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Public financing of Indian agriculture and its returns: some panel evidence

Nusrat Akber, and Kirtti Ranjan Paltasingh*

School of Economics, SMVD University, Jammu 182 320, Jammu & Kashmir

*Corresponding author: kirtti@smvdu.ac.in

Abstract This paper compares the effectiveness of public investment and input subsidies in augmenting agricultural production. It uses an autoregressive distributed lag (ARDL) model on time-series data at the national level and panel data at the state level. The paper finds that subsidies have a positive and significant impact in augmenting agricultural production in the short run only, and public investment is more effective at the national and subnational level in the short and long run. The range of long-run elasticity is 0.03–0.368 and short-run elasticity is 0.030–0.205. Therefore, input subsidies should be rationalized and funds diverted to farm investment.

Keywords Investment, subsidies, production, Indian agriculture

JEL codes E22, H20, Q14

Since independence, the agricultural sector — driven by technological and institutional factors—has undergone several phases of growth. The agricultural gross domestic product (GDP) grew less than 2% per annum until the mid-1960s. The green revolution relied on modern methods of production and technology—high yield variety (HYV) seeds, fertilizers, mechanization, and irrigation. The government made tremendous efforts to help farmers make efficient use of these techniques of production (inputs), improve agricultural growth, and boost the agricultural sector, but farmers were not able to adopt these adequately. To solve the problem, the Foodgrains Prices Committee (1964) recommended that the Government of India institute an agricultural subsidies scheme, and the central, state, and local governments began subsidizing inputs (fertilizers, electricity, irrigation, etc). Input subsidies have been increasing continually since then (Figure 1). The curve has been concave after 2014, but the decline is not as per expectations, and it still remains high. The gap between the mounting input subsidies and public investment has widened since 2005. Public investment remained constant up to 2002, despite some fluctuations, and improved slightly afterwards. But, since 1994 the increase in public investment has been less than the subsidies, and the gap widened after 2005.

In the 2015 financial year, the subsidy on fertilizers, INR 71,076 crore, was the highest of all input subsidies (Gulati et al. 2018), the water subsidy through irrigation and power was INR 37,246 crore, but public investment in Indian agriculture was only INR 42,313 crore. Agricultural subsidies increased—eating into government resources and raising the revenue deficit—and led public sector agricultural investment to fall (Gulati and Sharma 1995; Gulati and Bathla 2001; Chand and Kumar 2004; Singh 2014; Akber 2020).But input subsidies do not raise agricultural productivity (Akber and Paltasingh 2019 a), and these are losing their share in revenue (Vyas 2001) and have become unproductive and financially unsustainable (Fan et al. 2008).

The agricultural farm acts of 2020 ignore the issue of public financing of Indian agriculture.To what extent do public financing patterns help Indian agriculture? How effective are subsidies compared to public

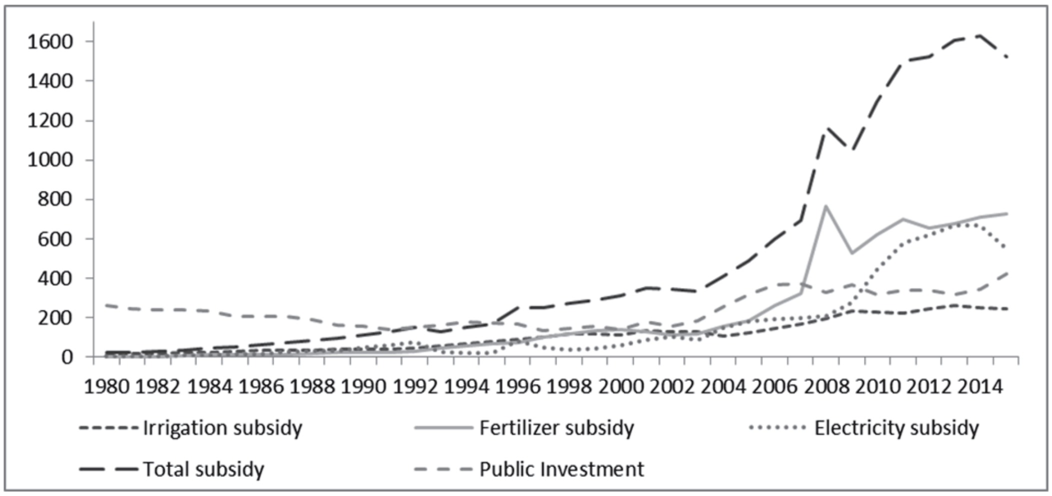

Figure 1 Input subsidies and investment in Indian agriculture in billion Rupees (2011-12 prices)
Source: Ministry of Agriculture, Government of India, CSO.

investment in improving agricultural production? This paper attempts an answer by analyzing the data at the national and subnational level using the auto-regressive distributive lag (ARDL) models. The results could have strong policy implications.

Materials and methods

Data and variables

This study is based on time series data for the 1980–2015 period (36 years) at the national level and on panel data for the 1990–2017 period (26 years) for 17 major agricultural states at the subnational level. The regression model incorporates public investment (gross capital formation in agriculture (GCFA) as per the Central Statistical Organisation (CSO), intensity of public canals, power consumption, and expenditure on agricultural research) and input subsidies, alongwith other explanatory variables (such as institutional credit, agricultural terms of trade, area under HYV seeds, cropping intensity, and weather index).

The data on the GCFA is compiled from various issues of the National Account Statistics (NAS). The data on canal intensity, power consumption, the area under HYV seeds, and cropping intensity is compiled from *Agricultural Statistics at Glance* pertaining to different years. The investment in research and education data is compiled from the Government of India. The agricultural terms of trade (gross barter terms of trade) are taken from the NAS of the CSO as the ratio of agricultural GDP deflator to non-agricultural GDP deflator.

