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Investment, subsidy and productivity in Indian agriculture: an empirical analysis

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Abstract Using time series data, this study compares the effectiveness of public investment with that of subsidies on the total factor productivity (TFP) of Indian agriculture at the national and subnational levels. Our findings show that public investment is more effective than subsidies in raising agricultural productivity in both the short and long run. At the national level, the elasticity of public investment ranges from 0.03 to 0.10 in the long run and from 0.03 to 0.05 in the short run. At the state level, too, we find a positive and significant effect of public investment in the short and long run. But the impact of subsidies is mixed: subsidies negatively impact the TFP of most states (barring a very few developed states). The implication is that for the efficient and sustainable growth of Indian agriculture, the government needs to gradually convert subsidies into investment.

Keywords Investment, subsidies, total factor productivity (TFP), autoregressive distributed lag (ARDL) model, Indian agriculture

JEL classification E22, H20, Q14

1 Introduction

Since independence in 1947, both the central and state governments of India have taken several technological and institutional measures to accelerate agricultural growth; and notable progress has been made as a result in the production and productivity of cereals, oilseeds, cotton, sugarcane, fruits and vegetables (Chand et al. 2012). The improvement in agricultural growth can be attributed to the right kind of investment and incentives (Evenson et al. 1998). However, of late, public investment has declined and input subsidies have increased (Gulati & Sharma 1995; Gulati & Narayanan 2000; Chand & Kumar 2004; Singh 2014), indicating that given the limited financial resources there are trade-offs between public investment and subsidies. Are subsidies more effective than public investment in raising agricultural productivity? Chand & Kumar (2004) show that public investment is more effective than subsidies, and Fan et al. (2008) argue that input subsidies in Indian agriculture have become unproductive and financially and environmentally unsustainable. In recent years, the fiscal burden of subsidies has grown significantly, and the issue has become politically sensitive and debatable, given especially that financial resources are limited.[1] This calls for a need to reconsider the trade-off between investment in agriculture and subsidies.

In this paper, we assess the effectiveness of investment versus subsidies in Indian agriculture. We consider total factor productivity (TFP) as a measure of performance of agriculture – not agricultural productivity – measured as gross domestic product (GDP) per hectare, net domestic product per hectare or total production per hectare. Most previous studies estimate the effectiveness of investment and subsidies through either a trend analysis or a simple ordinary least squares (OLS) regression. Instead, we use the most recent

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[1] Some researchers point out that mostly medium and large farmers in developed states reap the benefits of subsidies, but Singh (2004) and Sharma & Thaker (2010) – examining fertilizer subsidy only – argue that there is a fair degree of inter-class equity in the distribution of fertilizer subsidy despite inter-crop and inter-state disparity.

econometric tool, the autoregressive distributed lag (ARDL) model, to quantify the relative effectiveness of two different types of government expenditures at national and subnational levels.

2 Conceptual framework

Let us assume the following aggregate production function with the technical change

$$Q = A(\mathrm{I,S,TOT,C,HYV,IRI})\, F(\mathrm{L,K,M})e^{\mu} \quad \ldots(1)$$

where Q is output index, I indicates public investment, S subsidies, TOT terms of trade, C institutional credit, HYV area under high yielding varieties and IRI indicates irrigation intensity. $F(.)$ is the well behaved neoclassical production function. K is the physical capital, L is labour, M is quality-adjusted material inputs and $A(.)$ is the technical parameter with μ as error term. Now we can define TFP as

$$\mathrm{TFP} = Q/F(\mathrm{L,K,M}) = A(\mathrm{I,S,TOT,C,HYV,IRI})e^{\mu} \ldots(2)$$

Taking natural logarithm on both sides of equation (2), we get the linear equation as

$$Ln\mathrm{TFP}_t = \beta_1 + \beta_2\, ln\mathrm{I}_t + \beta_3 ln\mathrm{S}_t + \beta_4 ln\mathrm{TOT}_t + \beta_5 ln\mathrm{C}_t + \beta_6 ln\mathrm{HYV}_t + \beta_7 ln\mathrm{IRI}_t + \mu_t \quad \ldots(3)$$

where 't' represents the time period, including the intercept term, the unconditional expected value of the random disturbance term μ_t is zero. All the β_i coefficients indicate the elasticity of TFP with respect to (I,S,TOT,C,HYV,IRI).

3 Materials and methods

3.1 Data and variables

The data set used in this paper is the all-India time series of 36 years (1980-2015) and panel for a period of 26 years for 17 major states. To measure TFP, various inputs like cropping intensity, gross irrigated area, fertilizers, pesticides, mechanization and seeds have been used to construct the total input index. The data on these variables and agricultural production have been compiled from the Ministry of Agriculture and Farmers' Welfare, Government of India and other sources. The data on TOT, institutional credit and cropping intensity have been compiled from the Reserve Bank of India Handbook of Statistics on the Indian Economy. Table 1 defines all the variables and provides the descriptive statistics.

