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Public Expenditure and Growth Dynamics in Indian Agriculture
Trends, Structural Breaks, and Linkages

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Notices

Contents

Tables

Figures

ABSTRACT

The present study analyzes temporal and spatial trends in public expenditure on agriculture and irrigation in India. It links sub-period growth performance with expenditure based on structural breaks. The analysis pertains to the period between 1992/1993 and 2019/2020. This is a period that has witnessed a stagnation, and even a decrease in public expenditure in the agricultural sector and a resulting deceleration in productivity growth, which was then followed by a revival in both expenditure and output. Significantly expenditure on subsidies of key inputs, viz. fertilizer, irrigation, and power, however, has not incentivized farmers to increase output and productivity to achieve a higher rate of growth. Empirical findings based on the first-difference regression analysis confirm that agricultural growth is determined by public expenditure on agriculture and irrigation; across the states, however, input subsidies alone are shown to be less, or not at all, efficient. Funds to agriculture and irrigation should be increased in proportion to their contribution to the state domestic product, and input subsidies should be rationalized by weighing their positive welfare effects against their cost to the exchequer.

Keywords: Public investment, input subsidies, structural break, kinked growth

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ACRONYMS

PR	Agricultural production
PB	Public Expenditure on Agriculture and Irrigation
SBSDY	Input Subsidy
RBI	Reserve Bank of India
EC	Electricity Consumption
CRI	Cropping Intensity
IR	Gross irrigated area
FRT	Fertilizer Consumption
RNF	Rainfall
EMP	Farm employment
EDU	Education
GOI	Government of India
GSDPA	Gross State Domestic Product from Agriculture and Allied Activities
MOSPI	Ministry of Statics and Programme Implementation
NSSO	National Sample Survey Office
PLFS	Periodic Labour Force Survey
TOT	Terms of Trade
MoA&FW	Ministry of Agriculture and Framers Welfare
PCSE	Panel-Corrected Standard Error
LM	Lagrange Multiplier
Δ	First Difference
GSDPA	Gross domestic product from the agricultural sector
AP	Andhra Pradesh
GUJ	Gujarat
HR	Haryana
HP	Himachal Pradesh
J&K	Jammu and Kashmir
KRT	Karnataka
KRL	Kerala
MP	Madhya Pradesh
MAH	Maharashtra
PB	Punjab
RAJ	Rajasthan
TN	Tamil Nadu
UP	Uttar Pradesh
WB	West Bengal

1 INTRODUCTION

Agricultural growth is driven by technology, labour, public and private capital, and sound institutions (Singh, Pal, Jha 2015). Bathla (2017), Akber and Paltasingh (2019, 2020), and Bathla, Joshi, and Kumar (2020a) have found public investment in agriculture to be a significant driver of farm growth and reduced incidence of rural poverty. Theoretically, public expenditure on agriculture addresses market failures and contributes to an increase in productivity. Among the various types of public spending, allocation of funds to irrigation, agricultural research and education, and health are found to yield the highest returns in terms of agricultural income and rural poverty reduction (Bathla 2017; Bathla, Joshi, Kumar 2020b). In contrast, public spending on key inputs shows a differential impact across the low, middle, and high per capita income states. Marginal returns from input subsidies are clearly shown to be either lower or almost close to that from other types of investment (Bathla, Joshi, Kumar, 2020b); However, one must take into account the consequences of investments in energy and water supply when assessing the welfare effects of subsidising inputs into, for example, irrigation and power. Even if expenditure on input subsidies is seen to be impinging upon investment, it cannot be discarded. Its removal is not possible for several reasons; these include persistent market failures, political infeasibility as farmers are an important vote bank, and the incentivizing effect that input subsidies have on farmers. (Dev 2009; USITC 2009; Roy and Jhilam 2009; Badiani, Jessoe, Plant 2012); Sharma 2012; Bathla, Kumar, Aggarwal 2021).

These issues notwithstanding, agricultural growth remains an important agenda and increasing public investment in this sector is essential to the alleviation of poverty (de Janvry and Sadoulet 2010). Higher public investment in irrigation and rural infrastructure encourages farmers to undertake investment because of a “crowding in effect”; it also increases the access of the poor to essential services and provides employment opportunities. In the long run, higher rates of public investment are expected to have highly positive effect on productive labour markets as increased agricultural output requires investments in human as well as physical capital (Schultz 1964; Anderson, De Renzio, Levy 2006).

In India, public spending on agriculture has experienced lows and highs. Particularly in rural areas, it holds significance given that it is depended on by about 118 million farmers and 143 million other workers for their livelihood, and given the need for higher long-term output and productivity.

Various studies have confirmed the positive relationship between public investment and agricultural growth in India and in other developing economies (Bathla 2017; FAO 2017 Akber and Paltasingh 2021). The analysis in the present study, however, deviates from others as it takes public expenditure on input subsidies and measures the structural breaks in public expenditure on agriculture and irrigation.

For estimating structural breaks, we use longer period data from 1992 to 2019 based on the Bai-Perron method (Bai and Perron 2003). This method allows us to find the structural breaks and to measure the public expenditure growth rates and agricultural performance in different sub-periods in the aftermath of the various technological and policy regimes that have been in place since 1992. This enables us to know whether total public expenditure on agriculture and irrigation matches agricultural growth in the country, or whether growth is due solely to input subsidies. This linkage has been further strengthened by using a "growth accounting method" to determine the influence of rate of growth of public expenditure and other factors on the growth rate of Gross State Domestic Product for agriculture (GSDPA) and on agricultural production in general. This enables us to know whether total public expenditure on agriculture and irrigation matches agricultural growth in the country, or whether growth is due solely to input subsidies.

The remaining paper is structured as follows. Section 2 explains the sources of data and methodological framework used in the study. Section 3 analysis the temporal and spatial trends in public expenditure on agriculture and irrigation and furnishes empirical results. A total of 17 major Indian states are considered for a detailed analysis. The states are grouped into developed and less-developed based on output per hectare. The final section offers conclusions and policy implications.

2 DATA SOURCES AND METHODOLOGICAL APPROACH

Data on public expenditure and other variables was collated for 17 major Indian states for the period 1992 to 2019. In order to provide a comparative picture, states are categorized into two groups: agriculturally developed states and less- or under-developed states. The categorization is based on output per hectare, that is, land productivity. Data was compiled from various published sources (Table 1). Public expenditure data on agriculture and irrigation was taken from the budget documents of the respective state governments. Data on GSDP in agriculture and allied activities was sourced from the Ministry of Statistics & Programme Implementation, Government of India (GoI). Data on production (output) was collected from *Agricultural Statistics at a Glance*, Ministry of Agriculture & Farmers Welfare (MoA&FW), GoI. Expenditure on subsidies was noted for four major inputs, that is, fertilizer, irrigation, electricity, and credit. The fertilizer subsidy was estimated as the proportional share of a state in the national consumption of fertilizers multiplied by the total fertilizer subsidy at the all-India level. The data was compiled from the MoA&FW. Irrigation subsidy was derived by subtracting receipts from operation and maintenance expenditure on irrigation (that is, revenue expenditure on major, medium, and minor irrigation) and adding 1 percent interest on capital stock and 10 percent depreciation on cumulative capital stock. This data was taken from budgets in the finance departments of the respective state government. Electricity subsidy was calculated by dividing the unit cost of supply and agricultural tariff multiplied by electricity consumption in the agricultural sector. The data was compiled from the Central Electricity Authority and the MoA&FW. We also estimated credit subsidy. It was calculated by dividing the weighted average lending rates of the agricultural and non-agricultural sectors and multiplying them by the total agricultural credit given by regional rural and commercial banks. Credit subsidy data was taken from the Reserve Bank of India (RBI); it may reflect only the interest subsidy and not the default subsidy, the latter being on account of non-payment of interest and the principal amount within the allotted repayment period.

All these data series are converted into constant (2011/2012) prices using the GDP deflator. We have also taken a few more variables to estimate the determinants of GSDPA and growth in agricultural output. These include electricity consumption in agriculture, cropping intensity, irrigated land, fertilizer use, rainfall, terms of trade (TOT), farm employment, and education.

Table 1. Description of the variables used

Variable	Definition	Sources
Agricultural GSDP (GSDPA)	Gross domestic product from the agricultural sector (in INR crores)*	Ministry of Statistics & Programme Implementation, Government of India (GoI)
Agricultural production (PR)	Production of food grains and non-food grains (in '000 metric tons)	*Agricultural Statistics at a Glance*, Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare (MoA&FW), GoI, various issues
Public expenditure on agriculture and irrigation (PB)	Government expenditure on agriculture and irrigation (in INR crores)	Budget documents of the finance departments of the respective state governments
Input subsidy (SBSDY)	Agricultural input subsidies on fertilizers, irrigation, electricity, and credit (in INR crores)	MoA&FW, budget documents of finance departments of the respective state government, Reserve Bank of India (RBI)
Electricity consumption (EC)	Electricity consumption in agriculture (GWh per million hectares of net sown area)	Central Electricity Authority Region/State-wise Consumption of Electricity for Agriculture Purpose in India, Ministry of Agriculture and Farmers Welfare, GoI. MoA&FW, GoI
Cropping intensity (CRI)	The ratio of net sown area to total cropped area (in '000 tons)	State-wise land use statistics, Directorate of Economics and Statistics, MoA&FW, GoI
Gross irrigated area (IR)	Gross irrigated area (in '000 tons)	State-wise land use statistics, Directorate of Economics and Statistics, MoA&FW, GoI
Fertilizer consumption (FRT)	Fertilizer consumption (kilograms per hectare of net sown area)	State-wise land use statistics, and *Agricultural Statistics at a Glance*, Directorate of Economics and Statistics, MoA&FW, GoI
Rainfall (RNF)	Annual rainfall (millimetres)	Rainfall statistics of India, reports (various years), India Meteorological Department, Ministry of Earth Sciences, GoI
Terms of trade (TOT)	Terms of trade index (ratio of agricultural and non-agricultural GDP)	Ministry of Statistics & Programme Implementation, GoI

Farm employment (EMP)	Employment in agriculture (number of persons employed in agriculture per hectare of net sown area)	Annual reports of Periodic Labour Force Survey (PLFS) for 2017/2018, 2018/2019, 2019/2020; National Sample Survey Office (NSSO) reports on key indicators of employment and unemployment in India 2011/2012, Employment and Unemployment Situation in India 2004/2005, and NSS surveys/reports of previous rounds/years, Ministry of Statistics & Programme Implementation, GoI
Education (EDU)	The average number of years in formal education (schooling) of rural sector persons	*Household Social Consumption on Education in India NSS Report No. 585 (75/25.2/1)*, and previous reports

Note: * A crore is the equivalent of 10 million; INR = Indian rupees.

With regard to empirical testing of the relationship between public expenditure and agricultural growth, we have used the Bai-Perron method and the production function approach. It enables us to find the multiple numbers of breakpoints that were not known before in the time series[1]

A structural break is characterized as an unexpected shift that leads to substantial forecasting errors. Consider the following multiple regression with *m* breaks (*m* +1) regimes as:

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

for *j* = 1,….., *m* + 1. In this model, Y_t is the observed dependent variable at time *t*; $x_t(p \times 1)$ and $z_t(q \times 1)$ are the vectors of covariates, and β and δ_j(*j* = 1,…., *m* + 1) are the corresponding vectors of the coefficients; u_t is the disturbance term at time *t*. The indices $(T_1, \dots .., T_m)$, or the break points are explicitly 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 and is estimated using the entire sample. When p = 0, we obtain a pure structural change model where all the coefficients are subject to change. The variance u_t does not need to be constant. Indeed, breaks in the variance are permitted provided they occur on the same dates as in the breaks in parameters of the regression. The detailed method is given in Appendix.

[1] The main advantage of the Bai-Perron approach over Chow (1960) is that this method automatically tests for the presence of multiple breaks without individually choosing the break dates. However, in the case of lateral, the break date is randomly chosen based on the judgment of the researcher. So, the problem of relying too much on the subjective assessment of the researcher renders this method a little biased.

Once the breakpoints in times series are known, we estimate the annual rate of growth in public expenditure, GSDPA, and value of production, using a kinked exponential growth model. This method provides a clear picture of growth rates at different sub-periods (Boyce 1986). The detailed method is given in Appendix.

By linking the growth performance of expenditure and agricultural output in three sub-periods based on the breakpoints, we estimate the impact of the former on the latter using the "first difference" (FD) model based on the growth accounting method. The growth rate of Y can be written as $\Delta \ln Y_{it} = \dot{Y}/Y$. Because approximating of $\Delta \ln Y_{it}$ as $d \ln Y_{it}$ for infinitesimal change and differentiating it with respect to time t, we get: $\frac{dlnY_{it}}{dit} = \frac{dlnY_{it}}{dY}\frac{dY}{dit} = \dot{Y}/Y$. So taking a Cobb-Douglas production function approximation of output, we get: $Y_{it} = PB_{it}^{\beta_1} SBSD_{it}^{\beta_2} EC_{it}^{\beta_3} CRI_{it}^{\beta_4} IR_{it}^{\beta_5} RNF_{it}^{\beta_6} TOT_{it}^{\beta_7} EMP_{it}^{\beta_8} EDU_{it}^{\beta_9} e_{it}{}^{\mu}$ and taking the difference of logarithmic approximation of it, we arrive at the estimable form of equations Eq. (2), (3), (4), and (5).