The data on subsidies is compiled from the Ministry of Agriculture and Farmers' Welfare, Government of India; Gulati et al. (2018); and Indiastat.com. The wholesale price index (WPI) is used to deflate the data and to convert it into constant series (2011–12 prices). The credit data is compiled from the Reserve Bank of India (RBI); the weather data from the Ministry of Statistics and Programme Implementation, Government of India; and the state-wise data from the RBI. Table A1 in the Appendix lists the descriptive statistics and the definitions of all the variables.

Empirical model specification

Following Akber and Paltasingh (2019b) and Gulati and Bathla (2001), we develop two baseline models: the cumulative public investment as per CSO (Model 1) and the major components of public investment in terms of government canals and rural electrification (Model 2). Power consumption is used as a proxy for cumulative investment by public authority for rural electrification. Gulati and Bathla (2001) argue that the yearly supply of water and power is in fact the accumulation of years of public investment in the canals and power sector. The two baseline models are

$$lnPR_t = \alpha_0 + \alpha_1 lnI_{gt} + \alpha_2 lnSBSDY_t + \alpha_3 lnTOT_t + \alpha_4 lnCRDT_t + \alpha_5 lnHYV_t + \alpha_6\, lnWI_t + \alpha_7 lnPR_{t-1} + \varepsilon_{1t} \quad \ldots (1)$$

$lnPR_t = \alpha_0 + \alpha_1 lnCNL_t + \alpha_2 lnPC_t + \alpha_3 lnRE_t + \alpha_4 lnSBSDY_t + \alpha_5 lnTOT_t + \alpha_6 \, lnCRDT_t + \alpha_7 lnCRI_t + \alpha_8 lnWI_t + \alpha_9 lnPR_{t-1} + \varepsilon_{1t}$ …(2)

where, '*ln*' represents natural logarithmic form, PR_t is agricultural production, I_{gt} is cumulative public investment, CNL_t is canal intensity (the ratio of net canal irrigated area to net sown area, as defined by the CSO within the Indian System of National Accounts (ISNA), PC_t represents power consumption, *RE* denotes the expenditure on agricultural research, *SBSDY* is input subsidy, TOT_t is terms of trade, $CRDT_t$ is credit, HYV_t is area under HYV seeds, and CRI_t is cropping intensity. WI_t is the weather index, defined—following Paltasingh et al. (2012) and Paltasingh and Goyari (2018)—as $WI = {}^{R_t}/{1.07^{T_t}}$ where R_t is average seasonal rainfall and T is average temperature of the corresponding time period, and $\alpha's$ are the coefficients.

ARDL specification

To estimate the effectiveness of subsidies and investment in enhancing agricultural production, we use the ARDL bound test approach proposed by Pesaran et al. (2001). In the bound test approach, the long- and short-run estimates or elasticities can be estimated simultaneously and endogeneity is controlled for. The approach can be used whether the variables are stationary at 1(0) or 1(1) or if there is a mixture of stationarity of data. The error correction mechanism integrates the short-run elasticities with the long-run equilibrium without losing the information (Akber and Paltasingh 2020; Sehrawat and Giri 2018). For lag selection, we use the Akaike information criteria and Hanan-Quinn criteria. The approach involves estimating the unconditional error correction version (UECM) of the ARDL model:

$$y_t = \sum_{i=1}^{p} \emptyset_j \, y_{t-i} + \sum_{i=0}^{q} \vartheta_j \, x_{t-i} + \delta_1 y_{t-1} + \delta_2 x_{t-1} + \varepsilon_t \quad \text{…(3)}$$

where, y_{it} is the dependent variable (agricultural production), x_{it} is $(K \times 1)$ vector of explanatory variables (public investment, subsidies, TOT, credit, and so on), and δ_1 and δ_2 are the long-run parameters while $\emptyset_i$ and ϑ_i are the short-run parameters.

The residual term (ε_t) is assumed to be normally distributed. The null hypothesis of no cointegration among the variables in the equation is H_0: $\delta_1 = \delta_2 = 0$ against the alternative hypothesis H_1: $\delta_1 \neq \delta_2 \neq 0$ which implies the cointegration among variables.

If the calculated F-test statistic is more than the respective upper critical values, we reject H_0 of no cointegration and confirm the existence of a long-term relationship between the variables. If the calculated F-statistic is less than the respective lower bound critical values, we do not reject the H_0 and we conclude that there is no cointegration among variables. If the calculated F-statistic falls in-between the lower bound and the upper bound, the result is inconclusive.

The next step is to obtain the short-run dynamic parameters by estimating an error correction model with the long-run estimates. The short-run model can be estimated by

$$\Delta y_t = \beta_1 + \sum_{i=1}^{p} \emptyset_j \, \Delta y_{t-i} + \sum_{i=0}^{q} \vartheta_j \, \Delta x_{t-i} + \varphi ECM_{t-1} + \epsilon_t \quad \text{…(4)}$$

where $\emptyset_i$ and ϑ_i are the short-run dynamic parameters to equilibrium, and represent the short-run multiplier with respect to all the relevant variables. The error correction term ECM_{t-1} indicates the speed of adjustment back to the long-run equilibrium after a short-run shock.

Panel ARDL specification

To confirm the impact at the subnational level, we apply the panel ARDL model or the pooled mean group (PMG) estimator. The ARDL dynamic heterogeneous panel regression can be written by using the ARDL (p, q) approach where p is the lag of dependent variable and q is the lags of independent variables. The time period t = 1,2,3…,T, and groups i=1, 2, 3,..., N (Pesaran et al. 1999). The panel ARDL model can be written as:

$$y_{it} = \sum_{i=1}^{p} \emptyset_{ij} y_{i,t-j} + \sum_{i=0}^{q} \vartheta_{ij} \, x_{i,t-j} + \mu_i + \varepsilon_{it} \quad \text{…(5)}$$

where, y_{it} is the dependent variable (farm production), x_{it} is (vector of explanatory variables for group 'i', ϑ_{ji} are the $(K \times 1)$ coefficient vectors, $\emptyset_{ji}$ are the coefficients of the lagged dependent variable, μ_i are the unit-specific fixed effects, p and q are the optimal lag orders, and ε_{it} is the error term.