Table 1. Descriptive statistics of all study variables

Variable	Definition	Mean	SD
Cropping intensity (CRI)	Ratio of net sown area to total gross cropped area (area in million ha)	132.55	5.292
Gross irrigated area (GIR)	Total gross irrigated area (in million ha)	73.58	14.54
Seeds (SEED)	Total seeds sold and used (in lakh quintals)	122.69	102.10
Fertilizers (F)	Fertilizer consumed (in lakh tonnes)	18,967	17,045
Pesticides (P)	Total pesticides applied (in thousand tonnes)	53.63	10.47
Mechanization (M)	Total number of tractors and tillers (in number)	258,933	194,282
Agricultural output (O)	Total food grains and non-food grains (in million tonnes)	156.24	35.60
TFP	Index having a range of (0, 1)	0.742	0.021
Investment (I)	Public investment by government (in crore Rs)	23,631	8,401
Canal intensity (CNI)	Ratio of area under government canals to net sown area	116.41	5.980
Electricityconsumption (EC)	Power consumed for agriculture (in gigawatt hour=106x kw)	405,383	301,926
Subsidy (S)	Total subsidies provided (sum total of subsidies on irrigation, fertilizer and electricity in crore Rs)	54,599	78,353
Terms of trade (TOT)	Gross barter terms of trade (ratio of agricultural GDP deflator to non-agricultural GDP deflator)	36.96	14.18
Credit (C)	Institutional credit provided to farmers (in crore Rs)	1,606	1,825
Area under HYV seeds (HYV)	Area under HYV seeds (in million ha)	61,475	10,509
Irrigation intensity (IRI)	Ratio of net irrigated area to net sown area (area in million ha)	135.35	4.908

Source: Data collected from various sources like Central Statistical Office, Government of India; Reserve Bank of India, Handbook on Indian Economy; Indiastat.com and Centre for Monitoring Indian Economy (CMIE), etc.

3.2 Empirical methods

3.2.1 TFP index

Total factor productivity (TFP) may be defined as the ratio of aggregate output to the aggregate input index.[2] Let us assume that $q_{it} = (q_{it}, \dots, q_{jit})^I$ and $x_{it} = (x_{it}, \dots, q_{kit})^I$ are output and input quantity vectors of firm *i* in period *t*. Therefore, TFP can be measured by making the ratio between total output and total index as:

$$\text{TFP} = \frac{Q_{it}}{X_{it}} \qquad \dots(4)$$

Here $Q_{it} = (q_{it})$ is an aggregate output and $X_{it} = (x_{it})$ is an aggregate input, $Q(.)$ and $X(.)$ are the non-negative, non-decreasing and linear homogenous aggregator functions. The associated index numbers that measures the TFP of firm *i* in period *t* relative to the TFP of firm *h* in period *s* (base period) as:

$$\text{TFP}_{hs,it} = \frac{\text{TFP}_{it}}{\text{TFP}_{hs}} = \frac{Q_{it}}{X_{it}} \Big/ \frac{Q_{hs}}{X_{hs}} = Q_{hs,it} \big/ X_{hs,it} \qquad \dots(5)$$

Here, $Q_{hs,it} = Q_{it} / Q_{hs}$ is an output quantity index and $X_{hs,it} = X_{it} / X_{hs}$ is an input quantity index. Therefore, TFP growth can be expressed by measuring the ratio of output growth and input growth. There are different aggregator functions giving rise to TFP indexes. Here, we use the Färe–Primont TFP index developed by O'Donnell (2010, 2011 a), which is the ratio of two indexes defined by Färe and Primont (1995). In the Färe–Primont TFP index, the output index can be written as:

$$Q(q) = D_0(x_0, q, t_0) \qquad \dots(6)$$

And the input index can be written as:

$$X(x) = D_1(x, q_0, t_0) \qquad \dots(7)$$

where x_0, q_0 are the vectors of representative aggregate input and output quantities, t_0 denotes the representative time period, $D_0(.)$ and $D_I(I)$ are representative output and input distance functions. Substituting equations (6) and (7) into equation (5) TFP can be written as

$$\text{TFP}_{hs,it} = \frac{D_o\left(x_o, q_{it}, t_o\right)}{D_o\left(x_o, q_{hs}, t_o\right)} \frac{D_I\left(x_{hs}, q_o, t_o\right)}{D_I\left(x_{it}, q_o, t_o\right)} \qquad \dots(8)$$

The TFP can be estimated through the data envelopment analysis (DEA) methodology in DPIN software[3] because DEA is the underpinned assumption of output and input distance functions representing production technology available in period *t* which takes the form

$$D_0(x_{it}, q_{it}, t) = (q^I_{it}\,\alpha)/(\gamma + x^I_{it}\,\beta) \qquad \dots(9)$$

$$D_1(x_{it}, q_{it}, t) = (x^I_{it}\,\eta)/(q^I_{it}\,\phi - \delta) \qquad \dots(10)$$

The standard output-oriented DEA problem involves selecting the values of unknown parameters in equation (9) to minimize $OTE_{it}^{-1} = D_0(x_{it}, q_{it}, t)^{-1}$ and the input-oriented linear programming problem involves selecting the values of unknown parameters in equation (10) to maximize $ITE_{it} = D_1(x_{it}, q_{it}, t)^{-1}$. The resulting linear programmes are derived as

$$D_0\left(x_{it}, q_{it}, t\right)^{-1} = \text{OTE}_{it}^{-1} = \min_{\alpha,\gamma,\beta}\left\{\gamma + x^I_{it}\beta : \gamma l + X^I\beta \geq Q^I\alpha; q^I_{it}\alpha = 1; \alpha \geq 0; \beta \geq 0\right\} \qquad \dots(11)$$

and

$$D_0\left(x_{it}, q_{it}, t\right)^{-1} = \text{ITE}_{it} = \max_{\phi,\delta,\eta}\left\{q^I_{it}\phi - \delta : Q^I\phi \leq \delta_t + X^I\beta; x^I_{it}\eta = 1; \phi \geq 0; \eta \geq 0\right\} \qquad \dots(12)$$

where Q is a $(J \times M)_t$ matrix of observed outputs, X is a $(K \times M)_t$ matrix of observed inputs and l is an $M_t \times 1$ unit vector and M_t denotes the number of observations used to estimate the frontier in period *t*. DPIN software used these two linear programs to compute the TFP index.[4]

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[2] This section is drawn from O'Donnell (2011a), which discusses the methods and measurement procedures of various TFP indexes lucidly and in detail.