This method is widely used (Ricker-Gilbert et al. 2013; Chand 2005; Kumar, Ganguly, Sivamohan 2019, and Akber and Paltasingh 2021). The reasons for its wide use include that it is based on theoretical justification, it takes care of the non-stationarity problem that is identified in time series data, it solves the problem of heterogeneity that occurs in the regression models, and because the consistency of estimates is not affected in the presence of serial correlations. The robustness of the model is checked using the Prais-Winsten regression model with panel-corrected standard error (PCSE) in the absence/presence of autocorrelation, cross-sectional dependency, and heteroskedasticity. Based on the Monte Carlo analysis, the PCSE estimator is considered to be very robust in terms of efficiency obtained from the standard error (Beck and Katz 1995).[2]

Two baseline models are estimated, the first baseline model contains total public spending in agriculture and irrigation, and another includes input subsidies. The regression models are:

$$\begin{aligned} \Delta InGDPA_{it} = \beta_0 + \beta_1 \Delta InPB_{it} + \beta_2 \Delta InEC_{it} + \beta_3 \Delta InCRI_{it} + \beta_4 \Delta InIR_{it} + \beta_5 \Delta InFRT_{it} \\ + \beta_6 InRNF_{it} + \beta_7 \Delta InTOT_{it} + \beta_8 \Delta InEMP_{it} + \beta_9 \Delta InEDU_{it} + \mu_{1i} + \varepsilon_{1t} \\ + e_{1it} \end{aligned} \quad (2)$$

[2] The PCSE involves two-step estimation. In the first step, the data is transferred to eliminate serial correlation, and in the second step, ordinary least squares (OLS) is applied to the transferred data and the standard errors are corrected for autocorrelation, cross-sectional dependency, and heteroskedasticity.

$$\Delta InGDPA_{it} = \alpha_0 + \alpha_1 \Delta InSBSD_{it} + \alpha_2 \Delta InEC_{it} + \alpha_3 \Delta InCRI_{it} + \alpha_4 \Delta InIR_{it} + \alpha_5 \Delta InFRT_{it} + \alpha_6 InRNF_{it} + \alpha_7 \Delta InTOT_{it} + \alpha_8 \Delta InEMP_{it} + \alpha_9 \Delta InEDU_{it} + \mu_{2i} + \varepsilon_{2t} + e_{2it} \quad (3)$$

$$\Delta InPR_{it} = \gamma_0 + \gamma_1 \Delta InPB_{it} + \gamma_2 \Delta InEC_{it} + \gamma_3 \Delta InCRI_{it} + \gamma_4 \Delta InIR_{it} + \gamma_5 \Delta InFRT_{it} + \gamma_6 InRNF_{it} + \gamma_7 \Delta InTOT_{it} + \gamma_8 \Delta InEMP_{it} + \gamma_9 \Delta InEDU_{it} + \mu_{3i} + \varepsilon_{3t} + e_{3it} \quad (4)$$

$$\Delta InPR_{it} = \pi_0 + \pi_1 \Delta InSBSD_{it} + \pi_2 \Delta InEC_{it} + \pi_3 \Delta InCRI_{it} + \pi_4 \Delta InIR_{it} + \pi_5 \Delta InFRT_{it} + \pi_6 InRNF_{it} + \pi_7 \Delta InTOT_{it} + \pi_8 \Delta InEMP_{it} + \pi_9 \Delta InEDU_{it} + \mu_{4i} + \varepsilon_{4t} + e_{4it} \quad (5)$$

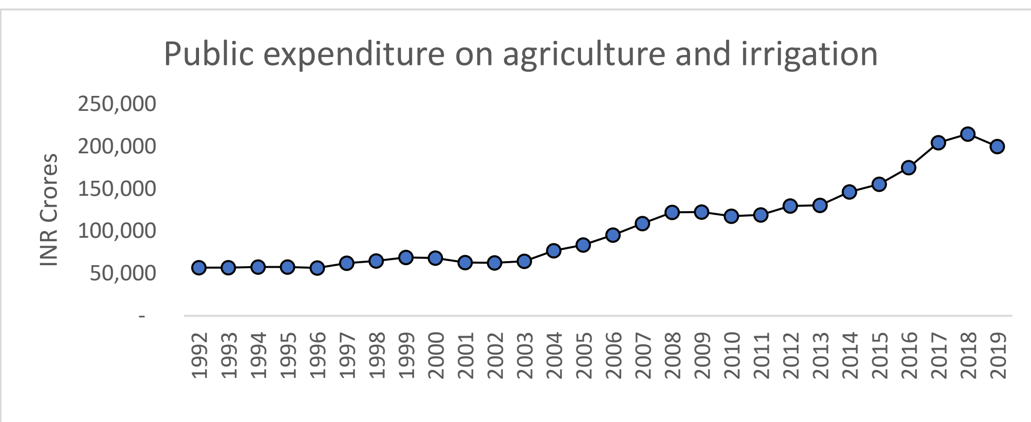
All the variables are logarithmically transformed, $\beta, \alpha, \gamma,$ and π are coefficients, and Δ is the difference term. $GDPA$ and PR are Gross Domestic Product in agriculture and allied activities, and value of agriculture production. The agriculture production contains the value of food grains and non-food grains. PB represents public sector expenditure on agriculture and irrigation, $SBSD$ is agriculture input subsidies, EC is electricity consumption in agriculture. CRI is cropping intensity, IR is irrigated land, and FRT is fertilizer consumption. RNF stands for annual rainfall, and rainfall is not taken in log difference form as, intuitively it does not grow over time. TOT is terms of trade (ratio of agricultural and non-agricultural GDP) EMP represents farm employment, and EDU is the percentage of the total population that is literate. μ_i and ε_t are state-specific and time-specific error terms, respectively, and e_{it} is the unique error term. Here we have not taken private investment as one of the explanatory variables because our motive is to analyze the linkage between agricultural performance and public expenditure.

3 EMPIRICAL RESULTS AND DISCUSSION

3.1 Trends and patterns in public expenditure in Indian agriculture

Public expenditure in India is broadly categorized as development and non-development expenditure. Development expenditures are provisioned for the promotion of economic development and social welfare; however, non-development expenditures are incurred in the maintenance of government operations. Public expenditures related to the agricultural sector come under development expenditure. The present study considers two important categories of public expenditure for the agricultural sector: total public expenditure in agriculture and irrigation, and agricultural input subsidies. The main motive of this section is to analyze the trend pattern of public expenditure over 27 years. Public expenditure includes different types of expenditure such as on crop husbandry, soil and water conservation, animal husbandry and dairy development, fisheries, forestry and wildlife, plantations, food storage, warehousing, agricultural research and education, cooperation, and major, medium, and minor irrigation and command development. Public spending in the context of the farm sector explicitly and implicitly impacts agricultural development through the development of investment in human and physical capital.

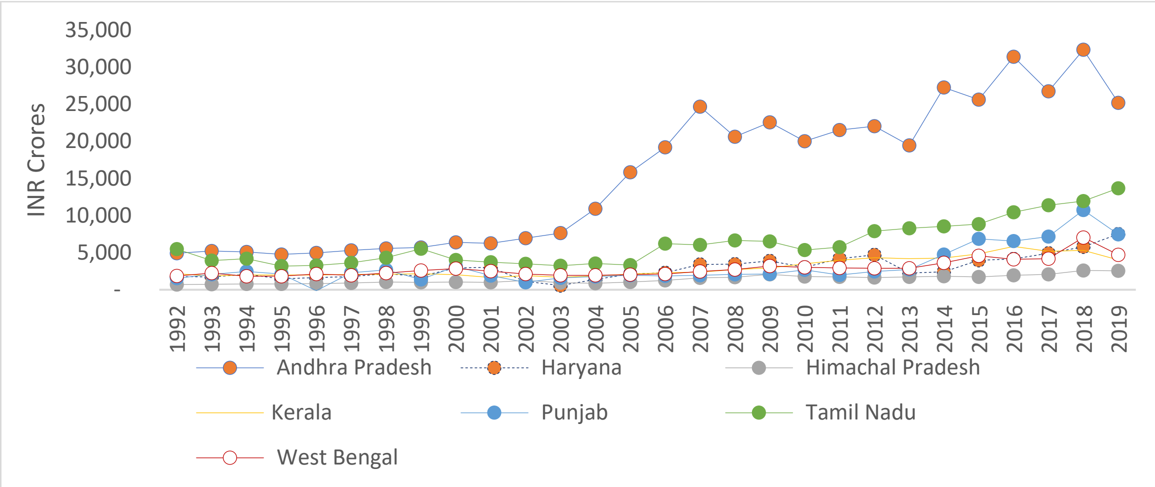
Figure 1. Public sector expenditure in the Indian agricultural and irrigation sector at constant prices (2011/2012 prices in INR crores)*



Note: * A crore is the equivalent of 10 million (approximately US$ 120,000).

Figure 1 depicts the trend in public expenditure on agriculture and irrigation at an aggregate level between 1992 and 2019. The trend analysis suggests in the first decade of the study, public expenditure was maintained at a constant level; since 2003, however, an increase has been observed.

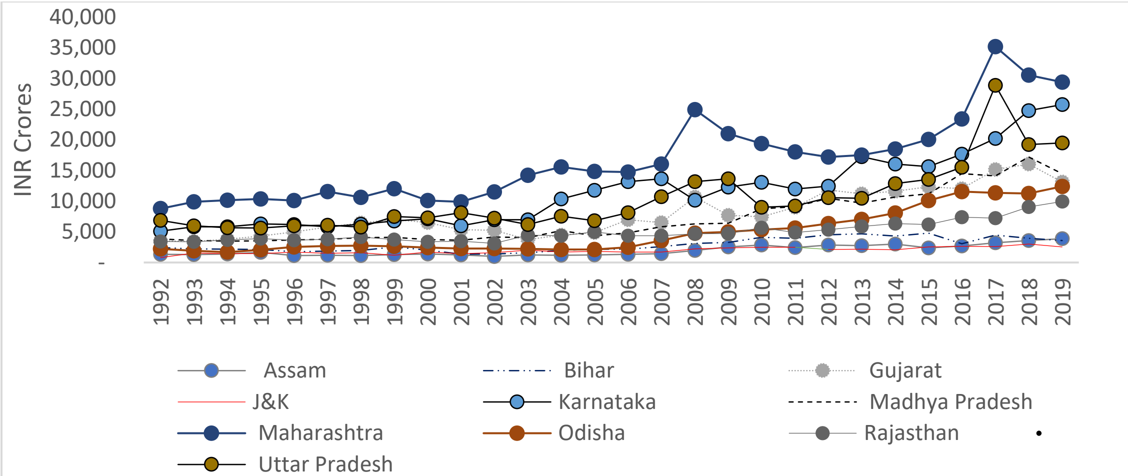
Figure 2. Public expenditure by developed states in the agricultural and irrigation sector at constant prices (2011/2012 prices in INR crores)*



Note: * A crore is the equivalent of 10 million (approximately US$ 120,000).

Figures 2 and 3 portray the trend of public expenditure on agriculture and irrigation for the developed and underdeveloped states over the 27-year period. The states observed a constant or declining trend in the first decade of the study (1992 to 2002). The trend analysis of developed states confirms that despite some fluctuations, Andhra Pradesh observed a continuously increasing trend since 2003; it grew sixfold from 1992 to 2018, rising from INR 4,922.12 crores (594.41 million US$) to INR 32,349.61 crores (3906.74 million US$); a downturn, however, was observed in the last period of the study. Throughout the study period, the public sector expenditure was lowest in Punjab, Haryana, Himachal Pradesh, Kerala, and West Bengal.

Figure 3. Public expenditure of underdeveloped states on the agricultural and irrigation sectors at constant prices (2011/2012 prices in INR crores)*



Note: * A crore is the equivalent of 10 million (approximately US$ 120,000).

The trend analysis of underdeveloped states that is depicted in Figure 3 similarly confirms that Maharashtra has observed an increasing trend up to 2008. A downturn is observed between 2008 and 2016, after which there is again an increasing trend; this trend was brief, however, and after 2018 a decline is again observed. Karnataka shows different trends during the study period, with a declining trend up to 2002 and an increasing trend thereafter. This increasing trend after 2002 was brief, however, and was reversed in 2008 when public sector expenditure in the state declined from INR 13,662.56 crores (1650.39 million US$) in 2007/2008 to INR 10,140.4 crores (122.48 million US$) in 2008/2009. An improvement was observed thereafter, but the trend was further disrupted in 2012 and 2015, after which an increasing trend was again observed.

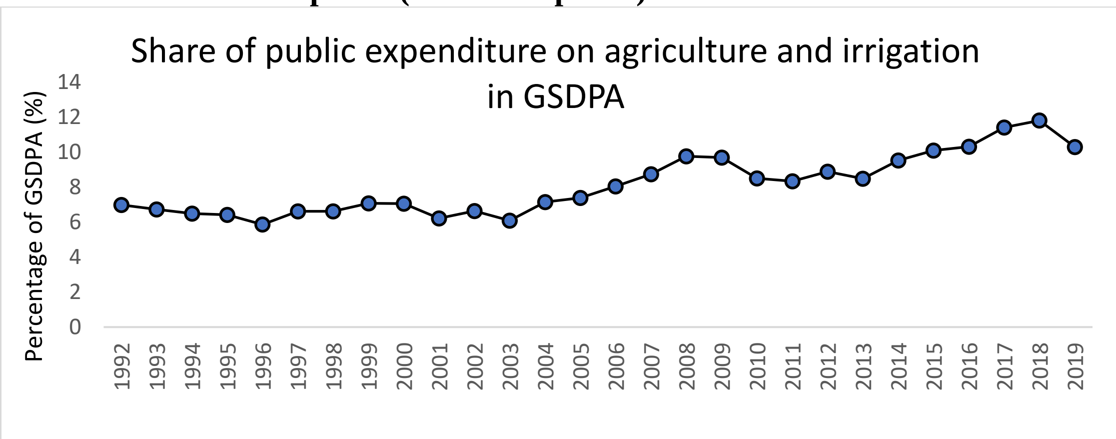
Similarly, in the case of Uttar Pradesh, the expenditure has accelerated since 2005. The trend analysis of the rest of the underdeveloped states shows that, despite some fluctuations, all the developed states faced a declining trend during the 1990s and a slight improvement in the 2000s.

The trend analysis of 17 major agricultural states confirms that except for a few states such as Andhra Pradesh, Maharashtra, Karnataka, Uttar Pradesh, Gujarat, Madhya Pradesh, and Odisha, all the developed and underdeveloped agricultural states are experiencing a declining trend in public farm expenditure, though with a slight improvement since 2005. There is also a high level of interstate disparity in public expenditure.

