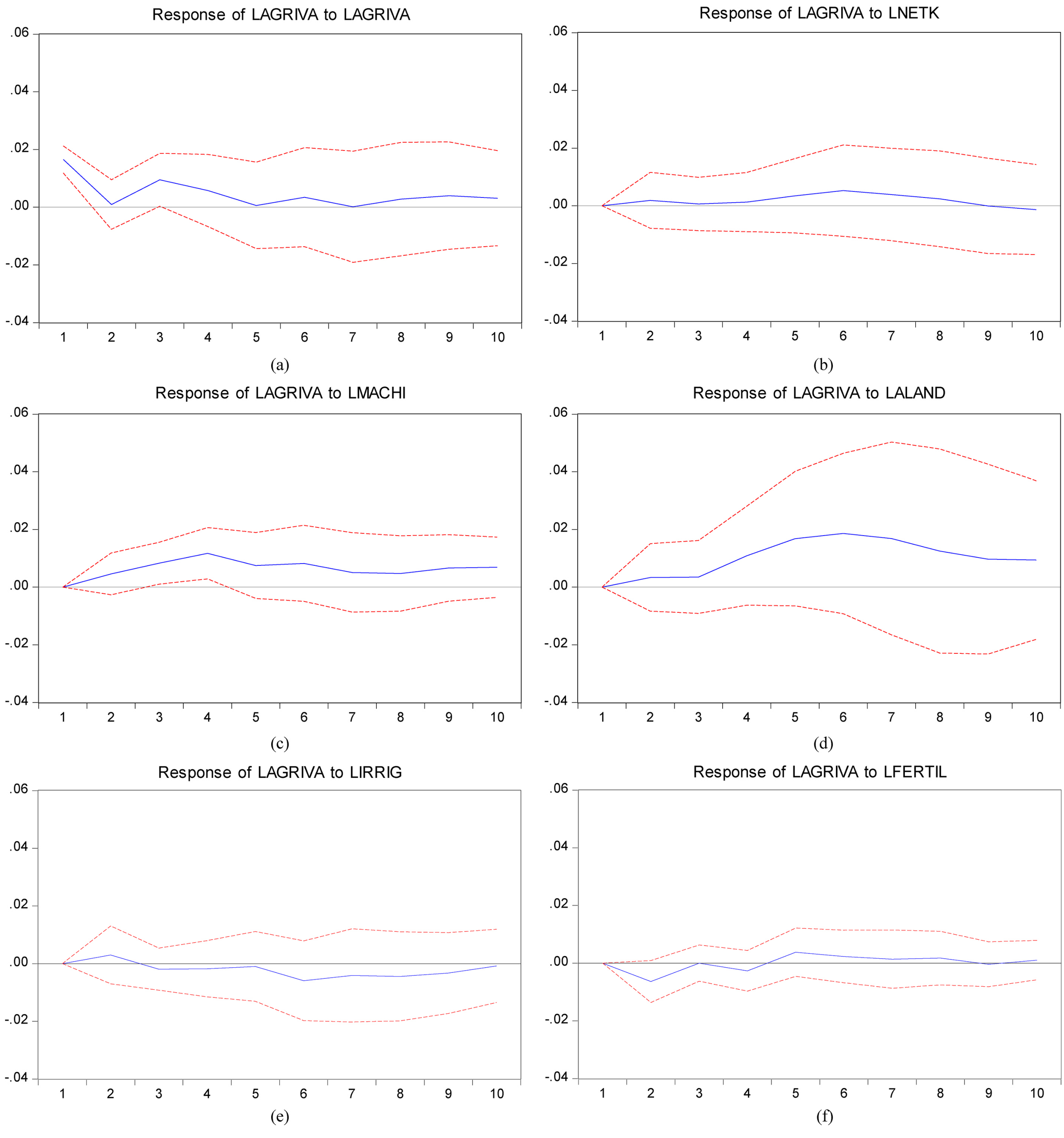

Fig. 4. Impulse response of agricultural value-added growth (1–10 years).

negative effects after 8 years (long term). Accordingly, it may be inferred that capital investments should be reinforced or renewed at opportune moments so as to keep steady the positive trend of the agricultural economic growth over the years.

The growth of agricultural value-added in Bihar may be responding negatively within 10 years further to a shock to irrigation technologies (LIRRIG) as indicated by Fig. 4e. However, this negative response may be reversed after 10 years, indicating that once farmers do appropriate soil characteristics and other subfactors relating to irrigation technologies management, these latter might impact positively the production growth. Meanwhile, the positive response of *LAGRIVA* to *LFERTIL*'s impulsion (Fig. 4f) is likely to dominate the negative effect in the long term (after 4 years).

However, the impulse response is plainly negative in the short term. For sustainable agricultural goal, it may be suggested that these chemical technologies should be applied in a balanced ratio.

Furthermore, it is found that the output growth may be reacting successfully within 10 years when a shock is directly put to the overall production system (Fig. 4a).

7. Conclusions and recommendations

This article examined the influence of agricultural technologies on the growth of agricultural value-added based on time series data (1990–2016) for Bihar which leads to the following conclusion.