[3] For details, refer O'Donnell (2011a, p. 8). The estimation procedure in DPIN software is also explained in O'Donnell (2011a).

[4] Similarly, the DPIN software uses variants of linear program (LP) formulations to estimate the various other types of TFP measure like Malmquist-hs index, Malmquist-it index and Hicks-Moorsteen index. The details about these LPs can be found in O'Donnell (2011a).

3.2.2 ARDL bound test approach

Two baseline empirical models have been framed to know the effectiveness of investment and subsidies on TFP. Public canal intensity[5] and electricity consumption in agriculture are taken as a proxy for public investment in one model; in the second model, public investment (at 2011-12 prices) as available with the Central Statistical Office (CSO) has been used. The values are in cumulative terms.

The bound test approach of ARDL model has been used to quantify the impact of public investment and subsidies. This method has some advantages: it can be used even if variables are of mix order of stationarity, that is, $I(0)$ or $I(1)$ or both; it also takes care of endogeneity problems in the model and provides both short- and long-run estimates. The ARDL bound test approach takes the following form:

$$\begin{aligned}\Delta \ln \mathrm{TFP}_t &= \beta_1 + \sum_{i=1}^{n}\varnothing_i \Delta \ln TFP_{t-t} + \sum_{i=1}^{n}\mu_i \Delta \ln I_{t-i} + \sum_{i=1}^{n}\vartheta_i \Delta \ln S_{t-i} + \sum_{i=1}^{n}\theta_i \Delta \ln TOT_{t-i}\\ &+\sum_{i=1}^{n}\pi_i \Delta InC_{t-i} + \sum_{i=1}^{n}\rho_i \Delta \ln \mathrm{IRI}_{t-i} + \sum_{i=1}^{n}\tau_i \Delta \ln \mathrm{HYV}_{t-i} + \psi_1 \ln \mathrm{TFP}_{t-1}\\ &+\psi_2 \ln I_{t-1} + \psi_3 \ln S_t + \psi_4 \ln \mathrm{TOT}_{t-1} + \psi_5 \ln C_{t-1} + \psi_6 \ln \mathrm{IRI}_{t-1} + \psi_7 \ln \mathrm{HYV}_{t-1}\\ &+\varepsilon_t\end{aligned} \quad \ldots(13)$$

where Δ is the difference operator, β_1 denotes the constant term, 'ln' stands for natural logarithm as all the variables are transformed into natural logs. ψ_s are the long run parameters and φ_i, μ_i, ϑ_i, θ_i, π_i, ρ_i and τ_i are the short run parameters. ε_t is the residual term which is assumed to be normally distributed. The null hypothesis of no co-integration among the variables in equation is H_0: $\psi_1 = \psi_2 = \psi_3 = \psi_4 = \psi_5 = \psi_6 = \psi_7 = 0$ against the alternative hypothesis H_1: $\psi_1 \neq \psi_2 \neq \psi_3 \neq \psi_4 \neq \psi_5 \neq \psi_6 \neq \psi_7 \neq 0$ which implies co-integration among variables. If the calculated F-test statistic is more than the respective upper critical values, we reject H_0 of no co-integration and ensure the existence of a long-term relationship between variables; but if it is less, we do not reject the H_0, and we conclude that there is no co-integration among variables. However, if the calculated F-statistic falls between the lower and upper bounds, the result is inconclusive.

The next step is to obtain short-run dynamic parameters by estimating an error correction model which can be estimated by using the following equation:

$$\begin{aligned}\Delta In\mathrm{TFP}_t &= \alpha_1 + \sum_{i=1}^{n}\varnothing_i \Delta \ln \mathrm{TFP}_{t-i} + \sum_{i=1}^{n}\mu_i \Delta \ln \mathrm{I}_{t-i} + \sum_{i=1}^{n}\vartheta_i \Delta \ln \mathrm{S}_{t-i} + \sum_{i=1}^{n}\theta_i \Delta In\mathrm{TOT}_{t-i}\\ &+\sum_{i=1}^{n}\pi_i \Delta In\mathrm{C}_{t-i} + \sum_{i=1}^{n}\rho_i \Delta In\mathrm{IRI}_{t-i} + \sum_{i=1}^{n}\tau_i \Delta In\mathrm{HYV}_{t-i} + \varphi \mathrm{ECM}_{t-1} + u_t\end{aligned} \quad \ldots(14)$$

where (ϕ_i, μ_i, ϑ_i, θ_i, π_i, τ_i) are the short-run dynamic parameters to equilibrium and they show the short-run multiplier with respect to all the relevant variables. ECM_{t-1} is the error correction term that indicates the speed of adjustment of TFP to its long-run equilibrium after a short-run shock.

4 Results and discussion

4.1 All-India level

Figure 1 demonstrates the share of both investment

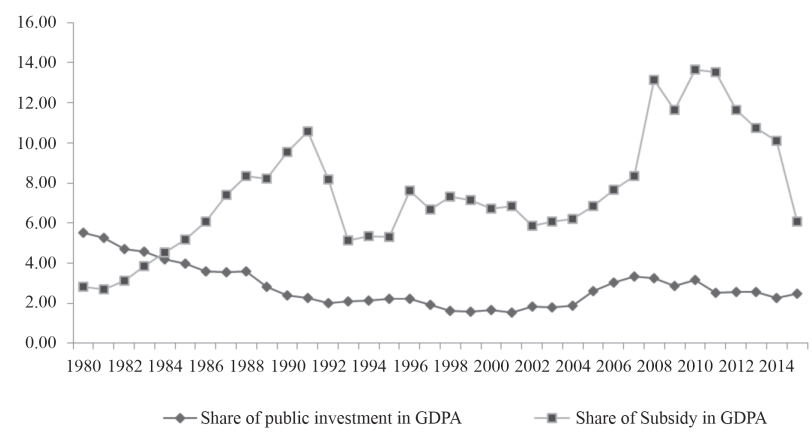

Figure 1. Share of public investment and total subsidy in GDP from agriculture (at 2011-12 prices)