3.1.1 Trends in the share of public expenditure in agriculture and irrigation in GSDPA

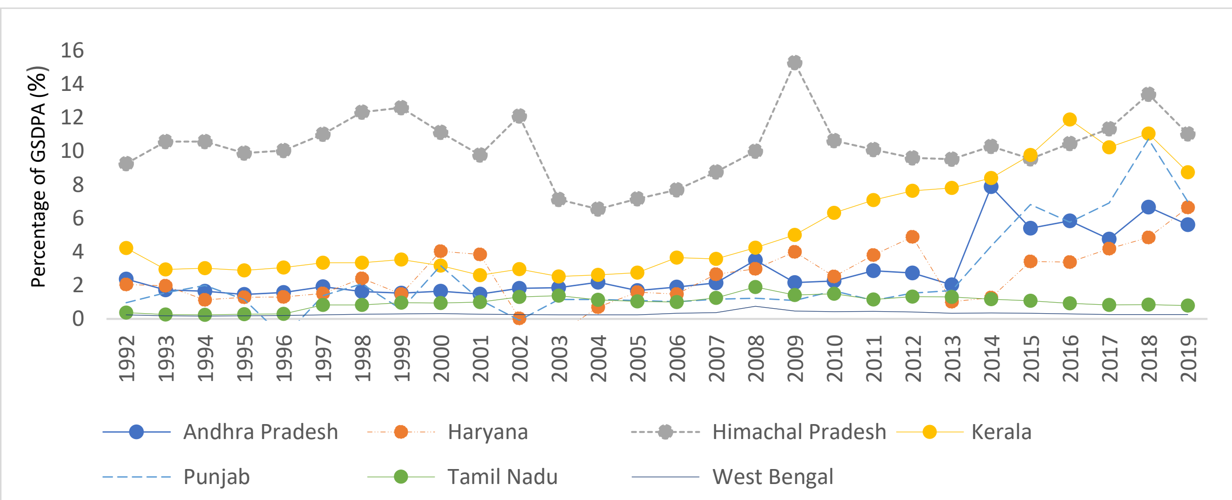
For more clarity, we tried to analyze the trends in the percentage share of public expenditure in GSDPA. Figures 4, 5, and 6, respectively, show the trend pattern of public expenditure as a share of GSDPA at an aggregate level, for developed states, and for underdeveloped states during the 1992 to 2019 period.

Figure 4. Share of public expenditure on agriculture and irrigation in GSDPA at the all-India level at constant prices (2011/2012 prices)



Note: GSDPA = Gross State Domestic Product for agriculture.

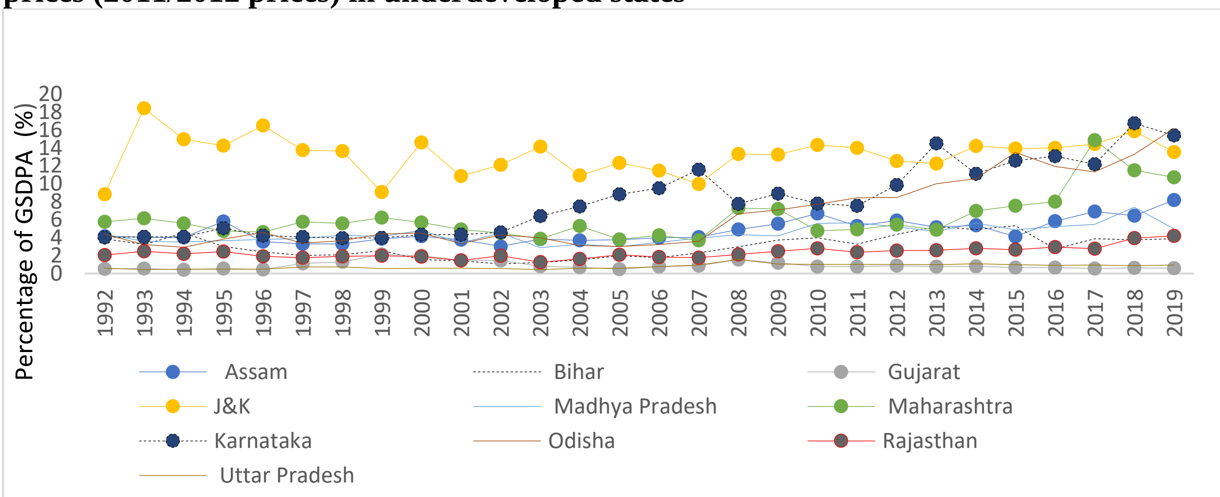
Figure 5. Share of public expenditure on the agricultural sector in GSDPA at constant prices (2011/2012 prices) in developed states



Note: GSDPA = Gross State Domestic Product for agriculture.

The figures corroborate that the states observe very unstable trends in the share of public expenditure that is allocated to the agricultural sector. Among agriculturally developed states, different trends can be observed; Himachal Pradesh, for instance, observed an increasing trend in the first eight years of the study and a declining trend thereafter until 2004/2005. After 2004, this declining trend reversed, and in 2009 it reached its maximum of 15.25 percent; subsequently, however, it again reversed. Kerala faced a continuously increasing trend, but the other developed states observed a declining trend with a slight improvement after 2005.

Figure 6. Share of public expenditure on the agricultural sector in GSDPA at constant prices (2011/2012 prices) in underdeveloped states



Note: GSDPA = Gross State Domestic Product for agriculture; J&K = Jammu and Kashmir.

Figure 6 depicts the trend analysis of the share of public expenditure in GSDPA of underdeveloped states. The trend clearly suggests that the share was highest in Jammu & Kashmir. Despite some fluctuations, Karnataka and Odisha witnessed an increasing trend in their share; Maharashtra and Madhya Pradesh, however, observed an increasing trend only in the last part of the study period. Other states faced a constant or declining trend in the share of public expenditure allocated to their agricultural sector.

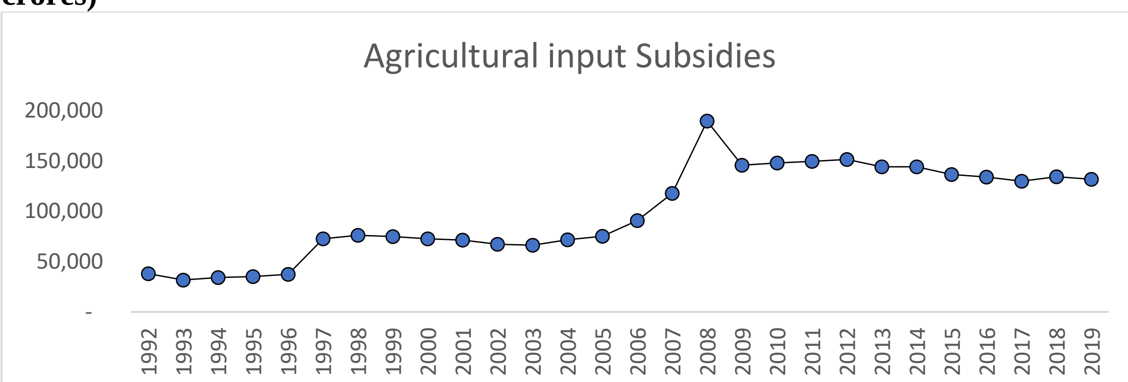
Several studies in the past have tried to analyze the trend of the share of public expenditure on GDPA at the state level. Singh (2014) divided the data series into sub-periods and examined the share of public capital expenditure in net state domestic product (NSDP) in agriculture. In the case of Punjab and Haryana, the share declined in the first and fourth periods, and the share in

Maharashtra, Jammu & Kashmir, and Gujarat continuously increased during the second to fifth periods. The study by Gulati, Terway, and Banerjee (2018) confirmed that public capital formation in Indian agriculture as a percentage of agricultural GDP declined from 4.8 percent to 2.8 percent between 1980 and 2015. Bathla, Joshi, and Kumar (2020c) divided the states into low-, middle-, and high-income. They found that the share of public spending on the agricultural sector in GSDPA was 5.55 percent in low-income states, 5.16 percent in middle-income states, and 7.21 percent in high-income states.

Our study tried to analyze the temporal and spatial trends in public expenditure on agriculture and irrigation and its share in GSDPA. We found that the majority of the states observed a declining trend in the expenditure series as well as in their share in GSDPA, though a slight improvement in expenditure and share of GSDPA was observed during the 2000s.

3.1.2 Trends in input subsidies in Indian agriculture

Figure 7. Input subsidies in Indian agriculture at constant prices (2011/2012 prices in INR crores)*



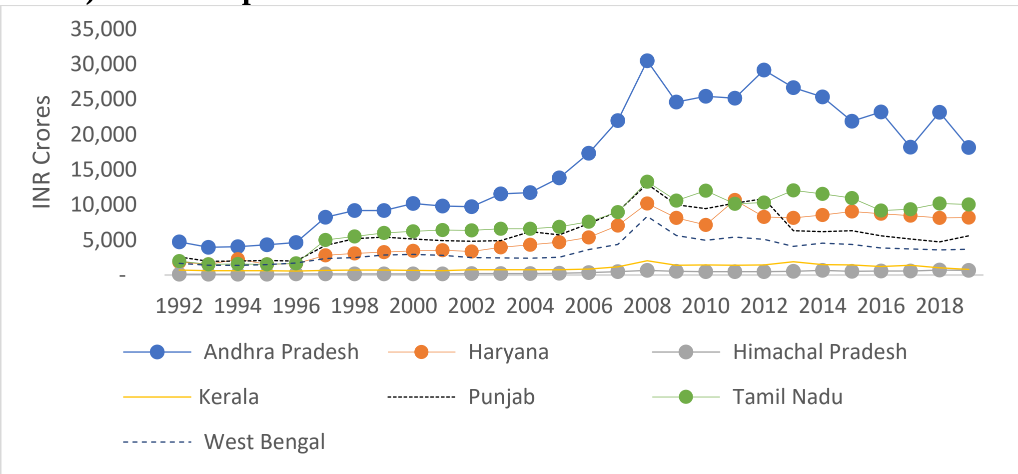
Note: * A crore is the equivalent of 10 million; INR = Indian rupees (approximately US$ 120,000).

Input subsidy is an essential government expenditure that is disbursed for the welfare of the farming community. India's input subsidy scheme was initiated on the recommendations of the 1964 Jha Committee on Food Prices to provide inputs such as fertilizers, irrigation, electricity, seeds, and credit to farmers at a subsidized rate. These input subsidies, however, have always been a controversial subject. They were considered to be effective in the 1970s and 1980s in helping farmers to increase their farm output, but it was later claimed that they were the reason for the decline in public sector investment. Over time, they have also become unproductive and environmentally unfriendly (Gautam 2015; Gulati and Narayanan 2003; Gulati and Sharma 1995;

Fan, Gulati, Thorat 2008; Gulati, Terway, Banerjee 2018; Singh 2014; Akber and Paltasingh 2019, 2020, 2022).

Figure 7 portrays the trend analysis of agricultural input subsidies in Indian agriculture at an aggregate level. The figure suggests two distinct trends, an increasing trend from 1992 to 2008 and a constant/declining trend after 2009.

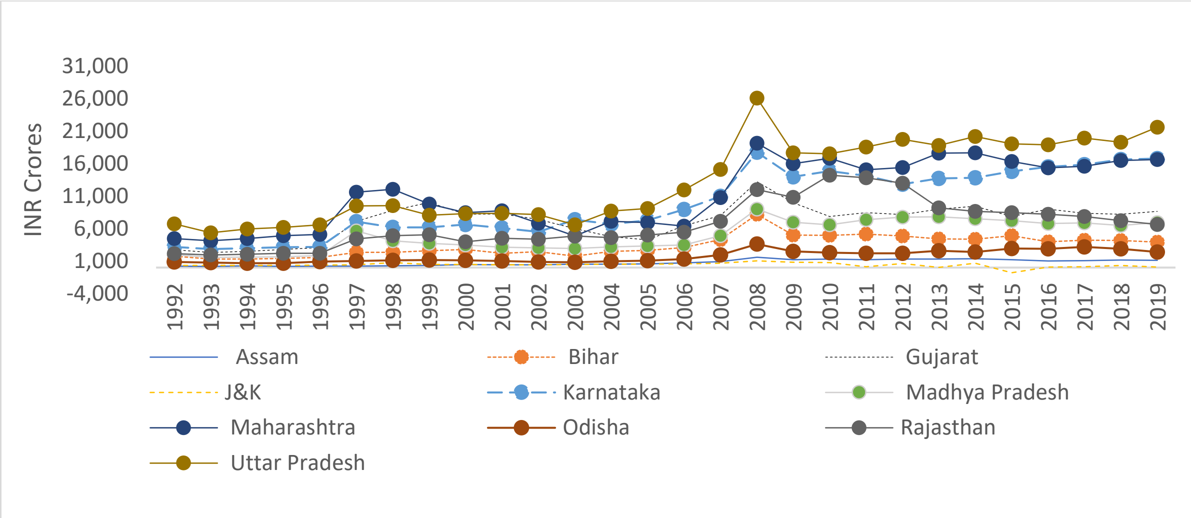
Figure 8. Agricultural input subsidies in India at constant prices (2011/2012 prices in INR crores)* in developed states



Note: * A crore is the equivalent of 10 million (approximately US$ 120,000).

The trend analysis of developed states depicted in Figure 8 confirms that the developed states observed a similar trend pattern, with a constant trend being registered for the first five years of the study period and an increasing trend being observed thereafter. In the case of Kerala and Himachal Pradesh, however, the curve is flat, suggesting that the states have followed a constant trend throughout the study period.