The short-run estimates can be written as:

$$\Delta y_{it} = \theta_i(y_{i,t-1} - \theta'_t x_{i,t}) + \sum_{j=1}^{p-1} \emptyset^*_{ij} y_{i,t-1} + \sum_{j=0}^{q-1} \vartheta^*_{ij} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it}$$

where

$\theta_i = -(1 - \sum_{j=1}^{p} \emptyset_{ij})$, $\emptyset_i = \sum_{j=0}^{q} \vartheta_{ij} / (1 - \sum_k \emptyset_{ik})$, $\emptyset^*_{ij} = -\sum_{m=j+1}^{p} \emptyset_{im}$; $j = 1, 2, \dots P-1,$

and $\emptyset^*_{ij} = -\sum_{m=j+1}^{q} \vartheta_{im}$; $j = 1, 2, \dots, q-1.$

Here, θ_i is the error-correcting speed of adjustment term for each unit. If $\theta_i = 0$, there is no evidence for a long-run relationship. The value of θ_i is expected to be highly significant and negative under the assumption that the variables show a return to long-run equilibrium.

Pesaran et al. (1997, 1999) propose the 'pooled mean group' (PMG) estimator, which combines both average and pooling the residuals. The given test incorporates the intercept, short-run coefficients, and different error variances across the groups. However, it holds the long-run coefficients to be equal across the groups like fixed effect estimators (Behera and Mishra 2019). The panel ARDL can be applied when the variables follow the integration of I(0), I(1), or when there is a mixture of both.

Results and discussion

Results of unit root test and optimal lag selection

We perform the unit root test with trend+intercept by the augmented Dickey–Fuller and Phillips–Perron tests. The results show that, except agricultural production, all the variables are non-stationary at level 1(0) (Table A2 in the Appendix). Therefore, we go for first difference 1(1) where all the variables have been found stationary. The mixture of stationarity of variables makes it appropriate to apply the ARDL to find the short- and long-run elasticities. Tables A3 and A4 in the Appendix present the result of optimal lag selection. The results of the Akaike information criteria (AIC), and Hannan–Quinn (HQ) information criteria, and Schwarz criteria (SC) indicate, respectively, two and one significant lags in the two model specifications respectively.

Long- and short-run elasticities at the national level

The results of the long-run elasticity of the ARDL model show that public sector investment in Indian agriculture positively and significantly impacts production (Table 1). The elasticity, 0.17, suggests that a 1% rise in public investment increases production by 0.17%; the coefficient is statistically significant at a 5% level of significance. Subsidies do not show any significant impact.

Farm production is significantly impacted by explanatory variables like institutional credit flow to agriculture, area under HYV seeds, etc. The elasticities—0.017 (institutional credit to agriculture) and 0.20 (area under HYV seeds)—are statistically significant at a 5% level of significance. The weather index negatively impacts farm production, but agricultural terms do not exert any significant effect.

Model 2 contains public investment as per broad series. The impact is positive and significant. The elasticity of government canal intensity, 0.37, implies that a 1% increase can induce a 0.37% rise in agricultural production; of power consumption, 0.19, implies a 0.19% rise; and of expenditure on agricultural R&D, 0.24, implies that a 1% increase can induce a 0.24% rise in agricultural production. The coefficients are statistically significant at 5% and 1% level of significance.

Subsidies do not show any significant impact in the longrun. This finding is in line with Chand and Kumar (2004), which finds that investment has a more significant impact on output than subsidies in the longrun. This finding is supported also by Akber and Paltasingh (2019 a), which finds that subsidies have no significant or positive impact on agricultural productivity.

In Model 2, agricultural production is positively and significantly impacted by credit, but not by cropping intensity, terms of trade, or the weather index. The values of the F-statistic are, respectively, 7.89 and 4.18 in both specifications—higher than the critical value of the lower bound and the upper bound at a 1% level of significance—confirm the existence of long-run cointegration in both the models.

Table 2 represents the result of short-run elasticities. In Model 1, the estimated short-run elasticity of lagged agricultural output is 0.12, but no significant impact is

Table 1 ARDL long"run elasticities of production for all–India level

Variable	Specification 1			Specification 2		
	Coefficient	Standard error	Probability	Coefficient	Standard error	Probability
Ln(IG)	0.166**	0.055	0.015			
Ln(CNL)				0.368**	0.169	0.041
Ln(PC)				0.187***	0.059	0.005
Ln(RE)				0.235**	0.016	0.047
Ln(SBSD)	0.115	0.074	0.153	–0.062	0.044	0.176
Ln(TOT)	0.43	0.403	0.625	–0.066	0.140	0.642
Ln(CRDT)	0.017**	0.094	0.010	0.066***	0.020	0.003
Ln(HYV)	0.200**	0.072	0.021			
Ln(CRI)				0.386	0.430	0.380
Ln(WI)	–0.141**	0.063	0.054	–0.002	0.017	0.912
Const.	–5.931	4.568	0.226	0.974***	0.388	0.021
Bounds test statistic	7.886			4.180		
Critical values for bounds test						
Level of significance		Lower bound 1(0)		Upper bound 1(1)		
10%		1.88		2.99		
5%		2.14		3.30		
1%		2.65		3.97		

Note: The asterisks (***), and (**) indicate significance at, respectively, 1% and 5% probability level.