[5] Following Gulati & Bathla (2001) and Akber & Paltasingh (2019), two major components of public investment in the form of public canal intensity and electricity consumption in agriculture have been taken in the analysis along with public investment itself. Gulati & Bathla (2001) argue that the yearly supply of water and power are in fact cumulative investments by government in canal and power sector in the past (Gulati and Bathla 2001; p. 1704).

and total input subsidies as share of GDP from agriculture at 2011-12 prices.

The share of subsidies during the early green revolution period was much less than the share of public investment but, after 1983-84, it exceeded that of investment and rose until 1991, when investment started falling continually. The gap between the two widened subsequently. After the economic reforms in 1991, there was little decline in the subsidy share till 2000-01, despite fluctuations, but it rose again till 2010 and then declined. However, public investment has been mostly on a declining trend over the years. This underlines the requirement to look into the effectiveness of both types of government expenditure boosting agricultural production and productivity quantitatively.

Before analysing the core results, we need to find the stationarity of data series. The Augmented Dickey–Fuller and Phillips–Perron tests have been used. Table 1A in the appendix shows the results of the unit root test (Augmented Dickey–Fuller and Phillips–Perron test) with intercept: the variables are non-stationary at level I(0) but at first difference I(1) they become stationary. Table 2A presents the results of the unit root test with intercept and trend, and there is a mixed result of stationarity. Irrigation intensity is stationary at level I(0) and all the other variables are stationary at first difference I(1). The ARDL model can be used in cases like this, and we use it to check short- and long-run elasticities (Pesaran et al. 2001).

Table 2, which presents results of the bound test approach, confirms the existence of the long-run relationship between variables in both models. The values of the *F*-statistic are 4.65 and 5.35, higher than the critical values of lower bound and upper bound at 1% level of significance. Different diagnostic tests have been used. Ramsey RESET, CUSUM and CUSUM square shows the stability of the results (figures 1.1A to 2.2 A in the appendix). These diagnostic tests make clear the existence of a long-run relationship between TFP, public investment, subsidies and other variables.

We estimate two empirical model specifications. In the first specification, we include two major components of public investment: public canal intensity and electricity consumption in agriculture. In specification 2, we include public investment itself. Table 3 presents the ARDL results of long-run estimates for two specifications having lag length of (2,0,2,0,1,2) and (1,0,0,2,2,2). We find that canal intensity has a positive and significant impact on TFP in the long run with an estimated elasticity of 0.10, or a 10% increase in government canal irrigation leads to a 1% increase in TFP. However, power consumption has a positive but insignificant coefficient indicating no significant impact on TFP; and subsidies do not have a significant impact. The TOT and institutional credit have a positive and significant impact on TFP. The results of specification 2 reveal that the impact of investment is positive and significant, while input subsidies have a negative and significant impact on TFP.

Table 2. ARDL bounds test results for co-integration and other tests

Model specification	Lag length	*F*-statistic	Serial correlation (χ^2 statistic)	Breuch–Pagan–Godfrey (χ^2 statistic)	ARCH	Ramsey RESET	Result
LnTFP(LnCNL,lnEc, lnS, lnToT, lnC, LnHYV)	(2,0,2,0, 1,2,2)	4.645***	0.071	-0.991 (0.424)	-0.634 (0.658)	0.111	Co-integration
LnTFP (lnI,lnS, lnC, lnToT, lnIRI, lnHYV)	(1,0,2, 1,2,0,2)	5.349***	0.437	-0.993 (0.263)	-0.991 (0.921	0.063	Co-integration

Critical values for bound testing

Level of significance	Lower bound 1(0)	Upper bound 1(1)
10%	2.12	2.23
5%	2.75	3.61
1%	3.15	4.41

Note: Values in the brackets are *p*-values. *** indicates the existence of co-integration at 1 % level of significance.

Table 3. ARDL estimates of long-run elasticities

Variable	Specification 1			Specification 2		
	Coefficient	Std. error	Prob.	Coefficient	Std. error	Prob.
Ln(CNI)	0.100**	0.048	0.053	–	–	–
Ln(EC)	0.003	0.009	0.723	–	–	–
Ln(I)	–	–	–	0.037*	0.020	0.08
Ln(S)	0.013	0.01	0.208	-0.120***	0.025	0.00
Ln(TOT)	0.112**	0.053	0.049	0.038	0.073	0.60
Ln (C)	0.026*	0.014	0.081	–	–	–
Ln(IRI)	–	–	–	2.307***	0.639	0.00
Ln(HYV)	0.005	0.007	0.448	0.012	0.017	0.48
Constant	0.457**	0.221	0.053	-3.564**	1.556	0.03

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 4. ARDL estimates for short-run elasticities

