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Agricultural Growth and Investments in India: Assessment of Recent Trends, Breaks and Linkages

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Abstract. This paper reviews the recent trends in agricultural investments (both public and private) and tries to find structural breaks in the trends over the period of 1960-2017. Comparing the growth performance of investments and farm output (GDPAg and production) in various sub-periods based on breakpoints in both investment series the study finds that the recent agricultural stagnation spawns from a low capital formation in Indian agriculture, especially low public investment. This has been further strengthened by the regression results where both public and private investments along with fertilizer consumption, HYV seeds, terms of trade, and weather pattern significantly affect the agricultural output. Therefore, the policy implication of the study calls for an immediate arrest of the declining trend of public investment in order to stimulate more private investment. This may break the shackles of growth stagnation in Indian agriculture.

Keywords: investments, structural break, kinked growth, regression, Indian agriculture.

JEL codes: E20, 013, Q14.

1. INTRODUCTION

Since independence, Indian agriculture has gone through different phases of growth influenced by several institutional and technological interventions during various policy regimes. The current crisis in agriculture is not new. Because in the 1950s and early 1960s, before the onset of the "Green revolution" (henceforth GR), the growth rate of agricultural Gross Domestic Product (henceforward GDPAg) used to be mostly less than 2%. However, due to a shift in policy emphasis and technological intervention in the late 1960s in the form of GR technology adoption, the sector saw some revival. The growth rate revived to 2.5-3% and for the next decade, during the 1980s and also early 1990s, the growth of output maintained that steady rate. However, again, the shift in policy regimes towards reform, rendered the sector to lose its tempo and the deceleration set in (Bhalla, Singh, 2001; Rao, 2003). During the 9^{th} plan and also 10^{th} plan, the growth rate dropped down to 2.50% and further to 2.47% (Dash, 2009). Till date, the growth rate of Indian agriculture sector has not touched the targeted 4% (Nadkarni, 2018; Sainath, 2018). The root causes of this slowdown in the primary sector have been intensively studied. Bhattarai and Narayanamoorthy (2003), pointed out that irrigation development and rural literacy could bring a reversal of growth stagnation. Gulati and Bathla (2002), Chandrasekhar and Ghosh (2002) argued that the relative "neglect of agriculture" in India's fiscal policy has slowed down the increase in public canal irrigation intensity rendering some deleterious impact on its growth prospect. Chand *et al.* (2007) pointed out the slowdown in the growth of fertilizer use, energy consumption (electricity), irrigation. Cropping intensity and gross cropped area either grew at a very slow rate or remained stagnant. Chand and Kumar (2004) argued that erratic and deficit rainfall is responsible for the slowdown in early post-reform periods after 1995-1996, other factors also played their role[1]. Similarly, other studies like Vyas (2001), Bhalla and Singh (2009) found the technology fatigue, reduction in public spending on irrigation, water management, and the gradual breakdown of agricultural extension systems in the country. Singh *et al.* (2015) and Akber and Paltasingh (2019a) also argued that there is a crowding-in effect of public investment on the private investmentat farmers' level which implies that significant public investment could be a major policy stimulus for sustained growth of Indian agriculture. Very recently, some studies like Bathla (2017), Bathla *et al.* (2020), and Kumar *et al.* (2020) analyzed investment as a major source of agricultural growth and thereby alleviation of rural poverty. Bathla (2017), Bathla *et al.* (2020) found that public spending on irrigation, agricultural research, and education and health have reaped higher returns.

In this context, a study by Chand and Parappurathu (2012) is a noteworthy one. They hypothesized that GDPAg has gone through different regimes of agricultural policy in India. Therefore, the series is characterized by multiple breaks. Using the Bai-Perron (2003) method of multiple breaks, they found five optimal break-points giving rise to six phases, and then they went on explaining the growth dynamics of GDPAg during those phases. Here, we build on that study and try to go beyond. We also hypothesize that capital formation in Indian agriculture has also gone through various phases of policy reforms and therefore, characterized by multiple structural breaks. So a similar attempt is made to find out the multiple breaks in the farm investment series (both public sector and private sector farm investments) by using the same Bai-Perron method over the period of 1960-2017. We then determine various sub-periods based on structural breaks in investment series and work out the growth performance of investments and farm output. The major objective of this paper is to check whether or not the growth performance in both the public sector and private sector capital formation in Indian agriculture corroborate sits growth performance in the form of GDPAg and production. This is done in two steps. First, we compare the growth performance of farm investments with that of GDPAg and agricultural production during those sub-periods. This will give us a broad idea of whether the growth dynamics in investments match the growth performance of farm output. But this linkage is further strengthened in the second step by finding the influence of growth rates of investments and other factors on the growth rate of GDPAg and production by adopting a "growth accounting method". Thus, by doing so we may probably arrive at an unambiguous and decisive conclusion that whether the growing crisis in Indian agriculture is somewhat driven by the slack performance of agricultural investments or something else.

This study differs from the earlier literature on numerous grounds. First, very few studies have been initiated to examine this relationship between investment and agricultural growth exclusively (Bathla, 2014; Bathla, 2017; Bathla *et al.*, 2020; Kumar *et al.*, 2020). So this will be an addition to the literature. Again, this study deviates from past literature in its approach. It finds the structural breaks in the investment series and then draws a comparison of the growth performance of investments with that of farm output during those sub-periods based on the breakpoints in the investment series. Second, by considering a long period of analysis from 1960-2017, we cover almost all regimes of major policy reforms in Indian agriculture. Hence, a better understanding of the dynamics of the farm investment and the fact of how it influences the growth prospects in the sector emerges from the analysis. This would help in devising an effective policy to boost farm sector growth. Third, we consider both components of farm investment, i.e., public and private investment over a long period, and carry out the exercise in order to delineate the relationship between investment and growth clearly. Fourth, this study is an improvement over others from a methodological point of view. It uses the "kinked growth model" developed by Boyce (1986) to work out the growth performance of investment and farm out-

[1] Chand and Kumar (2004) also argued that GDPAg is affected by subsidies and capital formation along with terms of trade. Though rate of return of one rupee spent on subsidies is much higher than that of public sector capital formation, but for long-term returns from investment is more than double. So capital formation is required for long-term growth of agriculture (p. 5616).

put. This is the most appropriate method in the case of sub-period growth analysis[2]. Hence, we believe that this study would be a worthy contribution to literature and a pertinent reference for policymakers.

