Irrigation Governance, Private Investment, and Agricultural Productivity in India

by Anjani Kumar, Seema Bathla, K. Elumalai, and Sunil Saroj

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ABSTRACT

This paper analyzes the correlation of irrigation investments among agricultural households across India's 20 major states with irrigation governance and agricultural productivity. A governance index is constructed based on select indicators that capture important dimensions of irrigation water governance. These dimensions include irrigation management, farmers' participation, accountability, and sustainable use. Using principal component analysis, the index is constructed for each of the selected states for the period 2001/2002 to 2015/2016. Results reveal that in some states farmers' dependence on electric tube wells, and hence groundwater, has increased extensively due to inadequate access to public (canal) irrigation. Irrigation accounted for 35 percent of the total investments undertaken by farmers, with little increase between 2002/2003 and 2012/2013. Over that period, there was an increase in farmers' expenditures on machinery, tractors, and livestock. Results further indicate that good governance has a positive influence on private investment in agriculture, which in turn can contribute to enhanced productivity and an increase in farmers' incomes. This argument is supported by the results obtained from a structural equation model and from ICAR–ICRISAT household, individual, and plot-level data. This suggests that states where both governance and private investment in irrigation are at very low levels should

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receive higher priority; these include Assam, Odisha, West Bengal, Kerala, Bihar and Jharkhand, and Uttar Pradesh and Uttarakhand. Other states which are low in governance but high in irrigation investment (Madhya Pradesh, Chhattisgarh, Himachal Pradesh, and Karnataka) should improve governance in order to enable efficient use of irrigation resources.

KEYWORDS: Private investment, irrigation, governance, agricultural productivity

JEL Codes: H410; Q320; Q190

1. INTRODUCTION

Public investment in agriculture "crowds in" private investment, especially investments by farm households; this leads to an increase in land productivity. An increase in agricultural productivity has a greater poverty-reducing impact than does growth in other sectors of the economy (Ahluwalia 1978; Datt, Ravallion, Murgai 2016). The role of public spending in accelerating agricultural growth and reducing rural poverty has been well documented in the literature (Barro 1990; Ravallion and Datt 1995; Sen 1997; Fan 2008; Bathla, Kumar, Joshi 2020). Although the poverty-reducing effects of public expenditures vary from country to country, returns on additional investment in irrigation have been found to be robust in many countries, including India. Over the years, the nature and form of irrigation investments in India have changed; from the late 1970s, there has been a rapid increase in private (farm household) investment in irrigation and, in fact, private investment in wells and electric pumps has played a crucial role in expanding groundwater irrigation.

With the liberalisation of the Indian economy in the 1990s, acreage under public surface irrigation declined and there was a corresponding increase in the area under private groundwater irrigation.[5] One of the government's policy objectives has been to make private investment in agriculture—particularly in irrigation—more attractive. In empirical research so far, however, there has been litte interest shown in farmers' investment behavior (and changes therein); scant attention has been paid, particularly, to understanding what induces farmers to undertake investments in irrigation, or to investigating the composition of those investments and their relationship to farm productivity. Previous research on private investment in agriculture, and particularly on irrigation, considered only the economic,

[5] The area irrigated by canals has increased considerably from 7.2 million hectares (ha) in 1950/1951 to 16.2 million ha in 2014/2015 (India, Ministry of Agriculture and Farmers Welfare, 2017); during the same period, however, its share in total area irrigated by various sources has declined from 47 to 26 percent.

environmental, and farm-level organizational parameters (Chand and Kumar 2004; Bisaliah, Dev, Saifullah 2013); additional parameters such as irrigation governance, however, play a significant role in determining private investment in agriculture.

The term "governance" is understood as referring to the institutions by which authority is exercised; it may include a number of elements: the process by which governments are selected, monitored, and replaced; a government's capacity to formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions (Kaufmann et al. 1999). As per the United Nations Development Programme (2014), "good governance" may refer to something that is broader than institutions and includes the people, the state, and their interactions. The mechanisms that promote good governance are transparency, democratic institutions, and effective public services; its processes may include quality of participation—which can encompass the involvement of the most vulnerable and poorest sections of society—as well as the accountability of institutions to the public and other stakeholders. The outcomes of good governance are a healthy and peaceful society and the delivery of public services (Keuleers 2004).