Variable	Specification 1			Specification 2		
	Coefficient	Std. error	Prob.	Coefficient	Std. error	Prob.
ΔLn(TFP(-1))	0.320*	0.179	0.09	0.074	0.186	0.695
Δ(CNI)	0.059***	0.017	0.00	–	–	–
ΔLn(EC)	0.038***	0.017	0.00	–	–	–
ΔLn(I)	–	–	–	0.045*	0.020	0.090
ΔLn(S)	0.018	0.005	0.13	0.040	0.030	0.205
ΔLn(TOT)	0.103***	0.024	0.00	-0.035	0.068	0.610
ΔLn(C)	0.016**	0.007	0.02	–	–	–
ΔLn (IRI)	–	–	–	1.368**	0.574	0.03
ΔLn (HYV)	0.006	0.004	0.16	0.014	0.015	0.348
ECM (-1)	-0.585***	0.181	0.00	-0.925***	0.186	0.00
Adj. R-squared	0.811	0.811				
D-W statistic	2.014				1.688	

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

In table 4 we present the short-run elasticity estimates of the ARDL model. The results show that the current TFP is positively and significantly impacted by its lag value in specification 1. The elasticities of public canal intensity and power consumption remain positive and turn out to be significant, indicating that a 1% increase in public investment in canal building raises TFP by 0.05% and a 1% increase in power consumption raises TFP by 0.03%. The elasticity of input subsidies is positive but not significant. The TOT and institutional credit have a positive and significant impact on TFP in the short run. From specification 2, we find that public investment affects TFP positively and significantly but subsidies have no significant impact in the short run. However, its elasticity is found positive. Surprisingly, the area under HYV seeds does not render any significant impact on TFP in the short or long run.

The lagged value of ECM is negative and significant in both the specifications. This indicates the speed of adjustment of TFP to its equilibrium in case there is a shock rendering deviations from its equilibrium. The models pass all the diagnostic tests; the value of R-squared is 0.89 in both the specifications, and the Durbin–Watson statistic is 2.01 for specification 1 and 1.68 for specification 2.

Clearly, public sector agricultural investment has a positive and significant impact on TFP in the short and long run, but subsidies have no significant impact in the long run in model specification 1. In specification 2, subsidies are found to have a negative impact on TFP in the long run. The CUSUM and CUSUMQ test ensures the stability of two models (figures 1.1A to 2.2 A in the appendix).

4.2 State level

Using a panel data set for 17 major agricultural states, we try to quantify the impact of public investment and subsidies on TFP. We estimated the public investment figures by adding capital expenditure on different heads – soil and water consumption, plantations, agricultural research and education and so on. The data have been compiled from the RBI Handbook on State Finances (2010 and 2016). Total subsidies have been calculated by adding subsidies on irrigation, power and fertilizers at the state level.

Since we have a panel data set for 17 states from 1990 to 2015, we need to check the stationarity of the data series. We did it applying different panel unit root tests like Levin, Lin and Chu test, lm, Pesaran and Chu W-stat, ADF-Fisher chi-square test and PP-Fisher chi-square test. Tables 3A and 4A in the appendix show the results of different unit root tests with intercept, and intercept with trend which confirm that there is a mixture of stationarity of variables; some like TFP, subsidy and TOT are stationary at level I(0) and others like public investment, institutional credit and cropping intensity are stationary at first difference I(1).

The ARDL model can be used whether all the variables are stationary at level I(0) or first difference I(1) or a combination of both. However, in the case of panel data, the co-integration test with critical values is not suitable when the variables are integrated with different orders (Asongu et al. 2016). Therefore, studies mostly use the co-integration test developed by Pedroni (2004). Table 5, which depicts the results of Pedroni's co-integration test, clearly shows that out of seven statistics we have only three statistics: panel PP-statistic, panel ADF and group PP-statistic reject the null hypothesis of no co-integration among the variables.

Table 6 shows the estimates of the long-run elasticities from the panel ARDL model having the lag length (2, 1, 1, 1, 1, 1). These results establish that public investment has a positive and significant impact on TFP at the state level and that subsidies do not have any significant impact.

Table 5. Results of Pedroni's co-integration test

Co-integration tests	Statistic	Prob.
Panel *v*-Statistic	-3.211	1.00
Panel rho-Statistic	1.896	0.99
Panel PP-statistic	-10.166***	0.00
Panel ADF-Statistic	-1.064*	0.099
Group rho-Statistic	3.663	0.99
Group PP-statistic	-8.920***	0.00
Group ADF-Statistic	-0.182	0.42

Note: *** and * indicate significance at 1% and 10%, respectively.

Table 6. Long-run elasticities from panel ARDL model

Variable	Coefficient	Std. error	Prob.
Ln(I)	0.053**	0.0021	0.012
Ln (S)	0.054	0.0063	0.394
Ln (TOT)	-0.048	0.0059	0.423
Ln (C)	0.048	0.0125	0.702
Ln (CRI)	0.032*	0.0128	0.091

Note: ** and * indicate significance at 5% and 10%, respectively.

The long-run elasticities by zone from the results of panel ARDL model (Table 7) reveal that in the north, east and south zone, investment turns out to be a positive and significant determinant of TFP. The elasticity of subsidies is positive and significant in the north zone but statistically insignificant in the east and west zone; it is negative and significant in the south zone. Among other variables, the elasticity of TOT is significant in the south zone and credit is significant in the east zone. Cropping intensity and institutional credit are positive and significantly affects TFP in almost all zones.

Table 8 represents the estimates of panel ARDL short-run elasticities. We find that current TFP is positively affected by its previous level. The elasticity of public investment and institutional credit and cropping intensity is positive and significance; the elasticity of subsidy is positive but not significant; and the TOT has a negative but insignificant impact on TFP. The value of lagged ECM is -0.184, which is significant at 5%. This indicates that at the combined state level, if there is any deviation of TFP from its long-run equilibrium, it takes more than five years to correct that error or deviation as every year only 18% of that is getting closed.