Figure 9. Agricultural input subsidies in India at constant prices (2011/2012 prices in INR crores)* in underdeveloped states



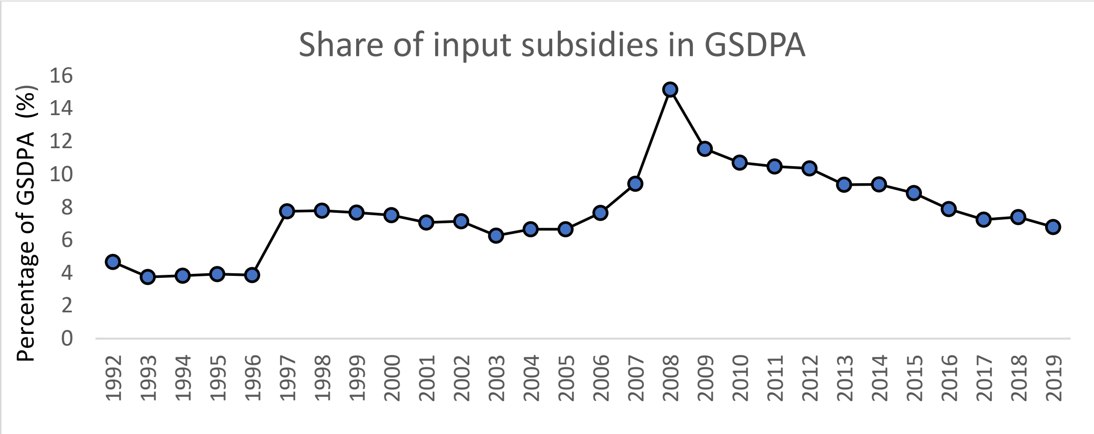
Note: * A crore is the equivalent of 10 million (approximately US$ 120,000).

Figure 9 similarly depicts the trends of agricultural input subsidies in underdeveloped states. The trend pattern shows that the agricultural input subsidies of Uttar Pradesh, Maharashtra, and Karnataka increased between 1992 and 2019, although some states, including Assam, Bihar, and Odisha, observed a constant trend. Jammu & Kashmir observed a constant trend up to 2011 and a declining trend thereafter. The trend analyses of four essential types of input subsidies also confirm interstate disparities.

The existing literature confirms that the total input subsidies in Indian agriculture increased around 12.8 times between 1980 and 2013 (Gulati, Terway and Banerjee 2018). Bathla, Joshi, and Kumar (2020c), however, analyzed the magnitude of input subsidies (fertilizer, irrigation, electricity, and credit) across low-, middle-, and high-income states and found that the magnitude of subsidies of different inputs increased inconsistently over the period of 1980 to 2013. More recently, Akber, Paltasingh, Mishra (2022) confirmed a 13-fold increase in fertilizer, electricity, and irrigation subsidies at an aggregate level between 1980 and 2018. Our study also confirms an increasing trend in agricultural input subsidies in developed and underdeveloped states; in the last period of this study, however, this trend was disrupted.

3.1.3 Trends in the input subsidies as a share of GSDPA

Figure 10. Share of input subsidies in GSDPA at constant prices (2011/2012 prices in INR crores)*

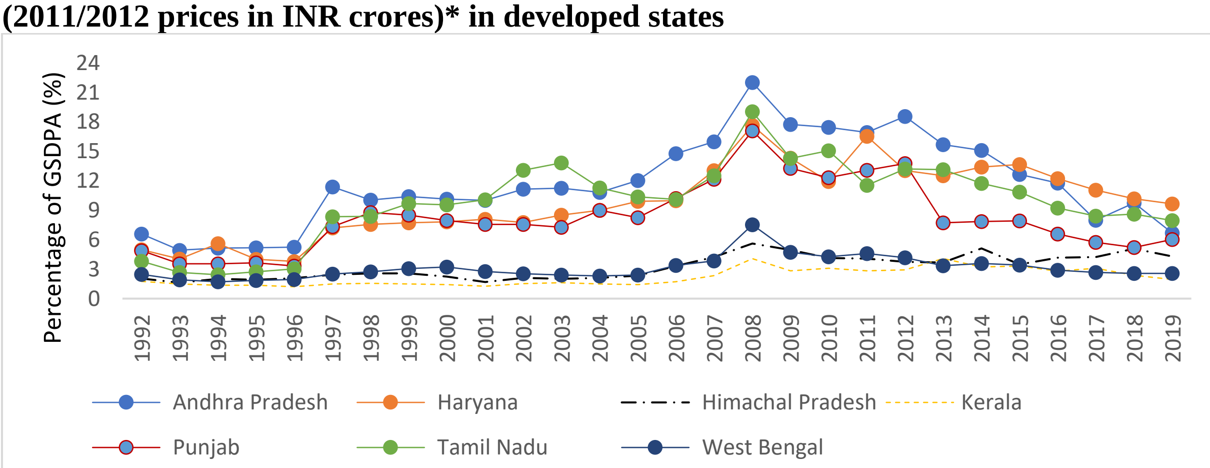


Note: GSDPA = Gross State Domestic Product in agriculture; *a crore is the equivalent of 10 million.

To get an idea of the real magnitude of input subsidies, we have analyzed the trends in the percentage share of input subsidies in GSDPA at an aggregate level (Figure 10), as well as for the two groups of states (Figures 11 and 12). Analysis of the trend of the share of input subsidies in GSDPA at an aggregate level (Figure 10), importantly, confirms an increasing trend up to 2008 and a declining trend thereafter.

Trend analysis of input subsidies as a percentage share of GSDPA for agriculturally developed states (Figure 11) shows that the states witnessed two important trends, that is, an increasing share up to 2008 and a declining share thereafter.

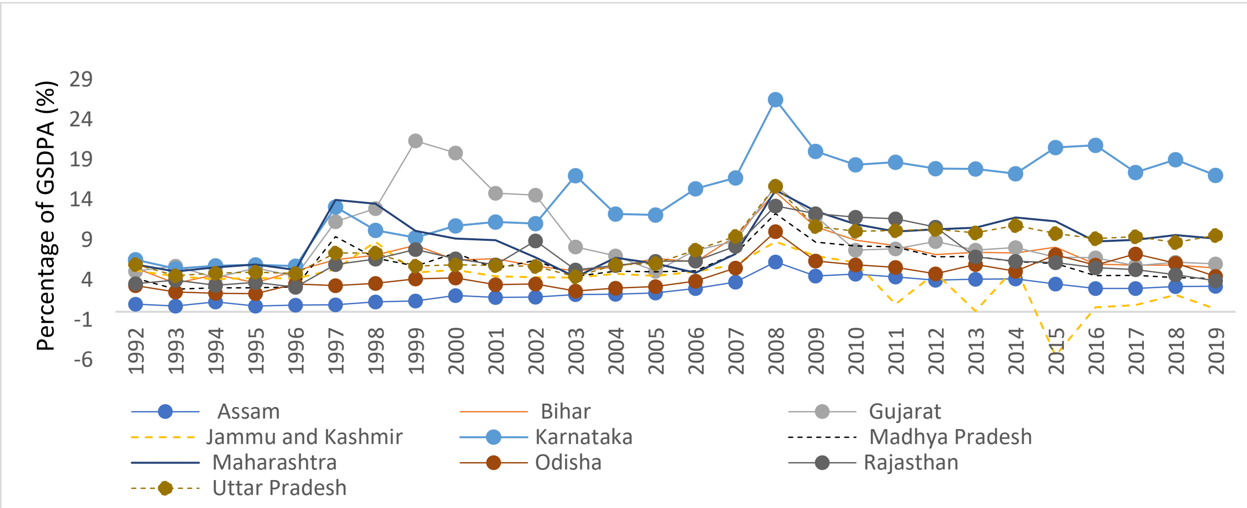
Figure 11. Share of agricultural input subsidies in GSDPA in India at constant prices (2011/2012 prices in INR crores)* in developed states



Note: GSDPA = Gross State Domestic Product in agriculture; *a crore is the equivalent of 10 million.

Figure 12 portrays the trend analysis of the percentage share of agricultural input subsidies in GSDPA for the agriculturally under- or less-developed states of India. Karnataka and Uttar Pradesh felt an increasing trend between 1992 and 2008; since 2009, however, the share has experienced a downturn. Other states confirm extremely variable trends in their share of agricultural input subsidies.

Figure 12: Share of agricultural input subsidies in GSDPA in India at constant prices (2011/2012 prices in INR crores)* in underdeveloped states



Note: GSDPA = Gross State Domestic Product in agriculture; *a crore is the equivalent of 10 million.

Earlier studies such as that of Gulati and Narayanan (2003) reported that fertilizer, electricity, and irrigation subsidies alone constituted 8.8 percent of the country's agricultural GDP. The study by Gulati, Terway, and Banerjee (2018) similarly found that the share of input subsidies in GDPA increased from 2.8 percent in 1980/1981 to 8.0 percent in 2013/2014. By analyzing the trend pattern of the percentage share of input subsidies in GSDPA, we observed a similar increasing trend in the agriculturally developed states in the first two decades of the study. Underdeveloped states, however, witnessed an oscillating trend in their shares of agricultural subsidies.

3.1.4 Composition of public expenditure in the agricultural sector

The composition of public expenditure in the agricultural sector reflects the respective states' spending priorities. Table 1A in the Appendix depicts the composition of public sector expenditure on irrigation, cooperation, research and education, food storage and warehousing, fisheries, crop husbandry, soil and water conservation, and animal husbandry and dairy development for all 17 states together and separately for India's developed and underdeveloped agricultural states. As indicated in the table, the percentage share of irrigation expenditure at the national level dipped from 59.6 percent during TE (triennium ending) 1992 to 46.9 percent during TE 2019. The percentage share in cooperation improved slightly, moving from 4.2 percent to 5.2 percent, however the percentage share of research and education remained between 3.3 and 3.5 percent. Between 1982 and 2019, similarly, the share of expenditure on food storage and warehousing remained between 4.1 and 5.7 percent. The fisheries sector received only 1 percent of the total share, however the share of crop husbandry was 14.0 percent in TE 1992 and rose to 28.8 percent in TE 2019. The share of public expenditure allocated to soil and water conservation fell from 3.6 percent to 2.0 percent and animal husbandry received 5 percent of total expenditures. The percentage share of public expenditure devoted to dairy development dipped from 4.2 to 1.1 percent.

Table 1A clearly shows the variations from national averages in the states' percentage share of agricultural and irrigation expenditure. The top spending categories are crop husbandry and irrigation; spending on other categories such as agricultural research and education, animal husbandry and dairy development, fisheries, and soil and water conservation has received little attention from either group of states.

3.1.5 Structural breaks in public expenditure in Indian agriculture

This section identifies the structural breaks or acceleration/deceleration in total public sector agricultural expenditure and input subsidies over 27 years that may have arisen due to national and state governments' abrupt policy or technological changes. The methodology proposed by Bai-Perron (Bai and Perron 2003) has been applied to the identification of structural breaks, considering its ability to find multiple structural breaks in the time series. Table 2 reveals the results of structural breakpoints of total public expenditure and input subsidies for agriculturally developed states. The results clearly indicate two significant breakpoints in both categories of expenditure. During the break dates, the total expenditure series in the sector slightly improved across the states. This is consistent with studies by Chand and Parappurathu (2012) and Akber and Paltasingh (2021), who demonstrated a hike in public spending during the 2000s in Indian agriculture. Andhra Pradesh observed the break dates in 2005 and 2014; during these two time periods, public expenditure on agriculture and irrigation accelerated. Himachal Pradesh recorded breaks in 2007 and 2016, and in Punjab and Kerala the breakpoints came in 2010 and 2015, respectively. Tamil Nadu observed breaks in 2006 and 2016 and in the case of West Bengal the breaks occurred in 2008 and 2015. An analysis of the breakpoints of developed states thus confirms that, with slight deviations, the breakpoints almost coincide across the states.

Column 3 of Table 2 depicts the breakpoints in input subsidies. The estimated results confirm that all the states have observed two significant breakpoints since 1992. In the case of Andhra Pradesh, the breakpoints came in 1997 and 2006. The two optimal breakpoints in Haryana were in 1998 and 2007. Himachal Pradesh observed the breaks in 2006 and 2014 and West Bengal observed them in 1997 and 2007. The break dates in Kerala were observed in 2007 and 2016

and in both Punjab and Tamil Nadu optimal breaks were experienced in 2006 and 2013, respectively.

Table 2. Structural breaks in total agricultural public expenditure and input subsidies in developed states

Breaks	Public expenditure in the agricultural and irrigation sectors	Input subsidies
Andhra Pradesh		
1st breakpoint	2005	1997
2nd breakpoint	2014	2006
Haryana		
1st breakpoint	2007	1998
2nd breakpoint	2016	2007
Himachal Pradesh		
1st breakpoint	2007	2006
2nd breakpoint	2016	2014
Kerala		
1st breakpoint	2010	2007
2nd breakpoint	2015	2016
Punjab		
1st breakpoint	2010	2006
2nd breakpoint	2015	2013
Tamil Nadu		
1st breakpoint	2006	2006
2nd breakpoint	2016	2013
West Bengal		
1st breakpoint	2008	1997
2nd breakpoint	2015	2007

Note: All estimate breakpoints are significant at the 5 percent level and a trimming percentage of 15 percent (in the Bai-Perron test of 1 to *M* globally determined breaks).

The structural breaks in public expenditure of underdeveloped states shown in Table 3 suggest two optimal breakpoints. In the case of the total expenditure series, the results confirm that Assam observed the breaks in 2008 and 2016. In Bihar, the two break dates are 2006 and 2010. Gujarat observed two significant break dates in the series in 2006 and 2012; similarly, in the case of Jammu & Kashmir, the breakpoints were identified in 2001 and 2015. The breakpoints in Karnataka and Maharashtra coincide, in both cases occurring in 2004 and 2016. Madhya Pradesh and Rajasthan both observed breakpoints in 2010 and 2016. In Odisha's case, the breaks were experienced in 2008 and 2016, while Uttar Pradesh witnessed turning points in 2006 and 2017.