Table 2 ARDL short–run elasticities of production for all–India level

Variable	Specification 1			Specification 2		
	Coefficient	Standard error	Probability	Coefficient	Standard error	Probability
ΔLnPR(1)	0.115	0.173	0.520	–0.137	0.168	0.423
ΔLn(IG)	0.062**	0.022	0.021			
ΔLn(CNL)				0.205**	0.082	0.021
ΔLn(PC)				0.163**	0.057	0.010
ΔLn(RE)				0.030*	0.017	0.082
ΔLn(SBSD)	0.133*	0.062	0.061	–0.054	0.036	0.155
ΔLn(TOT)	1.064***	0.274	0.002	–0.058	0.126	0.651
ΔLn(CRDT)	0.141**	0.048	0.023	0.057***	0.019	0.000
ΔLn(HYV)	0.074**	0.033	0.050			
ΔLn(CRI)			0.337	0.368	0.370	
ΔLn(WI)	0.076**	0.020	0.018	–0.002	0.015	0.912
ECM(–1)	–0.885***	0.173	0.000	–0.873***	0.218	0.000
Adjusted R-squared	0.92			0.93		
D–W Statistic	2.36			2.40		

Note: The asterisks ***, **, * indicate significance at 1%, 5%, and 10% probability level.

observed. With the coefficient of public investment, agricultural investment (public sector) has a positive and significant impact on output in the shortrun. The elasticity, 0.06, is statistically significant at a 1% probability level. Subsidies show a positive and significant impact, but the coefficient, 0.133, is weakly significant at a 10% level of significance. The terms of trade, institutional credit, area under HYV seeds, and the weather index have a positive and significant impact on agricultural output in the shortrun.

In Model 2, public investment exhibits a positive and significant impact on agricultural production; the elasticity is estimated at 0.205 for government canals, 0.163 for power consumption, and 0.030 for investment in agricultural R&D. Subsidies show a positive impact, 0.018, but the elasticity is not statistically significant. Farm production is positively and significantly impacted by institutional credit, but not by the terms of trade, cropping intensity, or the weather index.

The values of the lagged error correction mechanism are –0.885 and –0.873 and these are statistically highly significant at a 1% level of significance. The value of R-squared is, respectively, 0.92 and 0.93. We conclude that public investment is more effective in augmenting farm production than input subsidies in both the long and shortrun. Institutional credit and area under HYV seeds positively influence agricultural output in both the short and longrun.

We conduct several diagnostic tests—normality, serial correlation and heteroscedasticity, and the Ramsey reset test (Table A5 in the Appendix). The results show that this ARDL model passes all the diagnostic tests: there is no serial correlation, functional misspecification, or non-normal error. We use the CUSUM and cumulative CUSUM of the square test (CUSUMQ)to check the consistency in parameters.

Stability test

We perform the CUSUM and CSUSMQ tests to check the stability of the model. The estimated line is within the boundaries of critical lines at 5% significance; therefore, the model is stable (Figures A1–A4 in the Appendix).

Zone-wise and state-level analysis

Now, we compare the effectiveness of subsidies and investment in augmenting farm production at the subnational level. We consider 17 major states. We incorporate, along with public investment and subsidies, explanatory variables like agricultural terms of trade, institutional credit to agriculture, and cropping intensity. We calculate the public investment data by adding the capital expenditure on different variables like soil and water consumption, plantations, agricultural research and education, and so on.

We compile the data on subsidies from various issues of the RBI Handbook and annual reports of state electricity boards, and we calculate the subsidy data by adding the subsidy on irrigation, power, and fertilizer. We perform the Pesaran cross-section dependence test. The results confirm the existence of cross-section dependence across the states (Table A6 in the Appendix).

Unit root and lag selection tests

We use unit root tests—Levin–Lin–Chu and Im–Pesaran–Shin tests with intercept and intercept+trend to check the stationarity of the data set. The results confirm the presence of a mixture of stationarity of variables (Tables A7 and A8 in the Appendix). Some variables like production, subsidy, and terms of trade are stationary at level 1(0). The variables like public investment, institutional credit, and cropping intensity are stationary at first difference 1(1).

Next, we apply the panel ARDL model to find out the short- and long-run elasticities. Table A9 in the Appendix shows the result of the optimal lag selection. Two significant lags are indicated by the results of the Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan–Quinn information (HQ) criterion. Therefore, we use two lags in our model.

Panel cointegration

We use a cointegration test (Pedroni 2004) to check the existence of cointegration between the variables (Table A10 in the Appendix). The null hypothesis of no cointegration is rejected by five (of seven) tests—panel rho-statistic, panel PP-statistic, panel ADF-statistic, group PP statistic, and group ADFstatistic.

Long- and short-run elasticities at zone level

The results of the long-run elasticities of the panel ARDL model for various zones show that public

Table 3 Panel–ARDL long–run elasticities of production at zone level

Variable	Coefficient	Standard error	Probability
LnIG	0.130***	0.029	0.00
LnSBSD	0.026	0.085	0.75
LnTOT	–0.037	0.095	0.69
LnCRDT	–0.093**	0.040	0.02
LnCRI	2.061***	0.116	0.00

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5%, and 10% respectively.

investment has a positive and significant impact on agricultural production (Table 3). The elasticity is 0.130, suggesting that a 1% rise in public investment increases agricultural production at 0.130%. The coefficient is statistically significant at a 1% level of significance, but subsidies or the terms of trade do not show any significant impact. Institutional credit shows a negative impact (–0.093), and cropping intensity a positive impact. Public investment had a positive and significant impact in the north, south, and west zones and subsidies had a negative impact in the south and east zones (Table 4). Clearly, public investment positively and significantly impacts agricultural production in the longrun.