Table 7. Panel ARDL long-run elasticities by zone

Variable	North zone			East zone			South zone			West zone		
	Coef.	Std. error	Prob.	Coef.	Std. error	Prob.	Coef.	Std. error	Prob.	Coef.	Std. error	Prob.
Ln(I)	0.025**	0.01	0.02	0.05**	6.5	0.00	0.02***	0.001	0.00	0.01	0.01	0.19
Ln(S)	0.021**	0.01	0.04	0.04	0.51	0.61	-0.10***	0.02	0.00	0.014	0.02	0.78
Ln(TOT)	0.021	0.02	0.78	-0.04	0.73	0.47	0.07**	0.03	0.04	-0.013	0.01	0.98
Ln(C)	0.019	0.01	0.74	0.04**	2.42	0.02	0.020*	0.01	0.06	0.016*	0.01	0.10
Ln(CRI)	0.20***	0.02	0.00		0.06***	3.72	0.00	0.42***	0.02	0.00		0.18***
0.04	0.00											

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 8. Panel ARDL short-run elasticities

Variable	Coefficient	Std. error	Prob.
Δ(TFP(-1))	0.264***	0.053	0.00
Δ ln(I)	0.011*	0.006	0.079
Δ ln(S)	0.007	0.007	0.312
Δln(TOT)	-0.012	0.008	0.113
Δln(C)	0.051*	0.029	0.082
Δln(CRI)	0.099**	0.047	0.034
ECM(-1)	-0.184**	0.086	0.033

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

The short-run estimates of elasticity of investment, subsidy and other variables for individual states are presented in table 9. The elasticity of investment is positive and highly significant in most of the states except Bihar, Gujarat and Himachal Pradesh, where the elasticity of investment is significant and negative. The elasticity of subsidies is positive and significant in states like Jammu & Kashmir, Punjab, Haryana, Himachal Pradesh, Andhra Pradesh, Uttar Pradesh and West Bengal. In other states, it is negative and mostly significant, except Odisha, where it is positive but insignificant. This corroborates the earlier results by zone. So the comparison says that while the investment is enhancing productivity in most states, subsidies have a mixed result. The positive effects of subsidies in agriculturally developed states like Punjab, Andhra Pradesh, Haryana and Uttar Pradesh can be attributed to the input subsidies given for commercial agriculture like growing cotton, chilli, sugarcane and so on, but in agriculturally developing states subsidies have deleterious effects on TFP. Among other variables, we observe a mixed result at the state level.

5 Conclusions

This study empirically examined the issue of effectiveness of input subsidies and public sector investment on TFP in Indian agriculture from 1980 to 2015 at the national and state levels (1990-2015), and has two major findings.

In the short and long run, at the national level, investment is found more effective than subsidies, which are found to have deleterious effects on TFP in the long run in model specification 2 and positive but insignificant effects in specification 1. Two, subsidies are not found to have any significant impact at the zone and state level except in the north zone, but the elasticity of investment was positive and significant (though weak in some cases). In the short run, the elasticity of investment is positive and significant in most of the states, but the result for subsidies is mixed. Subsidies are effective in the short run in a few agriculturally developed states like Punjab, Haryana, Andhra Pradesh and Uttar Pradesh, but they impact most states negatively.

Thus, this study concludes that public investment is more effective than subsidies in Indian agriculture, which is in line with the evidence found in Chand & Kumar (2004).

The declining trend of public investment threatens the growth of productivity in Indian agriculture, and it needs to be reversed. The need of the hour is to divert resources from input subsidies to public investments in Indian agriculture.

Table 9. Panel ARDL short-run elasticities at state level

Variable	Coefficient	Std. error	Prob.	Coefficient	Std. error	Prob.
		Andhra Pradesh			**Assam**	
ΔLn(TFP(-1))	0.085**	0.026	0.045	-0.204**	0.042	0.010
ΔLn(I)	0.004***	0.000	0.000	0.003***	0.000	0.000
ΔLn(S)	0.019***	0.000	0.000	-0.022***	0.001	0.000
ΔLn(TOT)	-0.007***	0.000	0.000	-0.003***	0.000	0.000
ΔLn(C)	-0.006***	0.000	0.000	0.050***	0.002	0.000
ΔLn(CRI)	-0.464**	0.027	0.000	-0.183**	0.023	0.004
ECM(-1)	-1.259**	0.048	0.000	-0.122***	0.020	0.009
		Bihar			**Gujarat**	
ΔLn(TFP(-1))	-0.172*	0.070	0.090	-0.062	0.033	0.160
ΔLn(I)	-0.001***	0.000	0.000	-0.003***	0.000	0.000
ΔLn(S)	-0.002*	0.001	0.070	-0.001***	0.000	0.000
ΔLn(TOT)	0.002***	0.000	0.000	0.003***	0.000	0.000
ΔLn(C)	0.011***	0.002	0.009	0.021***	0.000	0.000
ΔLn(CRI)	-0.098***	0.008	0.001	-0.151***	0.003	0.000
ECM(-1)	-0.095***	0.014	0.000	-0.028**	0.005	0.014
		Haryana			**Himachal Pradesh**	
ΔLn(TFP(-1))	0.067	0.037	0.174	-0.607***	0.073	0.000
ΔLn(I)	0.016***	0.000	0.000	-0.007***	0.000	0.000
ΔLn(S)	0.025***	0.002	0.000	0.012***	0.001	0.000
ΔLn(TOT)	-0.029***	0.000	0.000	0.004***	0.000	0.000
ΔLn(C)	0.103***	0.012	0.000	0.025***	0.001	0.000
ΔLn(CRI)	-0.121***	0.006	0.000	-0.021***	0.003	0.000
ECM(-1)	-0.808***	0.069	0.000	0.290**	0.049	0.010
		Jammu & Kashmir			**Karnataka**	
ΔLn(TFP(-1))	0.269***	0.034	0.000	-0.278***	0.042	0.000
ΔLn(I)	0.003***	0.000	0.000	-0.001**	0.000	0.010
ΔLn(S)	0.003***	0.000	0.000	-0.042***	0.001	0.000
ΔLn(TOT)	0.001***	0.000	0.000	-0.004***	0.000	0.000
ΔLn(C)	0.023***	0.000	0.000	-0.095**	0.019	0.010
ΔLn(CRI)	0.437***	0.011	0.000	-0.160***	0.024	0.000
ECM(-1)	-0.220***	0.007	0.000	-0.063***	0.035	0.000
		Kerala			**Madhya Pradesh**	
ΔLn(TFP(-1))	-0.829***	0.040	0.00	-0.538***	0.028	0.00
ΔLn(I)	0.019***	0.000	0.00	0.015***	0.000	0.00
ΔLn(S)	-0.043***	0.001	0.00	-0.041***	0.001	0.00
ΔLn(TOT)	-0.002***	0.000	0.00	-0.019***	0.000	0.00
ΔLn(C)	0.283***	0.007	0.00	0.170***	0.005	0.00
ΔLn(CRI)	-0.286***	0.010	0.00	-0.057***	0.005	0.00
ECM(-1)	-0.233***	0.011	0.00	-0.086***	0.014	0.00