An examination of structural breakpoints of input subsidies in the case of underdeveloped states suggest two different breaks. The two optimal breakpoints in Assam are found in 2000 and 2007 and in Bihar the break dates were observed in 2007 and 2012. States such as Gujarat, Madhya Pradesh, Maharashtra, and Rajasthan observed break dates in 1997 and 2008, while Karnataka and Uttar Pradesh observed turning points in 1997 and 2007. Jammu & Kashmir observed the breaks in 2007 and 2011; Odisha, however, felt the breaks in 2010 and 2014.

Chand and Parappurathu, in their 2012 study, hypothesized that Indian agriculture has gone through different policy regimes and is therefore characterized by multiple breaks. They used a similar Bai-Perron methodology (Bai and Perron 2003) and found five breakpoints in GDPA during the 1960 to 2010 period. A recent study by Akber and Paltasingh (2021) analyzed the multiple breakpoints in capital formation in Indian agriculture and confirmed that four and five structural break dates in public and private sector capital formation had occurred since the 1960s. We followed a similar methodology in our study and found two structural breakpoints in the public expenditure series during the 1992 to 2019 period. The main motive behind finding the structural breaks in the public expenditure series due to various policy regimes was to analyze the growth performance of total public expenditure on agriculture and irrigation and on input subsidies in different sub-periods and to compare the growth rates of public expenditure and output growth.

Table 3. Structural breaks in total agricultural public expenditure and input subsidies in underdeveloped states

Breaks	Public expenditure in the agricultural and irrigation sectors	Input subsidies
	Assam	
1st breakpoint	2008	2000
2nd breakpoint	2016	2007
	Bihar	
1st breakpoint	2006	2007
2nd breakpoint	2010	2012
	Gujarat	
1st breakpoint	2006	1997

2nd breakpoint	2012	2008
Jammu & Kashmir		
1st breakpoint	2001	2007
2nd breakpoint	2015	2011
Karnataka		
1st breakpoint	2004	1997
2nd breakpoint	2016	2007
Madhya Pradesh		
1st breakpoint	2010	1997
2nd breakpoint	2016	2008
Maharashtra		
1st breakpoint	2004	1997
2nd breakpoint	2016	2008
Odisha		
1st breakpoint	2008	2010
2nd breakpoint	2015	2014
Rajasthan		
1st breakpoint	2010	1997
2nd breakpoint	2016	2008
Uttar Pradesh		
1st breakpoint	2007	1997
2nd breakpoint	2016	2007

Note: All estimated breakpoints are significant at a 5 percent level and a trimming percentage of 15 percent (in the Bai-Perron test of 1 to *M* globally determined breaks).

3.1.6 Growth performance of public expenditure and farm output in India.

This section estimates the growth performance of public expenditure, GDPA, and farm production. The main motive for estimating sub-period growth rates based on structural breaks is to see whether trends in growth rates exhibit co-movement in all these macroeconomic variables. The number of sub-periods in public expenditure, for example, is three based on two breaks; we thus computed the growth rates by applying the “kinked growth model” for three different sub-periods of public sector expenditure on agriculture and irrigation and separately for input subsidies, and then for GSDPA and farm production during the same sub-periods of both expenditure series. The rationale for using the same sub-periods while computing the growth rates of public expenditure and farm output is to allow for the temporal coincidence of sub-periods while maintaining the homogeneity of the base for a meaningful comparison of growth trends in the states. This way, we can draw valuable insights into the link between farm expenditure growth and output growth in the country. The growth rates of public sector expenditure on agriculture and irrigation and of GSDPA in agriculturally developed states are presented in Table 4. The results reveal co-movement in the growth rates of public expenditure and farm output in all three sub-periods. In the case of input subsidies, however, the co-movement has been observed only in the growth rates of Andhra Pradesh and Kerala, while the other developed states observed reverse growth trends in input subsidies and farm output during the three different sub-periods that occurred between 1992 and 2019.

Table 4. Growth rates of public sector expenditure on agriculture and irrigation and of output in developed states

Periods	Public expenditure on agriculture and irrigation	GDPA	Periods	Input subsidy	GDPA
Andhra Pradesh					
1st period (1992–2005)	0.103***	0.037***	1st period (1992–1997)	0.025	-0.008
2nd period (2006–2014)	0.057***	0.045***	2nd period (1998–2006)	0.059***	0.018***
3rd period (2015–2019)	0.025**	0.096***	3rd period (2007–2019)	0.027*	0.063***
Haryana					
1st period (1992–2007)	0.002*	0.025***	1st period (1992–1998)	0.078***	0.012**
2nd period (2008–2016)	0.006*	0.032***	2nd period (1999–2007)	0.118***	0.031***
3rd period (2017–2019)	0.008***	0.038***	3rd period (2008–2019)	0.014	0.035***
Himachal Pradesh					
1st Period (1992–2007)	0.047**	0.043***	1st Period (1992–2006)	0.086***	0.042***
2nd period (2008–2016)	0.035**	0.021***	2nd period (2007–2014)	0.072***	0.029***
2nd period (2017–2019)	0.117**	0.047***	2nd period (2015–2019)	0.016	0.020
Kerala					
1st period (1992–2010)	0.041***	0.009***	1st period (1992–2007)	0.020***	0.002
2nd period (2011–2015)	0.044***	0.009***	2nd period (2008–2016)	-0.003***	-0.01*
3rd period (2016–2019)	0.080	-0.027***	3rd period (2017–2019)	-0.028**	-0.013
Punjab					
1st period (1992–2010)	-0.006	0.020***	1st period (1992–2006)	0.108***	0.022***
2nd period (2011–2015)	0.244***	0.008***	2nd period (2007–2013)	-0.02	0.013***
3rd period (2016–2019)	0.091**	0.004***	2nd period (2014–2019)	-0.099**	0.027***
Tamil Nadu					
1st period (1992–2006)	0.018**	0.013***	1st period (1992–2006)	0.129***	0.010**
2nd period (2007–2016)	0.104***	0.063***	2nd period (2007–2013)	0.009	0.053***
3rd period (2017–2019)	0.085**	0.050**	2nd period (2014–2019)	-0.032	0.052***
West Bengal					
1st period (1992–2008)	0.014**	0.027***	1st period (1992–1997)	0.079***	0.028***

2nd period (2009–2015)	0.070***	0.014***	2nd period (1998–2007)	0.010	0.011**
3rd period (2016–2019)	0.090**	0.036***	3rd period (2008–2019)	-0.064	0.030***

Note: *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels; periods are based on their respective breaks in the agricultural investment of developed states.

Table 5 depicts the growth performance of public sector expenditure and farm output of less- or under-developed agricultural states. The growth rates of the macroeconomic variables suggest a co-movement in the growth rates of expenditure on agriculture and irrigation and in farm output. In contrast, the growth rates of input subsidies and farm output of underdeveloped states suggest the reverse growth trends by these macroeconomic variables. The growth rates of input subsidies and farm output in terms of GSDPA thus suggest an inverse movement of growth trends by both groups of states. The growth rates of Andhra Pradesh and Kerala have experienced a similar trend.

The trends in growth rates of total public expenditure, input subsidies, and agricultural production of developed and underdeveloped states presented in Tables 2A and 3A in the Appendix I confirm a similar co-movement in the growth rates of public expenditure and agricultural production and reverse movements in the growth trends of input subsidies and agricultural production.

The positive link in most states between public sector expenditure on agriculture and irrigation and output growth in three different sub-periods signifies the importance of public expenditure in stimulating growth in India's farm sector; however, one cannot rule out the possibility that at different phases other factors are driving farm sector growth.

Table 5. Growth rates of public sector expenditure in agriculture and agricultural output in underdeveloped states

Periods	**Public expenditure in the agricultural and irrigation sectors**	**GDPA**	**Periods**	**Input subsidy**	**GDPA**
		Assam			
1st period (1992–2008)	-0.017***	-0.019	1st period (1992–2000)	0.130***	-0.004
2nd period (2009–2016)	0.089**	0.052***	2nd period (2001–2007)	0.067	0.010*
3rd period (2017–2019)	0.067	-0.022	3rd period (2008–2019)	0.067***	0.025***
		Bihar			
1st period (1992–2006)	-0.008	0.009	1st period (1992–2007)	0.075***	0.027***
2nd period (2007–2010)	0.013*	0.018***	2nd period (2008–2012)	0.043	0.060***

3rd period (2011–2019)	0.060***	0.050***	3rd period (2013–2019)	-0.044	0.019
Gujarat					
1st period (1992–2006)	0.028***	0.031***	1st period (1992–1997)	0.228***	0.004
2nd period (2007–2012)	0.094***	0.063**	2nd period (1998–2008)	0.018	0.046***
3rd period (2013–2019)	0.057**	0.045*	3rd period (2009–2019)	0.008	0.050***
Jammu & Kashmir					
1st period (1992–2001)	0.032**	0.045***	1st period (1992–2007)	-0.014	0.030***
2nd period (2002–2015)	0.030***	0.021**	2nd period (2008–2011)	0.014	0.032***
2nd period (2016–2019)	0.002	0.051**	3rd period (2012–2019)	-0.125	0.030***
Karnataka					
1st period (1992–2004)	0.051***	0.006	1st period (1992–1997)	0.114	0.018
2nd period (2005–2016)	0.054***	0.036***	2nd period (1998–2007)	0.086	0.011
3rd period (2017–2019)	0.089***	0.028*	3rd period (2008–2019)	0.034	0.036
Madhya Pradesh					
1st period (1992–2010)	0.044***	0.026***	1st period (1992–1997)	0.118**	0.01
2nd period (2011–2016)	0.131***	0.113***	2nd period (1998–2008)	0.065***	0.025***
3rd period (2017–2019)	0.118*	0.014	3rd period (2009–2019)	0.024	0.085***
Maharashtra					
1st Period (1992–2004)	0.038**	0.034***	1st period (1992–1997)	0.120**	0.019
2nd period (2005–2016)	0.042***	0.033***	2nd period (1998–2008)	0.043**	0.041***
3rd period (2017–2019)	0.150*	0.014	3rd period (2009–2019)	0.042*	0.025***
Odisha					
1st period (1992–2008)	0.0067***	0.022***	1st period (1992–2010)	0.059***	0.016***
2nd period (2009–2015)	0.067***	0.020***	2nd period (2011–2014)	0.077***	0.041***
3rd period (2016–2019)	0.175	0.071*	3rd period (2015–2019)	-0.052	0.017
Rajasthan					
1st period (1992–2010)	0.021***	0.034***	1st period (1992–1997)	0.102***	0.033***
2nd period (2011–2016)	0.063***	0.068***	2nd period (1998–2008)	-0.038	0.068***
3rd period (2017–2019)	0.131***	0.024	3rd period (2009–2019)	-0.097	0.020
Uttar Pradesh					
1st period (1992–2007)	0.030***	0.020***	1st period (1992–1997)	0.043***	0.020***
2nd period (2008–2016)	0.069**	0.027***	2nd period (1998–2007)	0.072***	0.020***
3rd period (2017–2019)	0.104	0.037***	3rd period (2008–2019)	0.005	0.029***

Note: : *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels; periods are based on their respective breaks in agricultural investment in underdeveloped states.

The crisis period of the 1990s is clearly represented in the figures shown in Table 5. That period marked the initiation of economic reforms and is characterized by the complete neglect of the agricultural sector and massive cuts in public sector expenditure on agriculture, irrigation, and rural development (Gulati and Bathla 2002). During the 2000s, to control the situation, almost all state governments increased budgetary outlays. Chand and Parappurathu (2012) demonstrated a significant hike in expenditures on drought relief measures, employment generation programs, increasing irrigation intensity, and minimum support prices, which improved public capital formation in agriculture. The trend in growth rates also confirm a slight improvement in public sector agricultural expenditure and farm output since the 2000s; growth input subsidies, on the other hand, when segregated from total public expenditure, confirm a decline in the last sub-period of the study. During the given time periods, however, a slight improvement has been observed in farm output growth.

3.1.7 Linkage between output and public expenditure in agriculture

This section empirically examines the determinants of output growth in India in terms of GSDPA and production. The main objective of this section is to further strengthen this relation by analyzing the influence of public expenditure growth on agricultural growth with the help of the Prais-Winsten first-difference regression model with panel-corrected standard error (PCSE). Before proceeding toward the results of PCSE of this analysis, we checked for the existence of cross-sectional dependency across the states. Table 4A in the Appendix presents the results of the Breusch-Pagan LM test for cross-sectional dependency, and the results confirm its existence across the states.

Table 6 depicts the results of GSDPA growth for 17 major agricultural states of India using the PCSE estimator. The results clearly suggest that GSDPA growth is positively and significantly affected by the growth of public sector expenditure on agriculture and irrigation. Input subsidy growth also positively determines the growth of GSDPA. While carefully examining the elasticities and level of significance, a strong linkage has been observed between the growth of total public sector expenditure on agriculture and irrigation and GSDPA; however, a weak linkage is confirmed between the growth of input subsidies and GSDPA. The elasticity value of public sector expenditure is 0.163, which is statistically significant at a 1 percent level of significance; this indicates that a 1 percent increase in growth of public sector expenditure correlates with a GSDPA growth increase of 0.163 percent. The elasticity of input subsidies, however, is 0.045, which is significant at a 5 percent level of significance. Other notable contributors to the growth of GSDPA are increases in electricity consumption, cropping intensity, irrigated land, fertilizers, rainfall, TOT, and farm employment.

The estimated elasticities of PCSE confirm the robustness of our models, as the coefficient estimates are not affected even in the presence of serial correlation, cross-sectional dependency, and heteroskedasticity.