The paper is organized in the following manner: after a brief introduction, the second section contains the data and methods. The third section analyses the empirical results and discussion on the recent trends in investments, GDPAg, and production, breakpoints, and growth performance at the national level, a quantitative relationship between the agricultural growth and growth of investment and other factors. Finally, the study concludes with some policy implications.

2. MATERIALS AND METHODS

2.1. Data

The present study is based on time-series data over a period of 58 years (1960-2017) and 38 (1980-2017) years of input subsidy data. Data has been compiled from various sources like *National Account Statistics*, *Reserve Bank of India* (RBI) database and *Agricultural Statistics at Glance*. Apart from public investment (GCFA) as per CSO, public canal intensity is also used as a proxy for public investment. The data on GCFA is compiled from various issues of *National Account Statistics (NAS),* and data on canal intensity, the area under HYV seeds, and cropping intensity is compiled from various issues of *Agricultural Statistics at Glance.* Agricultural gross barter terms of trade variable is taken from NAS of Central Statistical Organization (CSO) by making the ratio of agricultural GDP deflator to non-agricultural GDP deflator. The subsidy data has been compiled from the Ministry of Agriculture & Farmers' Welfare, Government of India, and some other sources[3]. The wholesale price index (WPI) has been used to deflate the data and to convert it into constant series (2011-2012 prices). The credit data has been compiled from the *Reserve Bank of India* (RBI) database. Weather data is from the Ministry of Statistics and Programme Implementation, Government of India. The descriptive statistics along with the definitions of all variables are given in Table A.1. in the Appendix.

2.2. Bai-Perron method for structural breaks

A structural break in time series data is characterized as an unexpected shift which leads to huge forecasting errors. There area number of methods to test the structural breaks in time series data. Chow test (Chow, 1960) is one of the widely used methods where the break date is randomly chosen based on the judgment of the researcher. This problem of relying too much on the subjective assessment of researcher renders this method a little biased. But, the recently developed Bai-Perron (2003) method tests the presence of multiple breaks automatically without individually choosing the break date. Bai-Perron (2003) method is explained in detail here. To find out the multiple breakpoints that are not known before, Bai-Perron prepared a test on the basis ofthe following hypotheses as Ho: m = 0 against H_1: m = 1. When m=0, no structural breaks are present in the time series data and m =1 indicates that the structural breaks are present in the data set. This can be mathematically written as:

$$Y_t = x'_t\beta + z'_t\delta_j + u_t, \qquad (t = T_{j-1}+1,\dots,T_j) \tag{1}$$

For $j=1,\dots,m+1$. In this model, Y_t is the observed dependent variable at time t; $x_t(p\times1)$ and $z_t(q\times1)$ are the vectors of covariates and β and δ_j $(j=1,\dots,m+1)$ are the corresponding vectors of the coefficients; u_t is the disturbance term at time t. The indices $(T_1,\dots,T_m)$ are treated as unknown (we use the convention that $T_0=0$ and T_{m+1}). The purpose is to estimate the unknown regression coefficients together with the breakpoints when T observations on (y_t,x_t,z_t), are available. This is a partial structural change model since the parameter vector β remains constant. When p=0, we obtain a pure structural change model where all the coefficients are subject to change. The variance u_t needs not to be constant. Indeed, breaks in variance are permitted provided they occur at the same dates as in the parameters of the regression.

This multiple linear regression as mentioned in (1) can be written in matrix form as:

$$Y = X\beta + \bar{Z}\delta + U \tag{2}$$

Where $Y=(y_1,\dots,y_t)$, $X=(x_1,\dots,x_t)$, $U=(u_1,\dots,u_t)$, $\delta=(\delta'_1,\delta'_2,\dots,\delta'_{m+1})$ and $\bar{Z}$ is the matrix which diagonally partitions Z at $(T^\circ_1,\dots,T^\circ_m)$ with $Z_i=(zr_{t-1}+1,\dots,zr_i)$. We denote the true value of a parameter with a 0 superscript. In particular, $\delta^\circ=(\delta^\circ_1,\delta^\circ_2,\dots,\delta^\circ_{m+1})$ and $(T^\circ_1,\dots,T^\circ_m)$ are used to denote, respectively the true values of the parameters δ and the true breakpoints. The matrix $\bar{Z}$ diagonally partitions Z at (T°_1,T°_m). The data generating process is assumed to be as:

[2] Most of the studies including the one by Chand and Parappurathu (2012), Bathla (2014) and others use semi-log compound growth model for sub-period growth analysis. But that method has got some serious methodological loopholes. For details see Boyce (1986: 385).

[3] The other sources include Gulati *et al.* (2018) and also compiled from Indiastat.com.

$$Y = X\beta^{\circ} + \bar{Z}^{\circ}\delta^{\circ} + U \quad (3)$$

The method of estimation is based on the least-squares principle

$$(Y - X\beta - \bar{Z}\delta)Y - X\beta - \bar{Z}\delta = \sum_{i=1}^{m+1}\sum_{Ti-1+1}^{Ti}(Y_t - X_t\beta - \acute{Z}_t\delta)^2 \quad (4)$$

To carry out the asymptotic assumptions, we need to impose some restrictions on the possible value of break dates. Each break date should be asymptotically distinct and bounded from the boundaries of the sample. Let $\lambda_i = {T_i}/{T} (i=1,\ldots,m)$ and define the following settings for some arbitrary positive number ϵ, a trimming parameter which imposes the minimal lengthfor a segment h, i.e. $\epsilon = {h}/{T}$,

Before constructing the Sup F type test, we need to limit the possible breakpoints which give the following set:

$$\Lambda_\epsilon = \{(\lambda_1,\lambda_2,\ldots,\lambda_k):(\lambda_i+1-\lambda_i \geq \epsilon, \lambda_1 \geq \epsilon, \lambda_k \leq 1-\epsilon\} \quad (5)$$

Let $\hat{\beta}(\{T_j\})$ and $\hat{\delta}(\{T_j\})$ denote the estimates based on the given m partition $(T_1,\ldots,T_m)$, denote $\{T_j\}$. Substituting these in the objective function and denoting the sum of squared residuals as $S_t(T_1,\ldots,T_m)$, the estimated breakpoints are:

$$(\hat{T}_1,\ldots,\hat{T}_m) = \arg min_{(\lambda_1\ldots\lambda_m)\in\Lambda_\epsilon} S_t(T_1,\ldots,T_m) \quad (6)$$

The minimization is taken over all partitions $(T_1,\ldots,T_m)$ such that $T_i,\ldots,T_{i-1} \geq h = T_\epsilon$. Finally, the regression parameter estimates are associated with the m- partition $\hat{T}_j$. For the empirical illustration, we use the method based on a dynamic programming algorithm developed by Bai and Perron (2003).