Tables 5 and 6 represent the results of the short-run estimates of the panel ARDL model at the state and zone level. The current level of agricultural production is negatively affected by the previous level of agricultural production. The elasticity of the lagged value of production is –0.375. The coefficient is significant at a 1% level of significance. The elasticity of public investment (0.015) and institutional credit

Table 5 Panel–ARDL short–run elasticities of production at zone level

Variable	Coefficient	Standard error	Probability
Δ (PR(–1))	–0.375***	0.057	0.00
Δ (IG)	0.15*	0.08	0.07
Δ (SBSD)	0.47**	0.21	0.04
Δ (TOT)	–0.021	0.027	0.45
Δ (CRDT)	0.11	0.18	0.54
Δ (CRI)	–0.634*	0.34	0.06
ECM(–1)	–0.57**	0.109	0.03

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively

(0.110) is positive, but only investment has a significant impact. Subsidies have a significant impact. Cropping intensity has a negative and significant impact (–0.634) at a 10% level of significance. The value of lagged error correction mechanization is –0.57 at a 5% level of significance.

The short-run estimates at the zone level show that both public investment and subsidies enhance production in the short run, but the elasticity of subsidies is larger. In the short run, subsidies have a stronger effect than investment on agricultural production in nine major agricultural states, and public investment is effective in eight (Table 7). This finding supports the argument that subsidies are more effective than public investment in the shortrun. But subsidies have been found ineffective in the longrun, and public investment has a positive and significant impact in the short and longrun at the aggregate and state level. Therefore, public investment is effective than subsidies in the short and longrun, and there may be reason to

Table 4 Panel–ARDL long–run elasticities of production individual zones

Variable	North Zone			South Zone			East Zone			West Zone		
	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.	Coeff.	Std. error	Prob.
LnIG	0.04***	0.01	0.00	0.15***	0.02	0.00	0.11	0.01	0.63	0.09**	0.03	0.01
LnSBSD	0.012	0.04	0.87	–0.21***	0.05	0.00	–0.07**	0.03	0.02	0.023	0.05	0.95
LnTOT	0.031	0.03	0.26	0.26***	0.08	0.00	0.021	0.03	0.90	0.014	0.08	0.95
LnCRDT	–0.051	0.09	0.58	0.03	0.03	0.45	0.13***	0.03	0.020	0.10***	0.03	0.00
Ln CRI	0.281**	0.14	0.04	1.95***	0.55	0.00	0.013	0.11	0.90	0.49**	0.21	0.03

Note: The asterisks (***), (**), and (*) indicate significance at 1%, 5%, and 10% respectively.

Table 6 Panel–ARDL short–run elasticities of production individual zones

Variable	North Zone Coeff.	North Zone Std. error	North Zone Prob.	South Zone Coeff.	South Zone Std. error	South Zone Prob.	East Zone Coeff.	East Zone Std. error	East Zone Prob.	West Zone Coeff.	West Zone Std. error	West Zone Prob.
ΔLn(PR(–1))	–0.34***	0.08	0.00	–0.15	0.21	0.46	–0.49***	0.1	0.00	–0.49***	0.1	0.00
ΔLn(IG)	0.11**	0.03	0.03	0.11*	0.06	0.07	0.021*	0.01	0.10	0.15***	0.01	0.00
ΔLn(SBSD)	0.13**	0.04	0.02	0.12*	0.03	0.06	0.09**	0.02	0.04	0.02	0.06	0.79
ΔLn(TOT)	–0.13	0.14	0.34	–0.03	0.02	0.15	0.06	0.02	0.89	0.11	0.02	0.89
ΔLn(CRDT)	0.36	0.27	0.18	0.09	0.61	0.88	0.13	0.16	0.43	0.13	0.16	0.43
ΔLn(CRI)	–0.38**	0.17	0.03	1.99	1.43	0.17	–0.67	0.49	0.17	–0.67	0.49	0.17
ECM(–1)	–0.33***	0.14	0.00	–0.66***	0.39	0.00	–0.49	0.19	0.00	–0.49***	0.19	0.00

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

Table 7 Panel–ARDL short–run elasticities of production at individual states

Andhra Pradesh				Assam			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.348***	0.026	0.000	–Ln(PR)	–0.385***	0.018	0.000
ΔLn(IG)	–0.003	0.002	0.207	–Ln(IG)	0.028***	0.000	0.000
ΔLn(SBSD)	–0.078*	0.026	0.060	–Ln(SBSDY)	0.048***	0.002	0.000
ΔLn(TOT)	0.020**	0.003	0.010	–Ln(TOT)	1.009**	0.000	0.010
ΔLn(CRDT)	0.251**	0.085	0.050	–Ln(CRDT)	0.200***	0.004	0.000
ΔLn(CRI)	–4.919	3.682	0.273	–Ln(CRI)	0.000***	0.050	0.000
ECM(–1)	–0.551***	0.033	0.000	ECM(–1)	–0.008***	7.810	0.000
Bihar				**Gujarat**			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.618***	0.024	0.000	–Ln(PR)	–0.540***	0.030	0.000
ΔLn(IG)	–0.032***	0.000	0.000	–Ln(IG)	0.044***	0.003	0.000
ΔLn(SBSD)	–0.246***	0.012	0.000	–Ln(SBSD)	0.073**	0.016	0.010
ΔLn(TOT)	–0.009***	0.000	0.000	–Ln(TOT)	–0.001	0.004	0.838
ΔLn(CRDT)	0.158	0.282	0.180	–Ln(CRDT)	0.064	0.032	0.139
ΔLn(CRI)	–1.014**	0.092	0.030	–Ln(CRI)	0.023	–0.001	0.966
ECM(–1)	–0.143***	0.012	0.000	ECM(–1)	–0.022***	0.504	0.000
Haryana				**Himachal Pradesh**			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.231***	0.032	0.000	–Ln(PR)	–0.591***	0.028	0.000
ΔLn(IG)	0.003***	0.000	0.000	–Ln(IG)	–0.061***	0.001	0.000
ΔLn(SBSD)	–0.177***	0.008	0.000	–Ln(SBSD)	0.126***	0.017	0.000
ΔLn(TOT)	–0.028***	0.001	0.000	–Ln(TOT)	0.004***	0.000	0.000
ΔLn(CRDT)	0.021	0.053	0.716	–Ln(CRDT)	–0.128***	0.020	0.000
ΔLn(CRI)	–0.104***	0.021	0.010	–Ln(CRI)	0.002	0.057	0.980
ECM(–1)	–0.037***	0.003	0.000	ECM(–1)	–0.14***	0.000	0.000
Jammu & Kashmir				**Karnataka**			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.498***	0.041	0.000	–Ln(PR)	–0.326***	0.048	0.000
DLn(IG)	–0.015***	0.001	0.000	–Ln(IG)	0.028***	0.006	0.010
DLn(SBSD)	0.135***	0.012	0.000	–Ln(SBSD)	–0.246**	0.006	0.010

Contd...