Governance can be observed from various angles and at different scales. In the case of natural resources such as land, water, and forests, diverse stakeholders must show integrity in the coordination of multilevel decision-making. While developing irrigation governance indicators, Tortajada (2010) brought forth the rules and regulations for effective management of, and participation in, programs and irrigation schemes and for fulfilling dimensions of governance such as accountability, participation, transparency, and cooperation. Some governance rules represent fairness and equity, while others aim at the sustainable use of resources; together, these rules influence economic performance. Debroy and

Bhandari (2012) and Tortajada (2010) highlighted a nexus between governance, investment, and economic growth. It is generally believed that investment is important for growth and that governance considerably affects investment decisions; in other words, good governance is associated with higher investment. Debroy and Bhandari (2012) constructed an economic freedom index of the states in India in order to demonstrate how economic governance differs among them. As key variables for construction of the index, they considered size of government, legal structure and security of property rights, and regulation of business and labor. The index shows that economically freer states perform better on per capita growth, employment, sanitary conditions, and attraction of investment. Gulati (2012) maintained that the agricultural sector is among the least free from government intervention and that agricultural growth will be improved by the dismantling of state-level controls and regulations in both output and input markets and by reforming public irrigation.

Less attention, however, has been paid to analyzing the relationship between governance and agricultural investment. In particular, there is scant empirical research on the role of governance in accelerating the pace of private (household) investment in irrigation in India and elsewhere. Manjunath and Kannan (2017) prepared a district-level rural infrastructure index encompassing economic, social, and institutional indicators in order to analyze their effect on district-level agricultural development in India's Karnataka state. Their study finds that growth in agricultural productivity is positively related to rural infrastructure, that the effect of infrastructure utilization on productivity growth seems to exceed that of infrastructure availability, and that there is spatial convergence of land productivity across districts over time. Their study also highlights the need to make investments in irrigation and other rural infrastructures, and the importance of their effective utilization for agricultural development.

In another study, Kannan, Bathla, and Gautam (2019) developed a robust state-level irrigation governance index (IGI) in India which they employed to examine the effect of governance on the performance of public irrigation systems; the study found the IGI to show a significant positive relationship between the two variables. Until now, however, there has been no empirical evidence on the effect of governance on private investment and agricultural productivity. This paper makes an important contribution to the literature in addressing this research gap.

The paper is organized as follows: Section 2 gives an overview of the methodology and database used in the paper; Section 3 depicts patterns and temporal trends in private investment in agriculture and irrigation; Section 4 explains the relationship between governance and private investment in irrigation; the determinants of private investment and its impact on agriculture productivity are discussed in Section 5; and the final section offers conclusions.

2. METHODOLOGY AND DATA SOURCES

Private investment in agriculture is determined by various socio-economic characteristics of farm households. A few studies have identified the determinants of private investment in agriculture in India. Binswanger, Khandker, and Rosenzweig (1993) observed that education, infrastructure availability, and the presence of rural banks have played an overwhelmingly important role in determining farmers' investment. Misra and Hazell (1996) found that favorable terms of trade and agricultural technology had a significant positive impact on private investment in agriculture. Among others, Shetty (1990), Dhawan (1998), and Gulati and Bathla (2002) undertook a detailed analysis of various price and non-price factors in agriculture and showed that private investment has a complementary relationship with public investment. A few studies conducted at the disaggregate farm level have had similar findings. Dhawan and Yadav (1995, 1997) found that farmers' decisions to invest in agricultural machinery and implements was primarily driven by the development of canal irrigation capacity. Bisaliah, Dev, and Saifullah (2013) studied private investment disaggregated by size of landholding and found that for marginal, small, and large farmers, literacy and the availability of credit had a positive impact on farm asset creation; they found, however, that for semi-medium and medium-sized farmers, only land and credit had a positive influence on private investment in agriculture.