2.3. Kinked compound growth rates

After finding out the breakpoints of the data series, we find out the growth rates of agricultural investments, GDPAg, and production by using the kinked compound growth model. The method of kinked compound growth rate estimation provides a clear picture of growth rates at different sub-periods (Boyce, 1986).

The unrestricted generalized kinked model for '***m***' sub-periods with '***m-1***' kinks such as $\boldsymbol{k_1, k_2, \ldots, k_{m-1}}$, and $\boldsymbol{D_1, D_2, \ldots D_m}$ sub-periods dummiescan be written as:

$$LnY_t = \alpha_1 D_1 + \alpha_2 D_2 + \ldots + \alpha_m D_m + (\beta_1 D_1 + \beta_2 D_2 + \ldots + \beta_m D_m)t + \epsilon_t \quad (7)$$

Applying ***m-1*** linear restrictions as $\alpha_i + \beta_i k_i = \alpha_{i+1} + \beta_{i+1} k_i$ for all i =1, 2,3,**.....*m-1***, the restricted generalized kinked compound model as:

$$\begin{aligned} LnY_t &= \alpha_1 + \beta_1\left(D_1 t + \textstyle\sum_{j=2}^m D_j k_1\right) + \\ &\beta_2\left(D_2 t - \textstyle\sum_{j=2}^m D_j k_1 + \sum_{j=3}^m D_j k_2\right) + \cdots \\ &\ldots + \beta_i\left(D_i t - \textstyle\sum_{j=i}^m D_j k_{i-1} + \sum_{j=i+1}^m D_j k_i\right) + \\ &\cdots + \beta_m(D_m t - D_m k_{m-1}) + \epsilon_t \end{aligned} \quad (8)$$

The βs give the values of growth rates for respective periods. From this generalized model, the required growth model for a fixed number of sub-periods depending on the number of kinks / breakpoints in the series can readily be derived.

2.4. Investment and agricultural growth linkage: first-difference regression model

Birthal *et al.* (2014) argue that the competition for land for non agricultural use is likely to be intensified. Therefore, to augment production and output, intensive cultivation is the only way out for which a large-scale investment is required. After linking the growth performance broadly between investment and farm output during various sub-periods based on break-points, here we try to further strengthen that connection. Hence, we try to find out the impact of investment growth and growth of other relevant factors on the growth of GDPAg and agricultural production by using the "first difference" (FD) regression model based on the growth accounting method[4]. This method adopted here is similar to that of Ricker-Gilbert *et al.* (2013), Chand (2005)[5], and Kumar *et al.* (2019)[6]. The regression models are:

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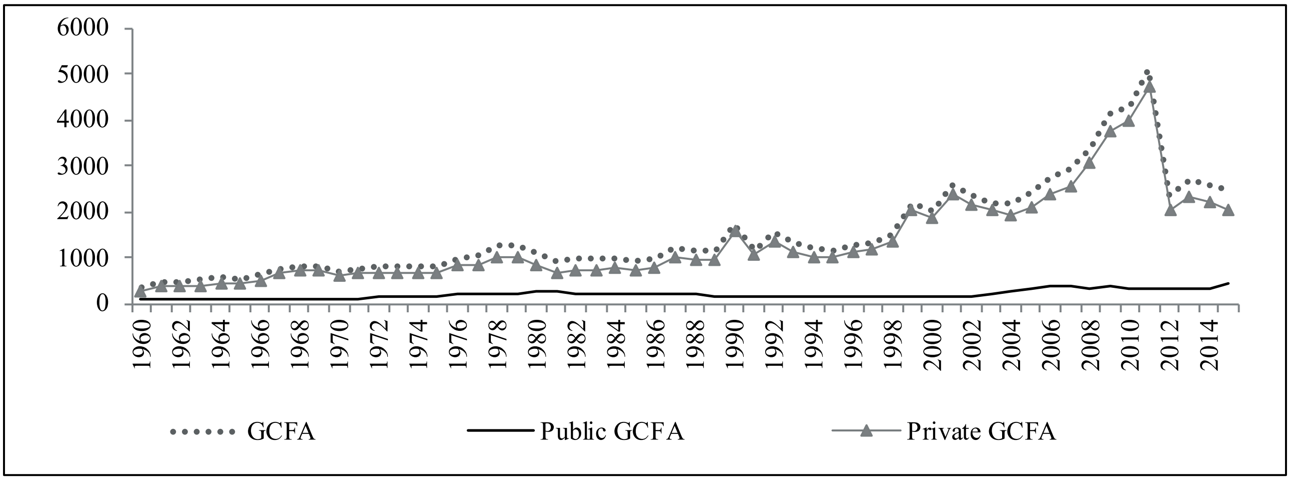
[4] We know that the growth rate of Y can be written as $\Delta\ln Y_t = {\dot{Y}}/{Y}$. Because, approximating of $\Delta\ln Y_t$ as $d\ln Y_t$ for infinitesimal change and differentiating it with respect to time t we get as: $\frac{dlnY_t}{dt} = \frac{dlnY_t}{dY}\frac{dY}{dt} = {\dot{Y}}/{Y}$. So taking a Cobb-Douglas production function approximation of output we get $Y = I_g^{\beta_1} I_g^{\beta_2} S^{\beta_3} C^{\beta_4} CI^{\beta_5} P^{\beta_6} W^{\beta_7} F^{\beta_8} e^{\mu}$ and taking difference of logarithmic approximation of it we arrive at the estimable form of the equation (9) and (10). This is similar to the growth accounting method to find total factor productivity (TFP) of a sector.

[5] Chand (2005), using this growth accounting method found the growth contribution of one factor by either assuming or estimating the growth rate of other factors. But here we just regress the annual growth of output on annual growth of inputs which will give the sources growth in output.

[6] Kumar *et al.* (2019) used the same methodology but regressed the agricultural growth on irrigation growth and rainfall deviation only.

Fig. 1. Trend in agricultural investments (GCFA, Public and Private sector GCFA).