Table 6. Determinants of GSDPA growth for all states

	Model specification 1				Model specification 2			
	PCSE	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**	**PCSE**	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**
Variables	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**
ΔPB	0.163*** (0.027)	0.170*** (0.026)	0.163*** (0.024)	0.172*** (0.026)	--	--	--	--
ΔSBSD	--	--	--	--	0.045** (0.021)	0.060** (0.231)	0.045** (0.179)	0.060** (0.231)
ΔEC	0.104*** (0.0174)	0.010*** (0.016)	0.104*** (0.018)	0.095*** (0.016)	0.122*** (0.019)	0.120*** (0.018)	0.122*** (0.019)	0.114*** (0.018)
ΔCRI	0.041*** (0.011)	0.037*** (0.012)	0.041*** (0.012)	0.044*** (0.012)	0.046*** (0.014)	0.040*** (0.010)	0.046*** (0.012)	0.040*** (0.010)
ΔIR	0.158*** (0.031)	0.154*** (0.029)	0.158*** (0.030)	0.159*** (0.029)	0.135*** (0.036)	0.126*** (0.035)	0.135*** (0.032)	0.123*** (0.035)
ΔFRT	0.254*** (0.028)	0.260*** (0.027)	0.254 (0.035)	0.258*** (0.027)	0.274*** (0.031)	0.275*** (0.030)	0.274*** (0.033)	0.283*** (0.030)
RNF	0.136*** (0.021)	0.134*** (0.02)	0.136*** (0.018)	0.131*** (0.02)	0.148*** (0.023)	0.146*** (0.025)	0.148*** (0.020)	0.140*** (0.025)
ΔTOT	0.103 (0.07)	0.077 (0.065)	0.103* (0.059)	0.042 (0.065)	0.006 (0.067)	0.039 (0.062)	0.006 (0.060)	0.065 (0.062)
ΔEMP	0.168*** (0.030)	0.173*** (0.028)	0.168*** (0.032)	0.176*** (0.028)	0.208*** (0.030)	0.206*** (0.028)	0.208*** (0.034)	0.214*** (0.026)
ΔEDU	0.0904** (0.046)	0.081* (0.045)	0.090*** (0.033)	0.074* (0.045)	0.090 (0.050)	0.084 (0.051)	0.090*** (0.034)	0.080 (0.049)
C	-0.027 (0.049)	-0.023 (0.045)	-0.027 (0.045)	-0.023 (0.045)	-0.030 (0.057)	-0.024 (0.045)	-0.030 (0.040)	-0.033 (0.045)
R-squared	0.728	0.747	0.728	0.755	0.694	0.713	0.694	0.713

Note: *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels; GSDPA = Gross State Domestic Product for agriculture; PCSE = panel-corrected standard error.

Table 7 reveals the determinants of the GDPA growth of developed agricultural states. The results suggest that the total public sector expenditure on agriculture and irrigation growth is a positive and significant determinant of the GSDPA growth of agriculturally developed states, but that the growth of input subsidies has no significant impact. The estimated elasticities are positive but not statistically significant, even at a 10 percent significance level. The other significant determinants are electricity consumption, cropping intensity, irrigated land, fertilizers, TOT, rainfall, and farm employment. The estimated elasticities of PCSE confirm the robustness of the models.

Table 7. Determinants of GSDPA growth in developed states

	Model specification1				Model specification 2			
	PCSE	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**	**PCSE**	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**
Variables	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**
ΔPB	0.063*** (0.019)	0.070*** (0.021)	0.063*** (0.019)	0.062*** (0.020)	--	--	--	--
ΔSBSD	--	--	--	--	0.002 (0.07)	0.002 (0.005)	0.002 (0.006)	0.002 (0.004)
ΔEC	0.079*** (0.024)	0.094*** (0.024)	0.079*** (0.023)	0.105*** (0.023)	0.094*** (0.025)	0.109*** (0.026)	0.094*** (0.024)	0.121*** (0.024)
ΔCRI	0.882*** (0.205)	0.655*** (0.108)	0.882*** (0.218)	0.673*** (0.207)	0.966*** (0.276)	0.7664*** (0.252)	0.966*** (0.264)	0.783*** (0.252)
ΔIR	0.248*** (0.049)	0.205*** (0.0500)	0.248*** (0.043)	0.205*** (0.048)	0.071*** (0.051)	0.74*** (0.051)	0.171*** (0.044)	0.280*** (0.049)
ΔFRT	0.311*** (0.083)	0.316*** (0.086)	0.311*** (0.075)	0.316*** (0.085)	0.323*** (0.087)	0.333*** (0.089)	0.323*** (0.078)	0.342*** (0.086)
RNF	0.026 (0.038)	0.036 (0.041)	0.026 (0.033)	0.039 (0.039)	0.030 (0.038)	0.038 (0.040)	0.030** (0.032)	0.036 (0.037)
ΔTOT	0.715*** (0.118)	0.678*** (0.115)	0.715*** (0.104)	0.683*** (0.110)	0.819*** (0.120)	0.797*** (0.1188)	0.819*** (0.102)	0.785*** (0.110)
ΔEMP	0.568*** (0.087)	0.521*** (0.083)	0.568*** (0.086)	0.522*** (0.080)	0.613*** (0.089)	0.574*** (0.087)	0.613*** (0.089)	0.575*** (0.082)
ΔEDU	0.039 (0.037)	0.0381 (0.036)	0.039 (0.036)	0.041 (0.037)	0.050 (0.038)	0.049 (0.038)	0.050 (0.036)	0.049 (0.038)
C	0.004 (0.010)	0.005 (0.008)	0.004 (0.008)	0.006 (0.008)	-0.018 (0.053)	-0.022 (0.043)	-0.018 (0.055)	-0.012 (0.035)
R-squared	0.730	0.745	0.730	0.758	0.716	0.730	0.717	0.749

Note: *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels; GSDPA = Gross State Domestic Product for agriculture; PCSE = panel-corrected standard error.

Similarly, Table 8 presents the results of determinants of GSDPA growth in India's less- or under-developed agricultural states. The elasticity value of public expenditure growth confirms that total public sector expenditure on agriculture and irrigation is a positive determinant of GSDPA growth, however the growth of input subsidies has had no significant impact. The estimated elasticities of other explanatory variables suggest that electricity consumption, cropping intensity, irrigated land, fertilizers, rainfall, TOT, farm employment, and education are positive and significantly affecting GSDPA.

The estimated elasticities of PCSE confirm the robustness of our models, as the estimated coefficients are not affected in the presence of serial correlation, cross-sectional dependency, and heteroskedasticity.

Table 8. Determinants of GSDPA growth in underdeveloped states

	Model specification 1				**Model specification 2**			
	PCSE	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**	**PCSE**	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**
Variables	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**
ΔPB	0.224*** (0.038)	0.228*** (0.036)	0.224*** (0.037)	0.224*** (0.038)	-- --	-- --	-- --	-- --
ΔSBSD	-- --	-- --	-- --	-- --	0.003 (0.016)	0.015 (0.017)	0.003 (0.015)	0.011 (0.017)
ΔEC	0.084*** (0.019)	0.056*** (0.018)	0.084*** (0.020)	0.084*** (0.019)	0.109*** (0.020)	0.098*** (0.020)	0.109*** (0.021)	0.096*** (0.020)
ΔCRI	0.675** (0.261)	0.678*** (0.242)	0.675** (0.257)	0.675*** (0.261)	0.591** (0.273)	0.592** (0.259)	0.591** (0.278)	0.565** (0.251)
ΔIR	0.152*** (0.037)	0.152*** (0.034)	0.152*** (0.040)	0.152*** (0.037)	0.131*** (0.039)	0.128*** (0.037)	0.131*** (0.042)	0.127*** (0.035)
ΔFRT	0.241*** (0.040)	0.230*** (0.038)	0.241*** (0.041)	0.241*** (0.040)	0.349*** (0.044)	0.340*** (0.043)	0.349*** (0.042)	0.342*** (0.042)
RNF	0.150*** (0.022)	0.133*** (0.024)	0.150*** (0.020)	0.150*** (0.022)	0.171*** (0.023)	0.154*** (0.023)	0.171*** (0.021)	0.148*** (0.023)
ΔTOT	0.314*** (0.075)	0.264*** (0.066)	0.314*** (0.063)	0.314*** (0.075)	0.337*** (0.078)	0.287*** (0.072)	0.337*** (0.066)	0.262*** (0.067)
ΔEMP	0.100**	0.117***	0.100**	0.100***	0.129**	0.137***	0.129**	0.142***

	(0.038)	(0.032)	(0.037)	(0.038)	(0.038)	(0.035)	(0.039)	(0.034)
ΔEDU	0.055	0.063	0.055	0.055	0.037	0.044	0.037	0.037
	(0.054)	(0.0062)	(0.043)	(0.058)	(0.058)	(0.061)	(0.044)	(0.060)
C	0.001	0.003	0.001	0.0012	0.004	0.005	0.004	0.006
	(0.008)	(0.006)	(0.007)	(0.007)	(0.009)	(0.009)	(0.007)	(0.008)
R-squared	0.610	0.622	0.610	0.610	0.550	0.563	0.550	0.571

Note: *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels; GSDPA = Gross State Domestic Product for agriculture; PCSE = panel-corrected standard error.

Table 5A in the Appendix presents the results of determinants of production growth for 17 major agricultural states of India. The results of PCSE confirm that total public sector expenditure growth is a positive and significant determinant of production growth in India. The estimated elasticity of public sector expenditure on agriculture and irrigation is 0.167, which is statistically significant at a 1 percent level of significance; this suggests that a 1 percent increase in public sector expenditure growth improves production growth by 0.167 percent. The elasticity value of input subsidies is 0.032, however, which is statistically significant at a 5 percent level of significance; this indicates that with a 1 percent increase in growth of input subsidies, agricultural production increases at 0.032 percent. The value of elasticities and their significance level confirms that total public expenditure on agriculture and irrigation has a strong positive impact on agricultural production; however, input subsidies alone have a weak positive impact. The elasticities of other explanatory variables confirm that electricity consumption, cropping intensity, irrigated land, fertilizers, rainfall, TOT, and farm employment positively and significantly affect production growth in Indian agriculture.

Similarly, Tables 6A and 7A reveal the results of determinants of production growth in agriculturally developed and underdeveloped states of India. The results suggest that public expenditure on agriculture and irrigation induces the production growth of both groups of states; however, the elasticity and level of significance of input subsidies confirm no significant impact on the growth of agricultural production.

While checking the impact at the aggregate level, agricultural input subsidies showed a weak positive impact on growth; at the disaggregated level of analysis, however, this weak effect fades and the input subsidies render no significant impact.

From the above analysis, we can draw various conclusions. First, public expenditure on agriculture and irrigation in 17 major agricultural states of India experienced massive cuts during the 1990s but showed a slight improvement during the 2000s. Second, public expenditure on input subsidies showed an increasing trend in the first two decades of the study, but a constant or declining trend was registered in the last period of the study. Third, a major proportion of state spending goes to crop husbandry and irrigation. Fourth, two significant optimal breaks in the public expenditure series have been confirmed by Bai-Perron test results (Bai and Perron 2003). Fifth, the kinked exponential growth rate suggests similar co-movements in the trend growth rates of total public expenditure on agriculture and irrigation and farm output in terms of GSDPA and farm production growth. Sixth, the growth rates of input subsidies and farm output have registered a reverse co-movement. Seventh, the growth of public sector expenditure on agriculture and irrigation induces improvement in agricultural growth, however, after segregating from total public expenditure, input subsidies render weak or no significant growth in agricultural performance.

We thus conclude that public sector expenditure on agriculture and irrigation is an efficient tool for accelerating the agricultural growth rate in the country, but that input subsidies are less or not efficient. The efficacy is therefore mainly due to the investment series in the sector. This is consistent with earlier literature such as the studies by Smith and Urey (2002), Chand and Kumar (2004), Fan, Gulati, Thorat (2008), Akber and Paltasingh (2019, 2020); they also considered that public investment in agriculture is more effective than input subsidies in improving Indian agriculture.

4 CONCLUSION AND POLICY IMPLICATIONS

The present study assessed the recent trends, breaks, and growth performance of public sector expenditure in 17 developed and underdeveloped agricultural states in India. The trend analysis of total public expenditure in the agricultural and irrigation sectors and its share in GSDPA during a 27-year period confirmed a declining trend in public expenditure since the 1990s and a slight improvement in the 2000s. The trend analysis of input subsidies and their share in GSDPA showed a continuously increasing trend in the first two decades of the study, although a stable or declining trend has been registered more recently. The pattern of the trends confirms a high level of interstate disparity in the distribution of public expenditure. The states have prioritized spending on irrigation and crop husbandry, ignoring other essential categories of spending in the agricultural sector such as agricultural research and education, soil and water conservation, dairy development, storage facilities, and the development of marketing networks.

We also examined the hypothesis of public expenditure being a major driver of agricultural growth in India by finding structural breaks in the expenditure through application of the Bai-Perron multiple breakpoint tests (Bai and Perron 2003) and then drawing a comparison between total public expenditure on agriculture and irrigation and GSDPA and farm production over the same periods. The Bai-Perron test confirmed two significant break dates in public expenditure during the given study period. The kinked exponential growth model has been used to measure the growth rate of public expenditure and farm output in three different sub-periods. Our examination of the patterns in growth rates confirmed that the trends in growth rates of GSDPA and production very closely followed the growth rate of total public expenditure on agriculture and irrigation; however, a reverse movement was observed in the growth rates of input subsidies, GSDPA, and farm production.

This linkage aspect was further explored with the help of the first-difference regression analysis. The regression results show that the growth of public sector expenditure in agriculture and irrigation, electricity consumption, cropping intensity, irrigated land, fertilizer use, rainfall, TOT, and farm employment all induce improvements in the growth of GSDPA and production. Growth in agricultural input subsidies, however, showed a weak or insignificant impact.

The above findings have significant policy implications for India's agricultural development. The agricultural sector continues to be the prime pulse of the Indian economy, as the primary goals of economic policy such as price stability, output growth, and rural poverty alleviation are best served by the expansion of this sector. Though it contributes approximately 14 percent of GDP and accommodates 50 percent of the population, it is still overlooked in fiscal policy budgetary allocations. The public authority should reverse the budget cuts to economic services and allocate funds to the farm sector that are proportional to its size. There is also a specific need to prioritize expenditure in numerous areas, including rural infrastructure, agricultural research and education, soil and water conservation, dairy development, storage facilities, development of marketing networks, and revamping of agricultural extension services for better diffusion of information. Input subsidies should be rationalized by weighing their welfare effects against their cost to the exchequer.