DLn(TOT)	0.005***	0.000	0.000	–Ln(TOT)	–0.003	0.007	0.717
ΔLn(CRDT)	0.054**	0.011	0.010	–Ln(CRDT)	0.681	0.343	0.141
ΔLn(CRI)	–0.483	2.316	0.840	–Ln(CRI)	0.454	1.324	0.754
ECM(–1)	0.005***	0.000	0.000	ECM(–1)	–0.134**	0.034	0.020

Kerala				Madhya Pradesh			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.429***	0.024	0.000	–Ln(PR)	–0.337***	0.045	0.000
ΔLn(IG)	0.094***	0.003	0.000	–Ln(IG)	–0.016***	0.001	0.000
ΔLn(SBSD)	0.223***	0.018	0.000	–Ln(SBSD)	0.043***	0.006	0.000
ΔLn(TOT)	0.020***	0.002	0.000	–Ln(TOT)	0.042***	0.002	0.000
ΔLn(CRDT)	–0.847***	0.136	0.000	–Ln(CRDT)	0.196*	0.042	0.070
ΔLn(CRI)	0.336	0.323	0.370	–Ln(CRI)	–0.644**	0.234	0.010
ECM(–1)	–0.024***	0.001	0.000	ECM(–1)	–0.070**	0.016	0.020

Maharashtra				Odisha			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.221***	0.020	0.000	–Ln(PR)	–0.508***	0.034	0.000
ΔLn(IG)	0.119***	0.004	0.000	–Ln(IG)	–0.019***	0.012	0.000
ΔLn(SBSD)	–0.695***	0.068	0.000	–Ln(SBSD)	–0.096	0.004	0.214
ΔLn(TOT)	–0.117*	0.041	0.060	–Ln(TOT)	0.008**	0.003	0.057
ΔLn(CRDT)	1.888***	0.224	0.000	–Ln(CRDT)	–0.165	0.135	0.309
ΔLn(CRI)	–1.358**	0.458	0.050	–Ln(CRI)	–0.040	0.212	0.862
ECM(–1)	–0.700***	0.030	0.000	ECM(–1)	–0.012***	0.001	0.000

Punjab				Rajasthan			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.323***	0.028	0.000	–Ln(PR)	–0.577***	0.015	0.000
ΔLn(IG)	0.039***	0.000	0.000	–Ln(IG)	0.027***	0.001	0.000
ΔLn(SBSD)	–0.011***	0.002	0.000	–Ln(SBSD)	0.105***	0.014	0.000
ΔLn(TOT)	0.025**	0.000	0.010	–Ln(TOT)	0.060***	0.003	0.000
ΔLn(CRDT)	0.066***	0.006	0.000	–Ln(CRDT)	–0.240***	0.023	0.000
ΔLn(CRI)	–0.005	0.082	0.952	–Ln(CRI)	1.164	0.816	0.249
ECM(–1)	–0.010***	0.001	0.000	ECM(–1)	–0.161***	0.009	0.000

Tamil Nadu				Uttar Pradesh			
Variable	Coefficient	Standard error	Probability	Variable	Coefficient	Standard error	Probability
ΔLn(PR)	0.394***	0.045	0.000	–Ln(PR)	–0.341***	0.022	0.000
ΔLn(IG)	–0.045***	0.006	0.000	–Ln(IG)	0.115***	0.001	0.000
ΔLn(SBSD)	–0.112**	0.025	0.020	–Ln(SBSD)	0.041	0.037	0.343
ΔLn(TOT)	0.066*	0.039	0.090	–Ln(TOT)	–0.431***	0.068	0.000
ΔLn(CRDT)	–1.552**	0.487	0.040	–Ln(CRDT)	1.269**	0.403	0.050
ΔLn(CRI)	–2.344	0.968	0.194	–Ln(CRI)	–0.491	1.238	0.718
ECM(–1)	–0.790***	0.122	0.000	ECM(–1)	–0.201***	0.011	0.000

West Bengal			
Variable	Coefficient	Standard error	Probability
ΔLn(PR)	–0.501***	0.028	0.000
ΔLn(IG)	–0.002*	0.001	0.060
ΔLn(SBSD)	0.070***	0.010	0.000
ΔLn(TOT)	–0.005	0.007	0.565
ΔLn(CRDT)	–0.049**	0.013	0.030
ΔLn(CRI)	–1.462	1.245	0.325
ECM(–1)	–0.032***	0.0008	0.000

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

divert resources from subsidies to investment in infrastructure and irrigation, institutional extension services and area under HYV seeds.

Conclusions

This study empirically examines the effectiveness of input subsidies and public investment in augmenting farm production in Indian agriculture. The exercise is undertaken at the national level (for the 1980–2015 period) and at the subnational level (1990–2015) for 17 major agricultural states. After checking the stationarity of the data, the study adopts the ARDL model.

The trend analysis shows that input subsidies have increased continually over the years while public sector agricultural investment has fallen. Agricultural production is found to be highly and significantly affected by public investment in the short and longrun, but subsidies have been found to be effective in the short-run only. The results of the panel ARDL model confirm the aggregate-level results: public investment is more effective than subsidies, in that it is a stimulating factor, in both the long and shortrun but, in the shortrun, subsidies have a little edge over public investment.