Source: National Account Statistics-2011 back series, 2014 and 2017.

$$\Delta InPR = \beta_0+\beta_1\Delta lnI_g + \beta_2\Delta lnI_p + \beta_3\Delta lnSBDY + \beta_4\Delta lnCRDT + \beta_5\Delta lnCI + \beta_6\Delta lnTOT + \beta_7\Delta lnW + \beta_8\Delta lnHYV + \alpha_9\Delta lnFERT + \mu_{1t} \quad (9)$$

$$\Delta InGDPA = \alpha_0 + \alpha_1\Delta lnI_g + \alpha_2\Delta lnI_p + \alpha_3\Delta lnS + \alpha_4\Delta lnC + \alpha_5\Delta lnCI + \alpha_6\Delta lnTOT + \alpha_7\Delta lnW + \alpha_8\Delta lnHYV + \alpha_9\Delta lnFERT + \mu_{2t} \quad (10)$$

All the variables are in logarithmic form and Δ is the difference term. PR and GDPAg are total agricultural production (million tonnes) and gross domestic product-agriculture (crores Rs) respectively. I_g is public sector GCFA (crore Rs), I_p is private sector GCFA (crores Rs), C is farm institutional credit (crore Rs), CI- cropping intensity (index), ToT is gross barter term of trade and W is weather index[7] and HYV stands for the area under high yielding varieties (million ha), FERT is fertilizer consumption (thousand tones); SBDY is total subsidies (crores Rs); s are the error terms, αs, and βs represent the parameters to be estimated. The FD framework used here has certain advantages: first, it is based on the theoretical justification; second, it takes care of the non-stationarity problem as many variables are non-stationary in nature. In addition to this, it also solves the problem of time constant heterogeneity in the regression models, and in the presence of serial correlations, the consistency of estimates will not be affected (Ricker-Gilbert *et al.*, 2013: 679). Following the study of Akber and Paltasingh (2019a) and Gulati and Bathla (2001), we set up two baseline models for both production and GDPAg growth. One contains public investment as per CSO and the second contains public canal intensity as a major component of public investment.

3. RESULTS AND DISCUSSION

3.1. Trends and Pattern of Investments in Indian Agriculture

The trends of agricultural investment as a share of GDPAg and as a share of total investment undertaken in the economy as a whole are depicted in various figures. Doing so captures the relative position of agricultural investment within the economy as a whole and the agricultural sector in particular. First, the trend of agricultural investments is analyzed, and then the ratio of investment to GDPAg, and finally the trends of the ratio of agricultural investment to the total aggregate investment in the economy are analyzed.

Figure 1 depicts the trend of agricultural investment in terms of gross capital formation in agriculture (GCFA), public sector GCFA, and private sector GCFA in India at 2011-2012 prices. It is clear that total agricultural investment increased during the period of the 1960s and 1970s and then declined in the 1980s and 1990s followed by an increasing trend since 2000 but this increase continued only for a decade. Since 2011, it again faced a decline in its trend. It is because the total investment is majorly contributed by private sector investment and the private investment is on a secular increasing trend mostly characterized with very little volatility till 2011

[7] For making the weather index, we use the Angstrom aridity index which is expressed as: $W = \left(R/_{T^{1.07}}\right)$ where R and T are average rainfall and average temperature. For details see Paltasingh *et al.* (2012), and Paltasingh and Goyari (2018).

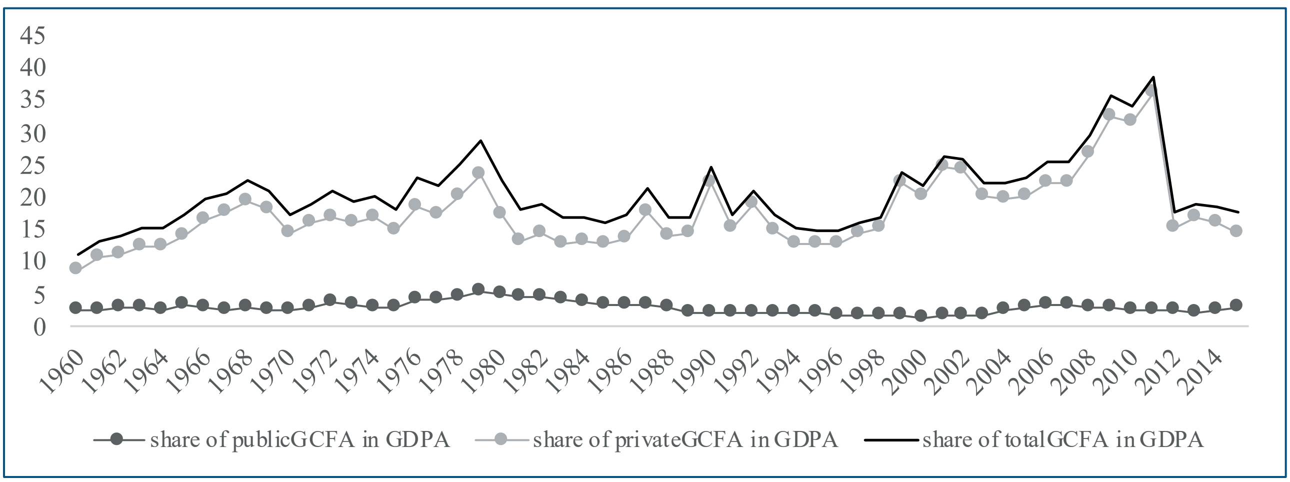
after which it declined. This corroborates the increasing trend in total investment. Hence, both trends are found increasing during the 1960s and 1970s and a decline since the 1980s and 1990s. Private sector GCFA again reversed its trend since 2011 but, the public sector GCFA continued to be mostly stagnant or increase very slowly, except little recovery in 2000. But again after 2000, it continues to be stagnant till 2004 after which it has slightly increased. This continuous stagnation or decline in public investment is caused by mounting expenditure from the public exchequer in the form of various input subsidies (Gulati, Narayanan, 2003; Mogues *et al.,* 2012; Akber, 2020). Though once considered crucial in helping the adoption of GR technology initially, these input subsidies are now found to be ineffective in enhancing production and productivity (Fan, 2008; Akber, Paltasingh, 2019b; Akber, Paltasingh, 2020). So there is a greater demand for their rationalization.

The trends of the share of agricultural investments as a percentage share of GDPAg in India at 2011-2012 prices are depicted in Figure 2. The share of public sector GCFA in GDPAg has remained very little within the range of 1 to 5% in the entire period of study. Since the 1960s, the share of total and private GCFA in GDPAg showed an increasing trend at constant prices (2011-2012), and their trends reversed during the 1970s. Since the 1970s, wide fluctuations between the share of total and private GCFA in GDPAg is observed. An improvement was observed in the year 1979, and thereafter it further declined. Since 1998, both started to revive and were at their peak in the year 2011 when the share of total GCFA in GDPAg was 38.84%, in the private sector it was 36.23%. However, they further declined afterward. Despite some fluctuations, the share of public sector GCFA remained almost constant. However, an increasing trend was observed in the case of private sector GCFA till 2011. The increasing trend of total GCFA as a ratio of GDPAg was recorded due to the increasing share of private-sector GCFA.