Understanding that Indian states differ in agronomic conditions, geography, marketing, institutions, and policy frameworks, the resource allocation for each category should be carefully evaluated to assist poorer regions and poor agricultural states and to prioritize investment in the sector. Under the public expenditure policy, there should also be an investigation of the viability of interstate resource transfers and avenues for generating/financing resources for asset creation.

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APPENDIX

Bai-Perron (2003) Method of Finding Structural Breaks

The multiple linear regression, as mentioned in Eq. (1), can be written in a matrix form as:

$$Y = X_{\beta} + \acute{Z}_{\delta} + U \tag{1A}$$

where $Y = (y_1, \dots, y_t), X = (x_1, \dots\dots, x_t)$, $U = (u_1, \dots\dots, u_t)$, $\delta = (\delta'_1, \delta'_2, \dots\dots, \delta'_{m+1}$, and $\acute{Z}$ is the matrix that diagonally partitions Z at $(T_1, \dots\dots, T_m)$, i.e. $\acute{Z} = diag(Z_{1,\dots,} Z_{m+1})$ with $Z_i = (ZT_{i-1} + 1, \dots., ZT_i)$. We denote the true value of a parameter with a 0 superscript. In particular, $\delta^{\circ} = (\delta^{\circ}_1, \dots., \delta^{\circ}_{m+1})$ and $(T^{\circ}_1, \dots\dots, T^{\circ}_m)$ are used to denote, respectively, the true values of the parameters δ and the true breakpoints. The matrix $\acute{Z}$ diagonally partitions Z at $(T^{\circ}_1, \dots, T^{\circ}_{m)}$. The data-generating process is assumed to be as follows:

$$Y = X\beta^{\circ} + \acute{Z}^{\circ}\delta^{\circ} + U \tag{2A}$$

The method of estimation is based on the least-squares principle. For each m-partition $(T_1, \dots.\ T_m)$, the associated least-squares estimates of β and δ_j are obtained by minimizing the sum of squared residuals

$$\left(Y - X\beta\ - \acute{Z}\,\delta\right)(Y - X\beta - \acute{Z}\delta) = \sum_{i=1}^{m+1} \sum_{Ti-1+1}^{Ti} (Y_t - X_t\beta - \ \acute{Z}_t\delta_i)^2 \tag{3A}$$

Let $\hat{\beta}$ $(\{ T_j\})$ and $\hat{\delta}(T_j)$ denote the estimates based on the given m-partition $(T_1, \dots.\ T_m)$ denoted $\{T_j\}$. Substituting these in the objective function and denoting the resulting sum of squared residuals as $S_T(T_1, \dots.\ T_m)$, the estimated break points $(\widehat{T_1} \dots.\ \widehat{T_M})$ are such that $\left(\widehat{T_1} \dots.\ \widehat{T_M}\right) = agrmin_{T_{1,\dots\dots}T_M}\, S_T(T_1, \dots.\ T_m)$, where the minimization is taken over all partitions $(T_1, \dots.\ T_m)$ such that $T_i - \ T_{i-1} \geq q^2$. Thus the break-point estimators are global minimizers of the objective function. The regression parameter estimates are the estimates associated with the m-partition $\{T_j\}$, i.e., $\hat{\beta} = \hat{\beta}\left(\{ T_j\}\right), \hat{\delta} = \hat{\delta}\left(T_j\right)$. Since, the break points are discrete parameters and can only take a finite number of values, they can be estimated by a grid search. This method becomes rapidly computationally excessive when $m > 2$. For the empirical illustration, we use the method based on a dynamic programming algorithm developed by Bai and Perron (2003) which is based on the principle of dynamic programming that allows the computation of estimates of the break points as global minimizers of the sum of squared residuals that is of order $O(T^2)$ for any number of structural changes m, unlike a standard grid search procedure which would require least squares operations of order $O(T^m)$.

Kinked Exponential Growth Model

The unrestricted generalized kinked model for "*m*" sub-periods with "*m-1*" kinks such as k_1, k_2…., k_{m-1}, and D_1, D_2,… *Dm* sub-periods dummies can be written as:

$$LnY_t = \alpha_1 D_1 + \alpha_2 D_2 + \cdots + \alpha_m D_m + (\beta_1 D_1 + \beta_2 D_2 + \cdots + \beta_m D_m)t + \epsilon_t \quad (4A)$$

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,… *m-1*, the restricted generalized kinked compound model can be expressed as:

$$\begin{aligned} LnY_t \ &= \alpha_1 + \beta_1\left(D_1 t + \sum_{j=2}^{m} D_j k_1\right) + \beta_2\left(D_2 t - \sum_{j=2}^{m} D_j k_1 + \sum_{j=3}^{m} D_j k_2\right) + \cdots \\ &+ \beta_i\left(D_i t - \sum_{j=i}^{m} D_j k_{i-1} + \sum_{j=i+1}^{m} D_j k_i\right) + \cdots + \beta_m(D_m t - D_m k_{m-1}) \\ &+ \epsilon_t \end{aligned} \quad (5A)$$

The βs give the values of growth rates for respective periods. The generalized model helps to derive the required growth model for a fixed number of sub-periods depending on the number of kinks/breakpoints in the series.

To illustrate, we have three sub-periods, denoted as m = 3, and the kink is denoted by k, which is calculated as k = m-1 = (3-1) = 2. So, two kinks are identified as:

$$\begin{aligned} LnY_t \ &= \alpha_1 + \beta_1(D_{1t} + D_2 K_1 + D_3 K_1) + \beta_2(D_{2t} - D_2 K_1 - D_3 K_1 + D_3 K_2) + \beta_3(D_{3t} - D_3 K_2) \\ &+ \mu_t \end{aligned} \quad (6A)$$

The βs give the values of the rate of growth in the respective periods.

Table 1A. Sectorial composition of public expenditure in the agricultural sector

Developed										Underdeveloped									
Variables	Years	All	AP	HR	HP	KRL	PB	TN	WB	Assam	Bihar	GUJ	J&K	KRT	MP	MAH	Odisha	Raj	UP
Irrigation	1992–2001	59.6	79.2	61.6	25.5	33.0	67.0	25.0	44.4	35.3	59.8	80.4	36.8	70.2	54.7	55.1	59.7	72.0	62.0
	2002–2011	62.8	85.7	60.8	39.8	25.2	58.0	30.4	39.4	41.0	57.0	73.3	36.5	59.6	60.8	65.2	54.4	67.1	57.9
	2012–2019	46.9	64.2	39.9	31.8	12.9	20.4	19.7	25.3	61.4	33.5	63.1	23.6	43.5	43.7	47.4	44.7	39.7	45.4
Cooperation	1992–2001	4.2	3.3	3.0	5.4	7.1	4.7	6.0	3.6	7.8	5.0	2.3	5.5	3.0	5.6	5.1	4.7	3.8	2.9
	2002–2011	5.8	1.4	5.7	2.5	10.1	3.7	24.0	5.1	4.2	3.4	1.4	2.3	9.4	3.9	8.9	3.8	2.3	2.6
	2012–2019	5.2	0.7	7.1	1.7	6.3	1.9	10.6	4.5	0.9	4.8	5.0	3.0	11.8	5.2	6.1	5.4	16.6	4.6
Research and education	1992–2001	3.3	3.0	4.8	11.0	6.4	6.7	4.4	3.6	7.0	3.9	2.5	3.5	2.5	2.3	2.7	1.8	2.6	2.5
	2002–2011	3.3	1.9	6.6	9.2	6.8	8.4	5.8	4.5	8.6	4.5	3.5	8.7	2.7	1.6	2.7	1.7	2.7	2.3
	2012–2019	3.5	3.2	6.0	9.7	7.5	4.9	5.3	3.0	3.7	7.6	4.6	10.0	2.6	1.0	3.6	1.2	2.4	1.3
Fisheries	1992–2001	1.3	0.7	0.7	1.7	7.8	0.4	1.7	4.4	2.7	1.0	0.9	2.9	1.0	1.2	0.6	2.4	0.4	0.6
	2002–2011	1.2	0.3	0.9	1.1	7.6	0.6	3.0	4.9	3.1	0.8	1.5	2.9	0.7	0.7	0.8	1.5	0.3	0.5
	2012–2019	1.4	0.7	0.7	1.2	10.1	0.3	4.6	3.7	0.9	1.3	1.5	3.3	1.2	0.5	0.9	1.2	0.2	0.4
Food storage	1992–2001	4.1	0.0	12.3	5.6	10.0	1.2	0.1	6.7	11.1	0.1	0.4	1.1	9.3	4.9	4.1	7.1	0.1	6.0
	2002–2011	4.5	0.0	2.9	6.9	13.4	3.7	0.1	6.1	2.4	0.8	0.7	12.6	10.9	8.9	2.7	13.5	0.0	10.0
	2012–2019	5.7	0.1	17.8	11.7	21.6	0.0	1.3	5.7	1.1	7.3	0.8	14.8	11.3	9.7	8.3	11.2	0.0	7.7
Crop husbandry	1992–2001	14.0	8.1	7.4	27.6	23.8	9.0	54.1	14.5	21.1	12.1	8.3	20.7	7.6	16.8	6.7	13.3	10.7	14.7
	2002–2011	13.3	8.3	10.5	18.2	22.3	11.5	26.8	21.9	25.1	25.8	12.6	16.8	9.6	16.0	7.9	16.5	18.6	15.8
	2012-2019	28.8	27.4	15.2	23.4	25.4	65.4	48.9	44.9	27.1	35.5	19.4	23.4	18.7	34.0	20.1	30.4	29.0	31.3
Soil husbandry	1992–2001	3.6	0.9	2.8	8.1	2.0	3.0	2.4	1.6	2.4	1.2	2.5	10.4	2.7	3.9	4.8	4.2	5.0	6.2
	2002–2011	2.5	0.2	2.0	7.7	2.5	2.9	3.4	1.0	2.9	0.5	3.6	4.5	2.2	1.3	2.8	3.3	2.5	6.0
	2012–2019	2.0	0.3	1.2	4.3	2.9	1.5	1.3	1.6	0.7	1.5	1.9	3.2	1.7	0.5	6.6	2.3	0.8	3.4
Animal husbandry	1992–2001	5.7	4.7	7.2	13.7	8.1	7.5	5.6	9.2	11.2	16.3	2.6	18.8	3.6	9.2	2.8	6.4	5.3	4.6
	2002–2011	4.8	2.2	10.4	13.6	10.1	10.2	5.7	11.2	11.1	5.5	2.9	15.7	3.6	6.8	2.7	5.1	6.3	4.3
	2012–2019	5.4	3.5	12.1	15.2	10.3	5.5	7.5	8.9	4.1	6.2	3.3	18.8	4.5	5.5	4.5	3.3	10.7	5.4

Dairy developme nt	**1992–2001**	4.2	0.1	0.4	1.4	1.8	0.3	0.8	11.9	1.5	0.6	0.1	0.3	0.2	1.4	18.2	0.4	0.2	0.7
	2002–2011	1.7	0.0	0.2	1.0	2.0	0.9	0.8	6.0	1.5	1.7	0.4	0.0	1.3	0.0	6.1	0.2	0.1	0.7
	2012–2019	1.1	0.0	0.0	1.0	3.1	0.2	0.7	2.2	0.1	2.3	0.4	0.0	4.8	0.0	2.4	0.4	0.6	0.5

Source: Finance Accounts (Ministry of Finance).

Table 2A. Growth rates of public sector expenditure in agriculture and agricultural production in developed states

Periods	Public expenditure on agriculture and irrigation	Production	Periods	Input subsidy	Production
		Andhra Pradesh			
1st period (1992–2005)	0.103***	0.016*	1st period (1992–1997)	0.025	0.007
2nd period (2005–2015)	0.057***	0.097***	2nd period (1997–2006)	0.059***	0.006
3rd period (2015–2019)	0.025**	0.053	3rd period (2006–2019)	0.027*	-0.050***
		Haryana			
1st period (1992–2007)	0.002*	0.015**	1st period (1992–1998)	0.078***	0.038
2nd period (2007–2016)	0.006*	0.005	2nd period (1998–2007)	0.118***	0.001
3rd period (2016–2019)	0.008***	0.020***	3rd period (2007–2019)	0.014	0.022
		Himachal Pradesh			
1st Period (1992–2006)	0.047**	–0.0007	1st Period (1992–1998)	0.086***	0.005***
2nd period (2007–2015)	0.035**	0.014**	2nd period (1998–2008)	0.072***	0.018
2nd period (2016–2019)	0.117**	0.002	2nd period (2008–2019)	0.016	0.007***
		Kerala			
1st period (1992–2009)	0.041***	0.004***	1st period (1992–2007)	0.020***	-0.007*
2nd period (2010–2014)	0.044***	0.003*	2nd period (2007–2016)	-0.003***	-0.045*
3rd period (2015–2019)	0.08	–0.070***	3rd period (2016–2019)	-0.028**	-0.042
		Punjab			
1st period (1992–2010)	-0.006	0.001	1st period (1992–2006)	0.108***	0.002
2nd period (2010–2015)	0.244***	0.028**	2nd period (2006–2013)	-0.02	0.006
3rd period (2015–2019)	0.091**	0.026*	2nd period (2013–2019)	-0.099**	0.037***
		Tamil Nadu			
1st period (1992–2006)	0.018**	0.0001	1st period (1992–2006)	0.129***	0.003
2nd period (2006–2016)	0.104***	0.02	2nd period (2006–2013)	0.009	0.022
3rd period (2016–2019)	0.085**	0.038	2nd period (2013–2019)	-0.032	-0.035
		West Bengal			
1st period (1992–2008)	0.014**	0.024***	1st period (1992–1997)	0.079***	0.015***
2nd period (2008–2015)	0.070***	0.029***	2nd period (1997–2007)	0.01	0.013
3rd period (2015–2019)	0.090**	0.088***	3rd period (2007–2019)	-0.064	0.078***

Note: **, and *** indicate statistical significance at the $p < 0.05$ and $p < 0.01$ levels.