The decline in public investment poses a threat to the sustainable growth of Indian agriculture. The policy implications of this study are that the decline must be arrested immediately, the provision of input subsidies should be rationalized by weighing their welfare effects against their cost to the exchequer. If an input subsidy is found ineffective, the resources should be diverted to public investment. However, research is needed to establish whether subsidies should be abolished.

References

Akber, N, and K R Paltasingh. 2019a. Investment, subsidy, and productivity in Indian agriculture: an empirical analysis. *Agricultural Economics Research Review,* 32(conference number):13–25. http://dx.doi.org/10.5958/0974–0279.2019.00014.4

Akber, N, and K R Paltasingh. 2019b. Is public investment complementary to private investment in Indian agriculture? evidence from NARDL application. *Agricultural Economics*, 50(5): 643–655. DOI: 10.1111/agec.12515.

Akber, N. 2020. Does input subsidy discourage public investment in Indian agriculture? evidence from ARDL applications. *Journal of Public Affairs*, e 2337. https://doi.org/10.1002/pa.2337

Akber, N, and K R Paltasingh. 2020. Market arrival of apples under risk in Jammu & Kashmir, India: evidence from an ARDL application. *Journal of Agribusiness in Developing and Emerging Economies*, 10(2):177–189. https://doi.org/10.1108/JADEE-03–2019–0033.

Behera, J, and A K Mishra, 2020. Renewable and non-renewable energy consumption and economic growth in G7 countries: evidence from panel autoregressive distributed lag P-ARDL model. *International Economics and Economic Policy,* 17(1):241–258. https://doi.org/10.1007/s10368–019–00446–1

Chand, R, and Kumar, P. 2004. Determinants of capital formation and agriculture growth: some new explorations. *Economic & Political Weekly,* 39(52):5611–5616. https://www.jstor.org/stable/4415977.

Dickey, D A, and Fuller, W A. 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74(366): 427–431. https://www.jstor.org/stable/2286348.

Dickey, D A, and Fuller, W A. 1981. Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica,* 49(4): 1057–1072. https://www.jstor.org/stable/1912517.

Fan, S, Gulati, A, and Thorat, S. 2008. Investment, subsidies, and pro poor growth in rural India. *Agricultural Economics,* 39(2): 163–170. https://doi/abs/10.1111/j.1574-0862.2008.00328.x

Foodgrain Prices Committee 1964, Report of the Foodgrain Prices Committee. New Delhi: Government of India.

Gulati, A, and Bathla, S. 2001. Capital formation in Indian agriculture: re-visiting the debate. *Economic & Political Weekly,* 36(20): 1697–1708. https://www.jstor.org/stable/4410633.

Gulati, A, and Sharma, A. 1995. Subsidy syndrome in Indian agriculture. *Economic &Political Weekly,* 30(39): A93-A102. https://www.jstor.org/stable/4403271.

Gulati, A, Terway, P, and Banerjee, P. 2018. Trends in Input Subsidies and Investments in Indian Agriculture, In: Ashok Gulati, M. Ferroni, and Yuan Zhou(Eds). *Supporting Indian Farms: The Smart Way*, Academic Foundation, New Delhi.

Im, K S, Pesaran, M H, and Shin, Y. 2003. Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115(1): 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7.

Jarque, C, and A Bera. 1987. A test for normality of observations and regression residuals. *International Statistical Review,* 55: 163–172. https://www.jstor.org/stable/1403192.

Levin, A, Lin, C F, and Chu, C S J. 2002. Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, 108(1): 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7.

National Account Statistics of Central Statistics Organization CSO – Various years. Back series 2011 and 2019.

Paltasingh, K R, and Goyari, P. 2018. Statistical modeling of crop weather relationship in India: a survey of evolutionary trend of methodologies. *Asian Journal of Agriculture and Development*, 15(1):41–60. https://ageconsearch.umn.edu/record/275688/.

Paltasingh, K R, Goyari, P, and Mishra, R K. 2012. Measuring weather impact on crop yield using aridity index: evidence from Odisha. *Agricultural Economics Research Review*, 25(2): 205–216. http://www.indianjournals.com/ijor.aspx?target=ijor:aerr&volume=25&issue=2&article=003.

Pedroni, P. 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory* 20(3): 597–625. https://doi.org/10.1017/S0266466604203073.

Pesaran, MH, Y Shin, and R P Smith. 1997. Estimating long-run relationships in dynamic heterogeneous panels. DAE Working Papers Amalgamated Series-9721. https://doi.org/10.1016/0304-4076(94)01644-F.

Pesaran, M H, Y Shin, and R P Smith. 1999. Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, 94(446): 621–634. https://doi.org/10.2307/2670182.

Pesaran, M H, Y Shin, and R J Smith. 2001.Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* 16(3): 289–326. https://DOI: 10.1002/jae.

Pesaran, M H. 2004. General diagnostic tests for cross-section dependence in panels. Unpublished manuscript, Faculty of Economics and Politics, University of Cambridge. https://link.springer.com/content/pdf/10.1007/s00181-020-01875-7.pdf.

Phillips, P C, and P Perron. 1988.Testing for a unit root in time series regression. *Biometrika, 75(*2): 335–346. https://doi.org/10.1093/biomet/75.2.335

Ramsey, J B. 1969. Tests for specification errors in classical linear least squares regression analysis. *Journal of the Royal Statistical Society: Series B Methodological*, *31*2, 350–371. https://www.jstor.org/stable/2984219.

Reserve Bank of India (RBI), 2007-19. Database on Indian Economy.

Sehrawat, M, and A K Giri. 2018. The impact of financial development, economic growth, income inequality on poverty: evidence from India. *Empirical Economics,* 55(4): 1585–1602.https://doi.org/10.1007/s00181–017–1321–7

Singh, P. 2014. Declining public investment in Indian agriculture after economic reforms: an interstate analysis. *Journal of Management & Public Policy,* 6(1): 21-33. http://www.indianjournals.com/ijor.aspx?target=ijor:jmpp1&volume=6&issue=1&article=003.