Many studies have tried to analyze the GCFA as a percentage of GDPAg. Shetty (1990) examined the relationship between GCFA and real GDP at 1980-1981 prices and found the share at 6-7% during the early 1960s and 1970s. In the period 1979-1981, the share was at its peak at 14%. Gulati and Bathla (2001) after refining and re-examining the capital formation in Indian agriculture have concluded that GDPAg varies narrowly with public sector GCFA. Since the 1980s, public sector GCFA has shown a decline while GDPAg increased due to an increase in private GCFA. The share of public GCFA at 1993-1994 prices have shown a declining trend in GDPAg while the private sector has shown an increasing trend during the period of 1980-2009 (Singh, 2014). Despite some fluctuations, there has been an increasing trend in the share of GCFA in GDPAg at current prices (Paltasingh *et al.,* 2017). Similarly, in this study, we also observed that public sector GCFA as a share of GDPAg (at 2011-2012 prices) constitutes very little for the whole period of study. But, the private sector share in GDPAg was found to be much higher as compared to the public sector.

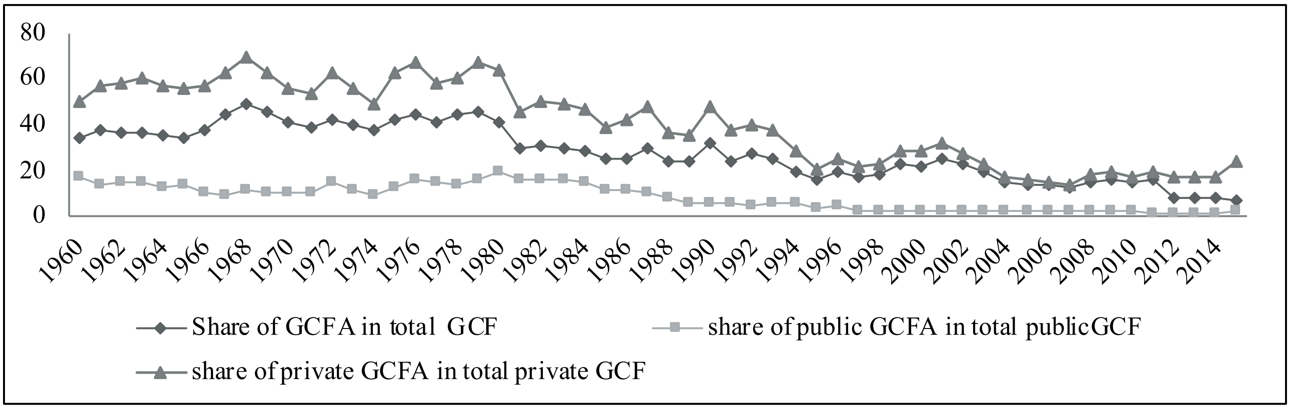
Figure 3 shows the trends of agricultural investment as a share of total investment in an economy. Two important points have been observed in the case of the trends of the ratio of total GCFA in total GCF, public sector GCFA in public sector GCF of the economy and

Fig. 2. Public, private and total GCFA as percentage of GDPAg (at 2011-2012 prices).



Source: National Account Statistics-2011 back series, 2014 and 2017.

Fig. 3. Public, private, and total GCFA as percentage of total GCF of Indian economy at 2011-2012 prices.



Source: National Account Statistics 2011 back series, and 2014 and 2017.

private sector GCFA in private sector GCF of the economy. The share of total agricultural investment in the economy-wide investment maintained its higher share up to 1979, but thereafter a secular declining trend has been observed in case of. Interestingly, the rising trend in the initial period from 1960 to 1979-1980 is coupled with much volatility while the declining trend is with almost no fluctuations. It means the decline in agriculture investment as a share of total investment has taken place constantly and continuously at a much faster rate after the 1980s. Public sector GCFA as a percentage of public GCF remained within the range of 1-16%, and the share of private-sector GCF in private GCF was in-between 6-48%. Similarly, the share of total GCFA in total GCF of the economy remained within the range of 13-66%. Initially, it was around 66% but now came down to little more than 10%. Since 1998 the share of public sector GCFA remained constant at 1-2%. The share of private-sector GCFA in private GCF has remained highest in all the periods of the study.

3.2. Structural breaks in investments series

Table 1 reveals the structural breakst hat exist in time-series investment data at the national level. Since we are finding the structural breaks in two investment series, public GCFA, and private GCFA, we don't name the periods as Chand and Parappurathu (2012) have done. Rather we just name them as 1st, 2nd and 3rd period and so on. However, the classification done in their study can be broadly followed here since the breakpoints found here in GDPAg by using the Bai-Perron method are more or less similar or very close to the ones found by them in their study. In the case of public GCFA we observe four optimal breaks while in for the private

Tab. 1. Structural breaks in investments and output series.

Breaks	Public GCFA	Private GCFA	Subsidy
1st breakpoint	1968	1968	1991
2nd breakpoint	1976	1988	2007
3rd breakpoint	1988	1996	2011
4th breakpoint	2003	2004	---
5th breakpoint	---	2011	---

Note: All estimate breakpoints are significant at a 5% level and a trimming percentage of 15% (in the Bai-Perron test of 1 to M globally determined breaks). For subsidies, the available data series considered here is from 1980-2015.

Source: Data compiled from *National Accounts Statistics*, Govt. of India and *Agricultural Statistics at Glance.*

GCFA, we find five optimal breaks. For subsidies, only three break points are observed. The optimal numbers of breakpoints are decided on the basis ofthe "Bayesian Information Criterion" (BIC)[8], an appropriate method as suggested by Bai and Perron (2003). From Table 1, the four optimal global breakpoints in public investment series are found in 1968, 1976, 1988, and 2003. Similarly, five optimal breaks in the case of private investment are found to be 1968, 1988, 1997, 2004, and 2011. The comparison of breakpoints between private and public GCFA reveals that three breaks points of public GCFA match with that of private GCFA. Even the breakpoints in total subsidies in later periods of the 1980s onwards don't follow the private GCFA. So, it does not support the arguments that the mounting input subsidies pave the way for a rise in private investment. Now the question of whether the investment growth corroborates a

[8] BIC figures are shown in Table 2. But can be produced on request from the authors.

similar growth trend in GDPAg and production needs to be analysed carefully?