Table 3A. Growth rates of public sector expenditure in agriculture and agricultural production in underdeveloped states

Periods	Public expenditure in the agricultural and irrigation sectors	Production	Periods	Input subsidy	Production
		Assam			
1st period (1992–2007)	-0.017***	-0.007***	1st period (1992–2000)	0.130***	-0.004
2nd period (2008–2016)	0.089**	0.039***	2nd period (2000–2007)	0.067	-0.019**
3rd period (2016–2019)	0.067	0.012	3rd period (2007–2019)	0.067***	0.021***
		Bihar			
1st period (1992–2005)	-0.008	-0.007	1st period (1992–2007)	0.075***	0.017**
2nd period (2006–2010)	0.013*	0.002	2nd period (2007–2012)	0.043	0.115***
3rd period (2011–2019)	0.060***	0.009***	3rd period (2012–2019)	-0.044	0.041***
		Gujarat			
1st period (1992–2006)	0.028***	0.025***	1st period (1992–1997)	0.228***	0.029
2nd period (2006–2012)	0.094***	0.03	2nd period (1997–2008)	0.018	0.01
3rd period (2012–2019)	0.057**	0.069***	3rd period (2008–2019)	0.008	0.029**
		Jammu & Kashmir			
1st period (1992–2000)	0.032**	-0.004	1st period (1992–2007)	-0.014	0.008**
2nd period (2001–2014)	0.030***	0.012**	2nd period (2007–2011)	0.014	0.006
2nd period (2015–2019)	0.002	-0.012	3rd period (2011–2019)	-0.125	0.002
		Karnataka			
1st period (1992–2004)	0.051***	-0.008	1st period (1992–1997)	0.114	0.045
2nd period (2004–2016)	0.054***	0.016	2nd period (1998–2007)	0.086	-0.024
3rd period (2016–2019)	0.089***	0.04	3rd period (2007–2019)	0.034	0.036
		Madhya Pradesh			
1st period (1992–2010)	0.044***	-0.003	1st period (1992–1997)	0.118**	0.009
2nd period (2010–2016)	0.131***	0.127***	2nd period (1997–2008)	0.065***	0.013
3rd period (2016–2019)	0.118*	0.0001	3rd period (2008–2019)	0.024	0.091***
		Maharashtra			
1st Period (1992–2004)	0.038**	0.006	1st period (1992–1997)	0.120**	0.021
2nd period (2004–2016)	0.042***	0.039	2nd period (1997–2008)	0.043**	0.013
3rd period (2016–2019)	0.150*	0.045	3rd period (2008–2019)	0.042*	0.044
		Odisha			
1st period (1992–2007)	0.0067***	0.001	1st period (1992–2008)	0.059***	0.006
2nd period (2008–2014)	0.067***	-0.002	2nd period (2008–2014)	0.077***	0.022
3rd period (2015–2019)	0.175	0.006	3rd period (2014–2019)	-0.052	0.006
		Rajasthan			
1st period (1992–2009)	0.021***	0.032***	1st period (1992–1997)	0.102***	0.032***

2nd period (2010–2015)	0.063***	0.036*	2nd period (1997–2008)	-0.038	0.036*
3rd period (2016–2019)	0.131***	0.077	3rd period (2008–2019)	-0.097	0.07
			Uttar Pradesh		
1st period (1992–2007)	0.030***	-0.004	1st period (1992–1997)	0.043***	0.007
2nd period (2007–2016)	0.069**	0.02	2nd period (1997–2007)	0.072***	0.01
3rd period (2016–2019)	0.104	0.139	3rd period (2007–2019)	0.005	0.054**

Note: **, and *** indicate statistical significance at the $p < 0.05$ and $p < 0.01$ levels.

Table 4A. Breusch-Pagan LM cross-sectional dependency test

All states			**Developed states**			**Underdeveloped states**		
Variable	**Statistic**	**Prob.**	**Variable**	**Statistic**	**Prob.**	**Variable**	**Statistic**	**Prob.**
GDPA	1495.23***	0.00	GDPA	679.11***	0.00	GDPA	171.42***	0.00
PR	1096.50***	0.00	PR	320.14***	0.00	PR	117.08***	0.00
PB	2560.91***	0.00	PB	634.91***	0.00	PB	570.31***	0.00
SBSD	1372.34***	0.00	SBSD	458.43***	0.00	SBSD	127.14***	0.00
EC	1191.40***	0.00	EC	473.98***	0.00	EC	345.69***	0.00
CRI	1104.16***	0.00	CRI	312.70***	0.00	CRI	166.21***	0.00
IR	2520.13**	0.00	IR	608.04***	0.00	IR	448.88***	0.00
FRT	1668.53***	0.00	FRT	347.33***	0.00	FRT	296.82***	0.00
RNF	392.54***	0.00	RNF	159.35***	0.00	RNF	61.88***	0.00
TOT	1795.39***	0.00	TOT	487.48***	0.00	TOT	304.84***	0.00
EMP	2346.14***	0.00	EMP	716.61***	0.00	EMP	341.71***	0.00
EDU	2392.69***	0.00	EDU	511.75***	0.00	EDU	633.29***	0.00

Note: *** indicates statistical significance at the $p < 0.01$ level.

Table 5A. Determinants of production growth in all states

	Model specification 1				**Model specification 2**			
	PCSE	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**	**PCSE**	**PCSE (autocorrelation)**	**PCSE (heteroskedasticity)**	**PCSE (autocorrelation panel-specific)**
Variables	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**	**Coeff. (Std error)**
ΔPB	0.167*** (0.023)	0.189*** (0.023)	0.167*** (0.022)	0.189*** (0.023)	--	--	--	--
ΔSBSD	--	--	--	--	0.032** (0.016)	0.040** (0.047)	0.032** (0.014)	0.040** (0.047)
ΔEC	0.056** (0.024)	0.066*** (0.022)	0.056** (0.025)	0.064*** (0.022)	0.060** (0.024)	0.072 (0.022)	0.060 (0.025)	0.072 (0.022)
ΔCRI	0.048*** (0.013)	0.042*** (0.011)	0.048*** (0.010)	0.038*** (0.011)	0.047*** (0.015)	0.640*** (0.011)	0.047*** (0.013)	0.640*** (0.011)
ΔIR	0.688*** (0.043)	0.655*** (0.040)	0.688*** (0.043)	0.656*** (0.040)	0.676*** (0.043)	0.158*** (0.045)	0.676*** (0.043)	0.158*** (0.045)
ΔFRT	0.149*** (0.048)	0.159*** (0.042)	0.149*** (0.049)	0.153*** (0.044)	0.150*** (0.049)	0.102*** (0.030)	0.150*** (0.050)	0.102*** (0.030)
RNF	0.103***	0.096***	0.103***	0.080***	0.109***	0.102***	0.109***	0.102***

	(0.029)	(0.030)	(0.028)	(0.030)	(0.028)	(0.030)	(0.028)	(0.030)
ΔTOT	0.321*** (0.071)	0.324*** (0.070)	0.321*** (0.085)	0.317*** (0.070)	0.276*** (0.069)	0.264*** (0.067)	0.276*** (0.082)	0.264*** (0.067)
ΔEMP	0.194*** (0.037)	0.184*** (0.035)	0.194*** (0.047)	0.184*** (0.035)	0.204*** (0.038)	0.194*** (0.036)	0.204*** (0.048)	0.194*** (0.036)
ΔEDU	0.030 (0.045)	0.046 (0.039)	0.030 (0.048)	0.054 (0.039)	0.032 (0.046)	0.059 (0.042)	0.032 (0.048)	0.059 (0.042)
C	0.035 (0.057)	0.031 (0.040)	0.035 (0.054)	0.029 (0.040)	0.035 (0.055)	0.031 (0.038)	0.035 (0.053)	0.031 (0.038)
R-squared	0.777	0.791	0.777	0.753	0.725	0.751	0.725	0.753

Note: **, and *** indicate statistical significance at the $p < 0.05$ and $p < 0.01$ levels; PCSE = panel-corrected standard error.

Table 6A. Determinants of production growth in developed states

	Model specification 1				**Model specification 2**			
	PCSE	**PCSE (autocorrel ation)**	**PCSE (heterosk edasticity)**	**PCSE (autocorrelation panel-specific**	**PCSE**	**PCSE (autocorrel ation)**	**PCSE (heterosked asticity)**	**PCSE (autocorrelatio n panel-specific**
Variables	**Coeff.** **(Std error)**	**Coeff.** **(Std error)**	**Coeff.** **(Std error)**	**Coeff.** **(Std error)**	**Coeff.** **(Std error)**	**Coeff.** **(Std error)**	**Coeff.** **(Std error)**	**Coeff.** **(Std error)**
ΔPB	0.165*** (0.051)	0.093*** (0.026)	0.165*** (0.054)	0.097*** (0.024)	-- --	-- --	-- --	-- --
ΔSBSD	-- --	-- --	-- --	-- --	0.082 (0.152)	0.092 (0.072)	0.082 (0.184)	0.090 (0.063)
ΔEC	0.529*** (0.014)	0.481*** (0.029)	0.529*** (0.022)	0.427*** (0.030)	0.561*** (0.0127)	0.485*** (0.032)	0.561*** (0.020)	0.425*** (0.029)
ΔCRI	2.84*** (0.485)	2.860*** (0.360)	2.841*** (0.460)	2.826*** (0.318)	2.945*** (0.136)	2.496*** (0.375)	2.945*** (0.254)	2.261*** (0.258)
ΔIR	1.035* (0.592)	0.917*** (0.225)	1.035*** (0.388)	0.805*** (0.167)	0.947*** (0.107)	0.898*** (0.215)	0.947*** (0.099)	0.760*** (0.158)
FRT	0.542 (0.540)	0.043 (0.178)	0.542 (0.559)	0.028 (0.110)	0.398 (0.550)	0.061 (0.171)	0.398 (0.597)	0.012 (0.112)
ΔRNF	0.134 (0.132)	0.062 (0.043)	0.134 (0.130)	0.072** (0.038)	0.128 (0.019)	0.054* (0.041)	0.128*** (0.023)	0.067* (0.035)
ΔTOT	0.128 (0.830)	0.058 (0.350)	0.128 (0.846)	0.058 (0.239)	0.199 (0.851)	0.086 (0.332)	0.199 (0.883)	0.154 (0.233)
ΔEMP	2.834** (0.756)	0.845** (0.401)	2.834*** (0.831)	0.880*** (0.328)	2.393*** (0.748)	0.735*** (0.149)	2.293** (0.813)	0.796 (0.282)
ΔEDU	0.608*** (0.189)	0.121 (0.098)	0.608** (0.230)	0.062 (0.085)	0.448 (0.163)	0.094 (0.093)	0.448 (0.216)	0.037 (0.079)
C	0.469 (0.459)	0.590 (0.432)	0.469 (0.394)	0.688 (0.3496)	0.187 (0.193)	0.446 (0.353)	0.187 (0.140)	0.498 (0.379)
R-squared	0.871	0.913	0.873	0.956	0.867	0.913	0.867	0.921

Note: **, and *** indicate statistical significance at the $p < 0.05$ and $p < 0.01$ levels; PCSE = panel-corrected standard error.

Table 7A. Determinants of production growth in underdeveloped states

	Model specification 1				Model specification 2			
	PCSE	PCSE (autocorrelation)	PCSE (heteroskedasticity)	PCSE (autocorrelation panel-specific)	PCSE	PCSE (autocorrelation)	PCSE (heteroskedasticity)	PCSE (autocorrelation panel-specific)
Variables	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)	Coeff. (Std error)
ΔPB	0.191*** (0.063)	0.226*** (0.058)	0.191*** (0.061)	0.215*** (0.057)	--	--	--	--
ΔSBSD	--	--	--	--	0.002 (0.023)	0.008 (0.024)	0.002 (0.022)	0.008 (0.024)
ΔEC	0.0954*** (0.031)	0.097*** (0.029)	0.0954** (0.032)	0.096** (0.028)	0.117** (0.029)	0.121*** (0.027)	0.117** (0.031)	0.115*** (0.026)
ΔCRI	0.544** (0.044)	0.3283 (0.039)	0.544*** (0.040)	0.289*** (0.037)	0.462*** (0.043)	0.251*** (0.039)	0.462*** (0.049)	0.178*** (0.370)
ΔIR	0.574*** (0.067)	0.532*** (0.062)	0.574*** (0.064)	0.547*** (0.059)	0.558*** (0.066)	0.535*** (0.061)	0.558*** (0.064)	0.553*** (0.059)
ΔFRT	0.204*** (0.078)	0.188*** (0.73)	0.204*** (0.071)	0.209*** (0.070)	0.301*** (0.079)	0.307*** (0.074)	0.301*** (0.072)	0.311*** (0.072)
RNF	0.126*** (0.035)	0.117*** (0.034)	0.126*** (0.034)	0.109*** (0.035)	0.141*** (0.034)	0.133*** (0.034)	0.141*** (0.042)	0.111*** (0.034)
ΔTOT	0.436*** (0.088)	0.436*** (0.084)	0.436*** (0.105)	0.432*** (0.098)	0.459*** (0.092)	0.449*** (0.090)	0.459*** (0.110)	0.445*** (0.090)
ΔEMP	0.325*** (0.0609)	0.304*** (0.054)	0.323*** (0.063)	0.3113*** (0.054)	0.351*** (0.061)	0.328*** (0.056)	0.351*** (0.063)	0.330*** (0.056)
ΔEDU	0.109 (0.085)	0.095 (0.074)	0.109 (0.073)	0.091 (0.076)	0.124 (0.083)	0.113 (0.075)	0.124 (0.073)	0.109 (0.078)
C	-0.006 (0.015)	-0.007 (0.010)	-0.006 (0.012)	-0.006 (0.010)	-0.005 (0.015)	-0.004 (0.011)	-0.005 (0.012)	-0.003 (0.011)
R-squared	0.676	0.705	0.687	0.708	0.676	0.689	0.676	0.692

Note: *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels.

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