Vyas, V S. 2001. Agriculture: second round of economic reforms. *Economic & Political Weekly,* 36(10): 829–836. https://www.jstor.org/stable/4410372.

Appendix

Table A1 Descriptive statistics and definition of all variables

Variable	Definition	Mean	SD
Production (PR)	Total agricultural production (in million tonnes)	156.24	35.6
Investment(IG)	Public investment by government (in crore INR)	23,631	8,401
Canal intensity (CNI)	Ratio of area under government canals and net sown area	116.41	5.98
Electricity consumption (PC)	Power consumed for agriculture (in giga watt hour =106xkilowatt)	4,05,383	3,01,926
Research expenditure (RE)	Total expenditure incurred on agricultural research	16,439	14,286
Subsidy (SBSD)	Total subsidies provided (total of subsidies on irrigation, fertilizer, and electricity)	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 crore INR)	1,606	1,825
Area under HYV seeds (HYV)	Area under HYV seeds (in million ha)	61,475	10,509
Cropping intensity (CRI)	Ratio of net sown area to total cropped area (million ha)	132.55	5.292
Weather index (WI)	Weather index ($WI=R_t/1.07^T$)	95.263	86.75

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.

Table A2 Unit root test with trend and intercept

Variables	Augmented Dickey–Fuller (ADF)		Phillips–Perron (PP)	
	Level	1st difference	Level	1st difference
LnPR	–4.120**	—–	–4.120**	—–
LnIG	–2.512	–8.459***	–2.358	–8.459***
LnCNL	–2.404	–7.995***	–2.277	–9.174***
LnPC	–1.793	–6.421***	–1.765	–6.4081***
LnRE	–2.412	–7.917	–2.279	–10.9807
LnSBSD	–1.706	–4.007**	–1.852	–3.983**
Ln TOT	–1.263	–10.408	–1.761	–29.72
LnCRDT	–0.899	–5.381***	–0.978	–5.371***
LnHYV	–3.193	–4.998***	–2.529	–5.079***
LnCRI	–0.795	–10.109***	–0.991	–23.54***
LnWI	–2.972	–7.920***	–2.885	–8.656***

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5%, and 10% respectively.

Table A3 VAR lag selection criteria (for model specification1)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	88.535	NA	0.004	–4.796	–4.481	–4.689
1	91.589	4.669*	0.0043	–4.917	–4.557*	–4.794
2	92.853	1.858	0.0042*	–4.932*	–4.528	–4.794*

Note: The asterisk (*) indicates optimal lag as per the respective test.

Table A4 VAR lag selection criteria (for model specification 2)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	480.004	NA	0.0025	–27.647	–27.198	–27.494
1	762.780	382.579	0.0029	–38.398	–33.460	–36.714
2	957.402	148.828*	0.0031*	–43.964*	–34.537*	–40.749*

Note: The asterisk (*) indicates optimal lag as per the respective test.

Table A5 Diagnostic tests

	Model specification 1		Model specification 2	
Diagnostic Tests	F Stat.	P–value	F Stat.	P–value
Normality (Jarque–Bera) test	2.27	0.321	0.961	0.618
Serial correlation	0.39879	0.5349	2.079234	0.1388
Breusch–Pagan–Godfrey test	0.604942	0.8359	0.306431	0.973
ARCH test	0.450823	0.5074	0.378962	0.5431
Ramsey RESET test	2.982675	0.1156	0.1301	0.111

Source: Authors' estimation.

Table A6 Pesearn CD cross-section dependence test

Variable	Statistic	Probability
PR	12.406***	0.00
PB	10.396***	0.00
SBSD	53.055***	0.00
TOT	27.069***	0.00
CRDT	57.277***	0.00
CRI	18.208***	0.00

Note: The asterisks (***) indicate significance at 1% probability level.

Table A7 Unit root test with intercept

Variables	Levin–Lin–Chu		Im–Pesaran–Shin	
	Level	1st difference	Level	1st difference
LnPR	–2.46***	——	–2.99***	——
LnIG	1.55	9.30***	1.241	12.68***
LnSBSD	–10.98***	——	–9.04***	——
LnTOT	–8.58***	——	7.77***	——
LnCRDT	6.65	2.68***	11.31	–4.92***
Ln CRI	1.16	–7.70***	1.17	–10.2***

Note: The asterisks (***), (**) and (*) indicate significanceat 1%, 5% and 10% respectively.

Table A8 Unit root test with trend and intercept

Variables	Levin–Lin–Chu		Im–Pesaran–Shin	
	Level	1st difference	Level	1st difference
LnPR	–2.53***	–””	3.31***	–””
LnIG	–0.24	–6.36***	–0.64	10.61***
LnSBSD	–11.83***	–””	10.47***	–””
LnTOT	–9.480***	–””	–7.81***	–””
LnCRDT	6.656	–2.68***	11.31	–4.92***
LnCRI	2.047	–4.91***	0.385	–7.55

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

Table A9VAR lag selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	27.26	NA	0.03	–0.44	–0.28	–0.37
1	110.71	154.72	0.00	–2.16	–1.97	–2.08
2	129.76	34.93*	0.00*	–2.53*	–2.32*	–2.45*

Note: The asterisk (*) indicates optimal lag as per the respective test

Table A10 Results of co–integration test (Pedroni 2004)

Various test	Statistics	Probabilities
Panel v statistic	–0.5855	0.7209
Panel rho statistic	–2.3249**	0.01
Panel PP statistic	–10.353***	0
Panel ADF statistic	–2.2886**	0.0111
Group rho statistic	–0.6247	0.2661
Group PP statistic	–12.23***	0
Group ADF statistic	–1.637**	0.0508

Note: The asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.