3.3. Growth Performance of Investments, GDPAg, and Production

In this section, we work out the growth performance of both investment series separately and then draw a comparison with the trend growth rates of GDPAg and production during those phases based on the breaks in that particular investment series. For instance, the public GCFA has got four breaks leading to five sub-periods. So in this case, we compute the growth rates of public GCFA, GDPAg, and production for those five sub-periods. Similarly, for private GCFA, we repeat the same exercise. In this way, ensuring the temporal coincidence of sub-periods, it allows a homogenous comparison of growth trends of these macroeconomic variables in the farm sector. This would partially explain the relationship between investment and farm outputs if there found to be a co-movement of their growth trends.

The growth performance of public sector GCFA, GDPAg, and production in those five sub-periods is given in Table 2. The results clearly reveal that public investment experienced growth stagnation (0.64%) during the first sub-period (1960-1968) which happens to be the pre-GR period. But, at the same time, private investment grew at a rate of 2.41%. Though the growth rate of public investment improved in the second period at 1.55%, this improvement does not continue for a long, it further declined in the third period (0.85%) and also continuously slide down in the fourth period. However, an improvement in public expenditure took place in the early 2000s so that its observed growth rate for the last period of 2004 onwards was 1.45%. Now looking at the trend growth of GDPAg and farm production, we observed a clear-cut co-movement of growth trends of GDPAg and also production with that of public sector GCFA. In the pre-GR period, the growth rate of GDPAg was found to be merely 0.56%. But, in the subsequent GR period (1969-1976), which is considered as the initial-GR period, the GDPAg and production grew at an impressive rate of 4.37% and 3.23% respectively. In this period, special emphasis was put on GR technology along with the development of public irrigation system. So the massive increase in public expenditure towards the transformation of Indian agriculture with irrigation development reaped the benefit. There was a phenomenal growth of GDPAg as well as production. Perhaps this is the only period when the growth rate of GDPAg touched that elusive 4% growth target. However, as public investment declined in the subsequent period (1977-1988), the growth rate of both GDPAg and production also declined, though the decline in production is relatively less in comparison to GDPAg. The next period, i.e., the 1990s registered a further decline in public expenditure towards agriculture. This crisis period of the 1990s which also marked the initiation of "Economic Reform", is termed as the period of "complete neglect of agriculture", and characterized by a huge cut-down in the public expenditure toward agriculture, irrigation, and rural development (Gulati, Bathla, 2002). The near-stagnation in irrigation intensity conjoined with intermittent droughts and the rising cost of inputs rendered agrarian distress in the farm sector (Haque, 2016; Bathla, 2017). However, realizing this crisis, there was an increase in the budgetary outlays during the 2000s by almost all state governments in the Indian union to control this situation. As Chand and Parappurathu (2012) evidenced that there was a significant hike in expenditure for drought relief measures as well as rural employment generation programs coupled with rising minimum support prices of key crops and rise irrigation intensity, etc. led to some improvement in public capital formation in agriculture. The growth rate of public sector GCFA during this period (2004-2017) comes out to be 1.45%. The corresponding growth rate of GDPAg and production were 2.88% and 2.53%. However, it is noteworthy to mention that there was a phenomenal achievement in the growth performance of agriculture in the decade of 2000s which came close to the 4% target growth rate. But, here since we calculated the growth of GDPAg and production for the entire sub-period of 2004-2017 on the basis of the breakpoint in the public GCFA, the growth rate comes out to be 2.88% and 2.53% respectively. It is because this period is also marked by a huge decline in private GCFA after 2011-2012 (refer to Fig. 1 and 2). So this dismal growth performance of private investment

Tab. 2. Growth rates of public investments and farm output during various phases (in 2011-2012 prices).

Periods	Public GCFA	GDPAg	Prod.
1st period (1960-1968)	0.64***	0.56*	1.07
2nd period (1969-1976)	1.55**	4.37***	3.23***
3rd period (1977-1988)	0.85**	2.78***	2.24***
4th period (1989-2003)	0.55***	2.29**	1.84***
5th period (2004-2017)	1.45**	2.88***	2.53***

Note: (a) The asterisks (***), (**) and (*) indicate significance at 1%, 5%, and 10% respectively. (b) The periods are based on their respective break points in public GCFA.
Source: Authors' estimation from compiled data. Data compiled from *National Accounts Statistics*, Govt. of India and *Agricultural Statistics at Glance.*

Tab. 3. Growth rates of private investments and farm output during various phases (in 2011-2012 prices).

Periods	Private GCFA	GDPAg	Prod.
1st period (1960-1968)	2.41***	0.56*	1.07
2nd period (1969-1988)	1.95***	3.77***	2.56***
3rd period (1989-1997)	4.37*	2.49***	1.85***
4th period (1998-2003)	3.73***	3.01*	1.66***
5th period (2004-2011)	7.63***	3.77***	2.33***
6th period (2012-2017)	- 3.13*	2.21*	2.46**

Note: (a) The asterisks (***), (**) and (*) indicates significant at 1%, 5%, and 10% respectively. (b) The periods are based on their respective breaks private GCFA.
Source: Authors' estimation from compiled data. Data compiled from *National Accounts Statistics*, Govt. of India and *Agricultural Statistics at Glance.*

might have nullified the achievement in the growth rate of GDPAg and production to some extent. But, overall growth trends of all three series move in tandem in one direction. This suggests that public financing of agriculture is crucial for its growth and should be emphasized in the economy's fiscal policy adequately (Bathla, 2017).