Technological progress appears to be a major determinant of boosting the potential productivity of land and affecting positively the growth of agricultural value added in Bihar through new farming devices and practices like multi-cropping, agro-forestry, new varieties of seeds, and new resources management. Investment in capital stock has shown a contribution of 13% in the present study (Table 2) and farmers have increased the agricultural value added by 0.59% with 1% increase in the capital stock, provided supporting infrastructure such as road is ensured. It has also been found that the contribution of the number machines in increasing the agricultural value added is 32%, so it is destined to capture the importance of agricultural mechanization (labour saving technology) – which might foster the drop of some production inputs like labour and the saving of work time. The growth of agricultural value-added in Bihar responding positively to a net capital stocks are positive for the first 8 years, but turning negative in the ninth and tenth years (depicted in Fig. 4b) which implies that in the short and medium terms (1–8 years) may be positively affecting the growth of agricultural value added, but it may be declining and turning into a negative effect after 8 years (long term). Accordingly, it may be inferred that capital investments should be reinforced or renewed at opportune moment so as to keep steady the positive trend of the agricultural economic growth over the years. It is found that today's innovation to machinery and arable land and permanent crops area in Bihar is continuously positive for the ten years (depicted in Fig. 4c and d) and may be affecting positively and steadily the growth of agricultural value-added within 10 years (long term). Therefore, the goal of sustainable agriculture should rely on mechanized technologies and farming practices involving multi-cropping and agro-forestry.

Permanent cropping may be encouraged as the contribution of the factor *ALAND* is established approximately to 21% in Bihar. The number of hectares arranged for arable land and permanent crops is significant and influences positively the growth of the agricultural gross domestic product. Since this variable includes sustainable farming practices like multi-cropping, crop rotation and agro-forestry, the probability that it is positively related to the sustainable agricultural growth and as such the practice of agro-forestry on a farmland might be quite beneficial to the green agricultural revolution with some staple crops namely rice, corn and wheat.

Both the number of hectares equipped for irrigation and the amount of chemical fertilizers appear to be negatively related to the growth of agricultural value-added. Many aspects must be considered in analyzing this outcome given that sometimes, the positive effects generated by applying land-conserving technologies may not compensate their negative externalities. Currently, the pursuit of the agricultural sustainable development goal in Bihar (India) not only relies on chemical fertilizers, but also considers their mixture with organic manure. None of variables *LABOR*, *FORES*, *CREDI*, and *ENERG* are found to be significant determinants of agricultural value-added growth. In other words, the underlying variables are not likely to foster increasing directly the agricultural value-added.

Conclusions derived from this study leads to following recommendations:

1. Bihar may take a large scale investment in agricultural capital as this factor appeared to be greatly related to the growth of agricultural production value.
2. The capital investments should be reinforced or renewed at opportune moments so as to keep steady the positive trend of the agricultural economic growth over the years.
3. The capital investment on agricultural mechanization may lead to a drop in labour, which may be imparted skill for new farming devices and resources management practices.
4. The labour force strengthened with new knowledge and modern practices may have a significant role in multi-cropping, agro-forestry, adoption of new varieties of seeds, and increasing area for arable land and permanent crops, which could influences positively the growth of the agricultural gross domestic product.

5. The credit received by the farmers do not impact the growth of agricultural value added. It needs to be examined whether the amount of credits is too insignificant to generate increasing return to scale or the amount vanish due to an imperfect management.
6. The contribution of the sub-sector of forest seems to be negligible. However, out of their economic role, forests may be recognized an environmental role like carbon dioxide sinks (positive externalities).

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Appendix

Year	AGRIVA (million MU)	NETK (million MU)	MACHI (number)	CREDI (million MU)	ENERG (terajoule)	LABOR (1000 people)	ALAND (1000 ha)	FORES (1000 ha)	IRRIG (1000 ha)	FERTIL (tons)
1990	295124.295927	472395.94	155	0	50.6044	1150	1720	5761	10	11003
1991	319006.425994	484616.04	158	11000	50.6044	1212	1730	5700	10	11817
1992	321140.374332	483696.95	162	430	50.6044	1279	1745	5621	10	15325
1993	353662.038410	492080.38	165	5510	50.6044	1311	1770	5551	10	17238
1994	365271.834742	480494.11	169	480	50.6044	1343	1850	5500	10	17055
1995	384536.97777	474901.39	172	600	50.6044	1371	1970	5411	10	3600
1996	406061.474990	476539.81	175	4530	50.6044	1395	2160	5341	10	30681
1997	430761.675887	481940.03	178	1000	50.6044	1416	2340	5300	11	38968
1998	453363.510806	488456.63	182	1000	50.6044	1435	2500	5201	11	3707
1999	480487.40523	495999.45	185	4134	50.6044	1455	2560	5131	11	56700
2000	506602.247692	508337.62	185	6100	50.6044	1478	2645	5061	11	35200
2001	537490.587059	526739.46	185	6600	50.6044	1504	2715	5011	11	31100
2002	564584.390067	544460.60	185	8110	51.4724	1531	2815	4961	12	47841
2003	577843.419442	557177.98	185	8900	51.4724	1561	2917	4911	14	2126
2004	627617.213824	580780.26	196	7990	51.4724	1587	3017	4861	16	145
2005	626195.000000	593481.70	200	8702	51.4724	1613	2970	4811	18	1226
2006	666418.585965	591628.97	203	6800	51.4724	1638	2785	4761	20	33
2007	698638.387536	595822.53	207	7300	51.4724	1663	2790	4711	21.5	614
2008	712719.778561	601192.06	210	9604	51.4724	1685	2895	4661	23	801
2009	746373.120555	609896.21	214	16770	51.4724	1705	2800	4611	23	16360
2010	731925.343952	609674.30	217	16770	51.4724	1723	2890	4561	23	22826
2011	746607.953106	605811.64	220	24562	51.4724	1740	2980	4511	23	11100
2012	770937.201984	618180.79	224	17170	51.4724	1755	3150	4461	23	26745
2013	811935.972543	618514.88	2271	17861	51.4724	1769	3200	4411	23	12903
2014	853461.901496	615280.64	231	18550	51.4724	1782	3200	4361	23	32954
2015	886550.215097	603621.64	234	34792	51.4724	1795	3200	4311	23	27924
2016	922621.648800	610097.86	234	34792	51.4724	1807	3200	4311	23	301298