contd...

Variable	Coefficient	Std. error	Prob.	Coefficient	Std. error	Prob.
		Maharashtra			**Odisha**	
ΔLn(TFP(-1))	-0.538***	0.028	0.00	-0.615***	0.032	0.00
ΔLn(I)	0.015***	0.000	0.00	0.104***	0.001	0.00
ΔLn(S)	-0.041***	0.001	0.00	0.110	0.000	0.13
ΔLn(TOT)	-0.019***	0.000	0.00	-0.012***	0.000	0.00
ΔLn(C)	0.170***	0.005	0.00	0.172***	0.011	0.00
ΔLn(CRI)	-0.057***	0.005	0.00	-0.089***	0.011	0.00
ECM(-1)	-0.086***	0.014	0.00	-0.070***	0.031	0.00
		Punjab			**Rajasthan**	
ΔLn(TFP(-1))	0.169**	0.042	0.020	-0.062	0.040	0.210
ΔLn(I)	0.005***	0.000	0.000	0.019***	0.000	0.000
ΔLn(S)	0.035***	0.001	0.000	-0.011***	0.002	0.000
ΔLn(TOT)	-0.006***	0.000	0.000	-0.013***	0.000	0.000
ΔLn(C)	-0.042***	0.006	0.000	-0.010**	0.003	0.040
ΔLn(CRI)	0.162**	0.035	0.010	-0.222**	0.083	0.070
ECM(-1)	-0.535***	0.035	0.000	-0.580***	0.053	0.000
		Tamil Nadu			**Uttar Pradesh**	
ΔLn(TFP(-1))	-0.235***	0.035	0.00	0.062**	0.013	0.010
ΔLn(I)	0.005***	0.000	0.00	0.037**	0.000	0.000
ΔLn(S)	-0.003***	0.000	0.00	0.019***	0.001	0.000
ΔLn(TOT)	-0.005***	0.000	0.00	-0.137***	0.002	0.000
ΔLn(C)	0.109***	0.003	0.00	0.446***	0.015	0.000
ΔLn(CRI)	0.02	0.010	0.13	-0.121**	0.034	0.037
ECM(-1)	-0.431***	0.032	0.00	-0.811***	0.020	0.000
		West Bengal				
ΔLn(TFP(-1))	-0.321***	0.027	0.00			
ΔLn(I)	0.006***	0.000	0.00			
ΔLn(S)	0.009***	0.001	0.00			
ΔLn(TOT)	-0.010***	0.000	0.00			
ΔLn(C)	0.026***	0.001	0.00			
ΔLn(CRI)	-0.473***	0.073	0.00			
ECM(-1)	-0.663***	0.060	0.00			

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

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Appendix

Stability Test

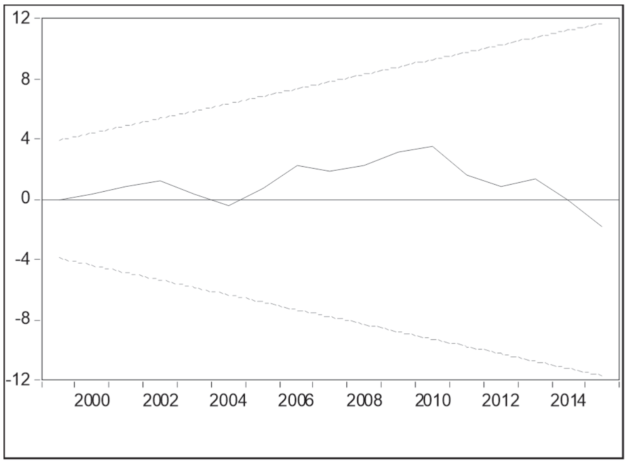

Figure 1.1A ARDL CUSUM test (Model 1)

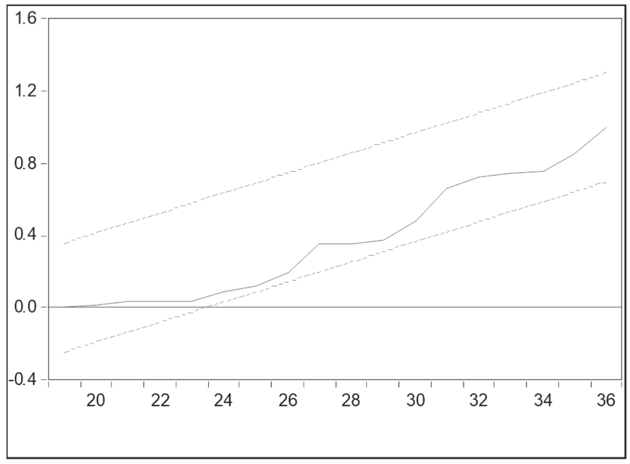

Figure 1.2A ARDL CUSUMQ test (Model 1)