Now observing the trend growth of the private investment and GDPAg and production in various sub-periods based on the breakpoints in private GCFA series, we don't find a close co-movement like that of public investment up to the third sub-period (Tab. 3). But subsequently, we find the co-movement growth trends of these variables. The growth rate of private investment in the pre-GR period (1960-1968) was 2.41%, but in the subsequent period, it dipped down to 1.95%. This is a strange phenomenon because this is the period of early GR period where public investment took off, but private investment did not follow it. Nonetheless, in the three subsequent periods (1988-1997, 1998-2003 and 2004-2011), the growth rates of private GCFA have been a little impressive (4.37%, 3.73%, and 7.63% respectively). But, after 2011 there was a sudden collapse in the rising trend and it fell so steeply after 2011 that we got a negative growth rate of -3.13 for the period of 2012-2017. Now drawing the comparison of sub-period growth rates of private investment series with that of GDPAg and production, we observed that growth stagnation inagricultural Production and GDPAg during the first sub-period, i.e., the pre-GR period could possibly be explained by the growth stagnation in public investment, though the private investment was slightly higher. But, when public investment peaked in the second period, the output growth rate also moved up, though the private investment was lower than the previous period. This period happens to be the period in which this elusive 4% growth in GDPAg target was achieved. But, this sub-period of private investment (1969-1988) is actually a combination of two sub-periods of public investment (1969-1976, and 1977-1988). So the growth rate of GDPAg in this period happens to be a little less than 4%. In the succeeding two sub-periods, the growth rates of GDPAg and production slowed down, which might be due to a slowdown in the growth of public investment, though slightly higher growth in private investment sustained the growth in GDPAg just above 3%. But subsequently, in the fifth sub-period (2004-2011) there was phenomenal growth in the private investment which sustained the agricultural growth at 3.77%. It should be noted that during this period, the public expenditure in the form of both investment and input subsidies also increased which led to a rise in private sector investment. Bathla (2017) showed that the subsidies and private investment grew at a rate of 6% and 9% respectively (at 2004-2005 prices) and irrigation intensity touched 50%. Therefore, the farm sector was able to achieve an all-time high growth rate of 3.8% annually during this period. So probably it can be argued that the increase of public investment not only directly affects the agricultural growth, it also stimulates a private sector capital formation, and thereby positively influences farm sector growth prospects. But in the subsequent sub-period (2012-2017) there is a sudden decline in private investment which rendered a slump in the farm sector growth as GDPAg and production grew at merely 2.16% and 2.24% respectively. Though the possibility of other factors driving the farm sector growth during different phases cannot be ruled out, this somehow explains the importance of investment in stimulating growth in the farm sector. Therefore, in the next section, we explore in detail the sources of agricultural growth.

3.4. Linkage between output growth and investment growth

Table 4 reveals the sources of GDPAg growth. It is clearly observed that agricultural GDPAg growth is positively and significantly affected by both the investment growth (public and private sector) in Indian agriculture. The coefficient of public investment growth ranges between 0.216-0.211% and significant at 10% probability level and the coefficient of growth of public canal intensity varies from 0.48 to 0.34 which are significant at 5% level of significance respectively, indicating that with a 1% increase in growth of public investment, the growth of GDPAg increases by 0.216-0.211% and 1% increase in growth of public canal intensity would raise the growth of GDPAg by 0.48% to 0.34%. The impact of private investment growth is observed to be little high and

Tab. 4. Determinants of GDPAg growth in Indian agriculture.

Variable	(1)		(2)		(3)		(4)	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
Constant	0.011**	0.020	0.010**	0.037	0.011**	0.028	0.012**	0.014
Δ(Ig)	0.216*	0.081	---	---	---	---	0.211*	0.067
Δ(CNI)	---	---	0.481**	0.039	0.344**	0.044	---	---
$\Delta(I_P)$	0.420**	0.043	0.38***	0.007	0.361**	0.036	0.414**	0.025
Δ(CRI)	3.306***	0.000	3.679***	0.000	3.643***	0.000	3.262***	0.000
Δ(CRDT)	0.010	0.337	0.014	0.191	0.014	0.188	0.010	0.340
Δ(FERT)	0.202***	0.009	0.207***	0.010	0.211***	0.008	0.206***	0.008
Δ(HYV)	0.037**	0.029	0.064**	0.035	0.063*	0.055	0.035**	0.032
Δ(W)	-0.028*	0.091	-0.023	0.193	-0.023	0.191	-0.028*	0.091
Δ(TOT)	0.399**	0.026	0.340*	0.079	0.363*	0.064	0.425**	0.020
Δ(SBDY)	0.031*	0.098	0.028	0.124	---	---	---	---
Adj. R-sq.	0.84		0.83		0.92		0.91	
Log-likelihood	97.957		96.73		93.56		94.84	
F-stat.	10186.420		9533.29		10676.16		11463.12	
Prob.(F-stat)	0.000		0.00		0.00		0.00	
D-W Stat.	2.14		2.33		2.29		2.11	
AIC criterion	-4.754		-4.68818		-4.698		-4.769	
BIC criterion	-4.319		-4.2528		-4.302		-4.373	

Note: (a) The asterisks (***), (**) and (*) indicate significance at 1%, 5%, and 10% respectively. (b) The number of observations in the case 3rd and 4th specification is only 38 as the time period is only 36 years from 1980-2017. For the other two specifications, it is 48 from 1970-2017.
Source: Author's estimation.

coefficient values are varying within the range of 0.36-0.42 at a 1% level of significance. Other significant contributors to the growth of GDPAg are growth cropping intensity, fertilizer consumption, and area under HYV seeds, weather risk, and growth of terms of trade. The coefficient of weather risk showed a negative impact on GDPAg growth. No significant impact is observed by the growth of institutional credit while aggregate subsidies show a very weak impact on GDPAg. The value of adjusted R-squared is around 83-92%, Durbin-Watson statistics vary in-between 2.14 to 2.11 which are higher than R-squared values, indicating the non-existence of spurious regression.

Table 5 depicts the sources of growth of agricultural production, which clearly indicates that investment growth has a positive effect on the production growth (both public and private sector investment). The coefficient of public investment varies within the range of 0.361 to 0.346 while the impact of public canal intensity varies within the range of 0.435 to 0.463 in various specifications. In the case of private investment, the coefficient values are all statistically highly significant and varying within the range of 0.321 to 0.362. Among other vital sources of production growth, we get growth of cropping intensity, fertilizer, HYV seeds, and terms of trade. The credit and subsidies are not significant while weather risk is significant in one of the specifications. Recently, Akber and Paltasingh (2019b) evidenced that public investment augments farm productivity more in comparison to input subsidies as a whole. The results of Table 5 in the case of growth of production resemble the results of the previous Table. The results are also in line with previous studies like Chand (2005), and Chand and Kumar (2004), and Mathur *et al.* (2006)[9]. The values of adjusted R-squared are around 91% and also Durbin-Watson Statistic values are 2.14 to 2.25 in all the specifications which confirm the non-existence of spurious regression.

From the given analysis, we get various facts. First, the public sector investment in Indian agriculture declined during the 1980s and 1990s and the private sector investment maintained its pace till 2010-2011. Though in 2003-2004 there was a slight improvement inthe trend of public sector GCFA, it still remains less in comparison to private investment in the farm sec-

[9] The results they got by using linear OLS model with or without logarithmic approximations but not with the FD framework.

Tab. 5. Determinants of production growth in Indian agriculture.