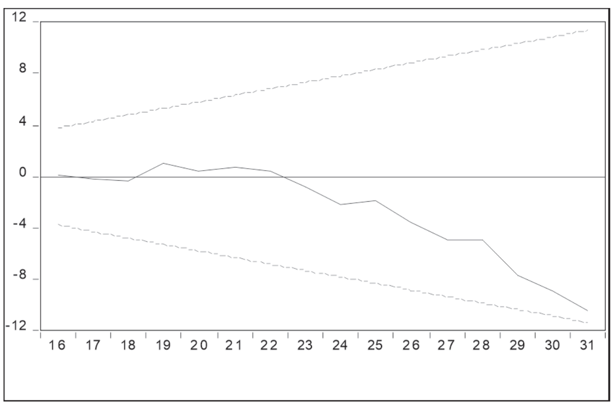

Figure 1.1A ARDL CUSUM test (Model 2)

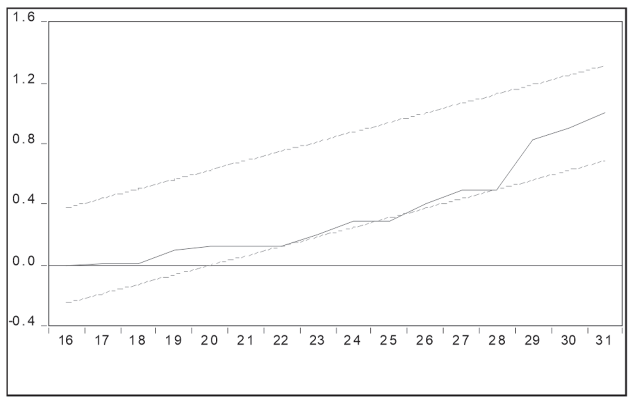

Figure 1.2A ARDL CUSUMQ test (Model 2)

Table 1A. Unit root test with intercept

Variables	Augmented Dickey–Fuller (ADF)		Phillips–Perron (PP)	
	Level	1st difference	Level	1st difference
Ln(TFP)	-1.517	-5.039***	-1.868	-6.116***
Ln (I)	-0.039	- 0.729***	-0.054	-0.846***
Ln(CNL)	-1.932	-7.967***	-1.763	-8.540***
Ln (PC)	-2.261	-5.855***	-2.393	-5.891***
Ln (S)	-2.494	-3.658***	-2.391	-3.708***
Ln (TOT)	2.179	-9.588***	5.936	-9.621***
Ln (C)	-1.314	-5.294***	-1.314	-5.294***
Ln (HYV)	-1.926	-5.078***	-2.132	-5.205***
Ln (IRI)	-0.037	-6.618***	0.213	-6.526***

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 2A. Unit root test with intercept and trend

Variables	Augmented Dickey–Fuller (ADF)		Phillips–Perron (PP)	
	Level	1st difference	Level	1st difference
LnTFP	-1.805	-5.078***	-2.084	-6.007***
Ln I	-0.092	-0.730***	0.091	-0.844***
LnCNL	-2.404	-7.995***	-2.277	-9.174***
Ln PC	-1.793	-6.421***	-1.765	-6.4081***
Ln S	-1.706	-4.007**	-1.852	-3.983**
Ln TOT	-1.364	-10.779***	-1.364	-10.592***
Ln C	-0.899	-5.381***	-0.978	-5.371***
Ln HYV	-3.193	-4.998***	-2.529	-5.079***
Ln IRI	-3.321*	-	-3.321*	-

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 3A. Unit root test with intercept

Variables	Levi, Lin and Chu		lm, Pesaran and Shin		ADF-Fisher chi-square		PP-Fisher chi-square	
	Level	1st difference	Level	1st difference	Level	1st difference	Level	1st difference
LnTFP	-3.15***	--	-2.402***	--	51.63**	--	99.71***	--
Ln I	1.55	9.30***	1.241	12.68***	27.49	207.5***	57.4	420.5***
Ln S	-10.98***	--	-9.04***	--	161.1***	--	151.92***	--
LnTOT	-8.58***	--	7.77***	--	126***	--	230.91***	--
Ln C	6.65	2.68***	11.31	-4.92***	1.439	85.50***	0.215	199.5***
Ln CRI	1.16	--7.70***	1.17	-10.2***	19.47	171.6***	44.04	296.9***

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 4A. Unit root test with intercept and trend

Variables	Levi, Lin and Chu		lm, Pesaran and Shin		ADF-Fisher chi-square		PP-Fisher chi-square	
	Level	1st difference	Level	1st difference	Level	1st difference	Level	1st difference
LnTFP	-2.02**	--	-1.642**	--	53.39**	--	103.16***	--
Ln I	-0.24	-6.36***	-0.64	10.61***	40.71	161.9***	100.6	1,435***
Ln S	-11.83***	--	10.47***	--	174.80***	--	112.63***	--
LnTOT	-9.480***	--	-7.81***	--	118.9***	--	261***	--
Ln C	6.656	-2.68***	11.31	-4.92***	1.439	85.50***	0.215	199.5***
LnCRI	2.047	-4.911***		0.385	-7.55		25.139	124.9***
65.71	940.8***							

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.