Variable	(1)		(2)		(3)		(4)	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
Const.	0.007**	0.036	0.007**	0.052	0.008*	0.058	0.008*	0.079
Δ(Ig)	0.361*	0.063	---	---	---	---	0.346**	0.028
Δ(CNI)	---	---	0.435**	0.049	0.463**	0.045	---	---
Δ(Ip)	0.343***	0.006	0.362**	0.037	0.346***	0.008	0.321**	0.043
Δ(CRI)	1.383***	0.000	1.260***	0.001	1.242***	0.005	1.513***	0.001
Δ(CRDT)	-0.005	0.610	-0.002	0.871	-0.003	0.977	-0.002	0.810
Δ(FERT)	0.275**	0.024	0.264*	0.063	0.271**	0.027	0.237**	0.026
Δ(HYV)	0.113*	0.689	0.190**	0.050	0.174**	0.030	0.166*	0.063
Δ(W)	-0.021	0.170	-0.014	0.368	-0.019	0.229	-0.026*	0.091
Δ(TOT)	0.076	0.510	0.102	0.370	0.111	0.507	0.025	0.880
Δ(SBDY)	---	---	---	---	-0.003	0.669	0.002	0.954
Adj. R-sq.	0.911		0.885		0.910		0.892	
Log-likelihood	119.718		120.922		101.213		99.703	
F-stat.	1701.73		1793.43		1781.22		1641.35	
Prob.(F-stat.)	0.000		0.000		0.000		0.000	
D-W stat.	2.159		2.163		2.241		2.218	
AIC criterion	-4.814		-4.866		-4.495		-4.413	
BIC criterion	-4.456		-4.508		-4.777		-4.695	

Note: (a) The asterisks (***), (**) and (*) indicate significance at 1%, 5%, and 10% respectively. (b) The number of observations in the case 3rd and 4th specification is only 38 as the time period is only 36 years from 1980-2017. For the other two specifications, it is from 1970-2017.
Source: Authors' estimation.

tor. Again, the growth rates of public sector investment closely follow the trend growth rates of GDPAg and production in various sub-periods while the co-movement of private investment with GDPAg and production appeared after 2000 onwards. This temporal coincidence of growth performance of investment and farm output partially explains the causal effect of investment on agricultural performance. However, this aspect was further explored in the next section with the help of the first difference regression analysis. From the regression results, it is confirmed that the growth in GDPAg and production is affected by the growth of public and private investment, fertilizer use, HYV seeds and weather index, and agricultural terms of trade.

4. CONCLUSION AND POLICY IMPLICATION

We examined the hypothesis of investment as a major driver of farm sector growth in a two-step manner. First, we found out the structural breaks in investment series and then drew a comparison of growth performance of the investment with that of GDPAg and farm production, by keeping the base period of analysis same. In the second step, we examined the sources of growth of GDPAg and agricultural production by using the "first difference regression" method. The major findings are as follows: public sector investment in agriculture declined since the 1980s and 1990s followed by a slight improvement since the early 2000s but it was lower than increase private investment in the whole study period. The public GCFA as a ratio of GDPAg at 2011-2012 prices has revealed a declining trend while the share of private investment has been on an increasing trend with fluctuations till 2011 after which it started declining. Similar declining trends have been observed in the case of ratio of GCFA in economy-wide gross capital formation (GCF). Five optimal breakpoints in the case of private investment and four breakpoints in public GCFA were found by the Bai-Perron method. The growth trend of public GCFA followed that of GDPAg and production very closely. But the same co-movement was absent in the case of private investment till the late 1990s. But from 2003 onwards, growth trends of all three were found to move in the same direction. However, this linkage was further explored by analyzing the sources of growth of GDPAg and production which established the fact that growth in GDPAg and production are largely driven by the growth of both types of investment, fertilizer use, HYV seeds, and weather index and also terms of trade. So the findings made it clear that the decline in investment, especially public sector investment could be one of the major reasons for the current growth stagnation of Indian agriculture though other important factors are also there.

The above-mentioned finding carries astrong policy implication for agricultural development in India. Agriculture is the mainstay of the Indian economy as the prime objectives of economic policy relating to price stability, output growth, and rural poverty alleviation are best served with help of the growth of this sector. It contributes around 14% to the GDP and accommodates 50% of the population but it is still neglected in the fiscal policy budgetary allocation. Therefore, it has been in crisis for a longtime. The declining public sector capital formation, as found in this analysis, is one of the pivotal reasons. Therefore, for sustainable growth in Indian agriculture, there is an urgent need to speed up the process of public sector capital formation which may stimulate more private investment at the farmers' level due to complementarity between the two. There is a specific need to enhance public sector investment in irrigation and rural infrastructure, research and development activities, storage facilities and transport, developing efficient marketing networks, revamping the agricultural extension system for smooth diffusion of information and technology, and so on. As evidence by one study that agriculturally dominant but economically poor states of North India experienced a huge decline in poverty in the late 2000s because of the rapid capital deepening process in agriculture which greatly enhanced their income. Therefore, the objective of rapid poverty eradication would be better served if the public investment is undertaken. Along with this, there is a need to link farmers with the food processing industry so that they can find a bigger market for their products and thereby get higher profit.

The main limitation of the present study is that due to the non-availability of private investment time-series data at the state level we have not extended the analysis to the state level. However, the length of the paper also puts some reasonable restrictions to have disaggregated analysis.

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APPENDIX

Tab. A.1. Descriptive statistics and definition of all variables.

Variable	Definition	Mean	SD
Production (PR)	Total agricultural production (in million tonnes)	156.24	35.6
Agri. GDP (GDPAg)	Agricultural GDP at 2011-12 prices (in ₹crores)		
Investment(Ig)	Public investment by government (in ₹crores)	23631	8401
Canal Intensity (CNI)	It is a ratio between area under government canals and net sown area	116.41	5.98
Subsidy (SBSD)	Total subsidies provided (total of subsidies on irrigation, fertilizer, and electricity) (in ₹crores)	54,599	78,353
Terms of Trade(TOT)	Gross barter terms of trade (ratio of agricultural GDP deflator to nonagricultural GDP deflator)	36.96	14.18
Credit (CRDT)	Institutional credit provided to farmers ((in ₹crores))	1,606	1,825
Area under HYV Seeds (HYV)	Area under high yielding variety seeds (in million ha).	61,475	10,509
Cropping Intensity(CRI)	It is the ratio of net sown area to the total cropped area (area in million ha).	132.55	5.292
Weather index	Weather index WI=(Rt/1.07T)is calculated as:	95.263	86.75

Note: Data on all these variables are taken for the period 1960-2017 except input subsidy for which data is available for the period 1980-2017.
Source: All the data are compiled from various sources like National Account Statistics, Govt. of India, Agricultural Statistics at Glance, Reserve Bank of India, and Indiastat.com, etc.