None of these studies specifically looked into the role of irrigation governance in influencing private investment in irrigation assets at the farm level; furthermore, few studies in India have examined the combined role of irrigation governance and private investment in increasing agricultural productivity. Using a system of equations, we analyze the impact of irrigation governance on private investment in agriculture and land productivity Data on the variables used in the analysis were compiled from various published sources and are given in Annex Table 1a and 1b; these tables also list 10 variables that are used in the construction of the state-level IGI for the period 2001/2002 to 2015/2016.

Methods used for constructing the IGI are outlined below. The min–max method was used to convert the quantitative variables to scale free. The min–max method of normalization[6] can be specified as follows:

$$\text{Scaled value of indicator } (Si) = \frac{Xi - \text{Minimum value } x}{\text{Maximum value} - \text{Minimum value}} \quad (1)$$

Pincipal component analysis (PCA) was then used to generate weights to combine the variables into an index. The PCA creates a new set of variables out of a given

[6] We used different units to measure variables, which were normalized to remove scales and make them unit-free. The min–max method allows values of indicators to lie between 0 and 1, which is a useful property and has an effect on the composite indicator.

set of variables (X_j, j = 1, 2, 3, …., k). These variables are called principal components (P_i), which are linear components of X_j and can be represented as:

$$P1 = a11X1 + a12X2 + a13X3 + \ldots\ldots + a1k\,Xk$$

$$P2 = a21X1 + a22X2 + a23X3 + \ldots\ldots + a2k\,Xk$$

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$$Pk = ak1X1 + ak2X2 + ak3X3 + \ldots\ldots + akk\,Xk, \quad (2)$$

where, a_{kk} are loadings chosen such that the first principal component captures the maximum possible proportion of the total variation in all X_j. The first principal component accounts for the maximum possible proportion of the variance of the set of variables, the second principal component accounts for the maximum of the remaining variance, and so on. In this study, the first component is used as a weight since it has the maximum variance of all the components. The composite index has been constructed by multiplying the weight with scale-free variables such as

$$\sum W_{it}\, X_{it}, \quad (3)$$

where, W_{it} is the weight of the i^{th} variable at time t, and X_{it} is the scale-free i^{th} variable at time t.

The effect of governance on private irrigation investment is analyzed through econometric techniques. The productivity equation is endogenized to capture the effect of various types of private investment in agriculture, fertilizer subsidies, employment in agriculture, and literacy rates; similarly, private investment is linked to governance index, share of expenditure to GDP, and per capita income. The relationship between productivity and private investment is defined in latent endogenous variables. We quantify these interlinkages using econometric techniques, such as the simultaneous equation model and generalized method of moments (Coady and Fan 2008). Of late, structural equation modeling (SEM) has increasingly come to be used to describe complex systems in a multivariate setting (Kline 2011; Widaman and Thompson 2003). This methodology provides a flexible framework for investigating more than one causal process among the variables. By estimating multiple equations, it has the advantage of permitting the evaluation of networks of direct and indirect effects, along with different error structures. It models the relationships between the unobservable latent variables by allowing multiple measures to be associated with a single latent variable. The model specification is based on relevant theory and research literature to account for socio-economic factors.

The system is estimated using SEM. Double-log functional forms are used for all equations in the system. The endogeneity problem, which generally occurs in time-series models, is controlled by applying the variable in the lagged form or redefining it using the instrumental variable method. The structural model represents how variables are related to one another. SEMs allow for direct, indirect, and associative relationships to be explicitly modeled, unlike the ordinary least squares (OLS) method with its implicit model associations. The structural component of SEMs enables substantive conclusions to be made about the relationship between latent variables and the mechanisms underlying a process or a phenomenon. The basic equation of the latent variable model is the following:

$$Y = \beta \, \theta \, \delta \, \epsilon + \rho, \tag{4}$$

in which θ is an $(m \times 1)$ vector of the latent endogenous variables, ϵ (*xi*) is an $(n \times 1)$ vector of the latent exogenous variables, and ρ is an $(m \times 1)$ vector of random variables. The elements of the β and δ matrices are the structural coefficients of the model; the β matrix is an $(m \times m)$ coefficient matrix for the latent endogenous variables; the δ matrix is an $(m \times n)$ coefficient matrix for the latent exogenous variables. The basic equations of the measurement model are the following:

$$X = \Delta_x \epsilon + \gamma, \text{ for the exogenous variables} \quad (5)$$

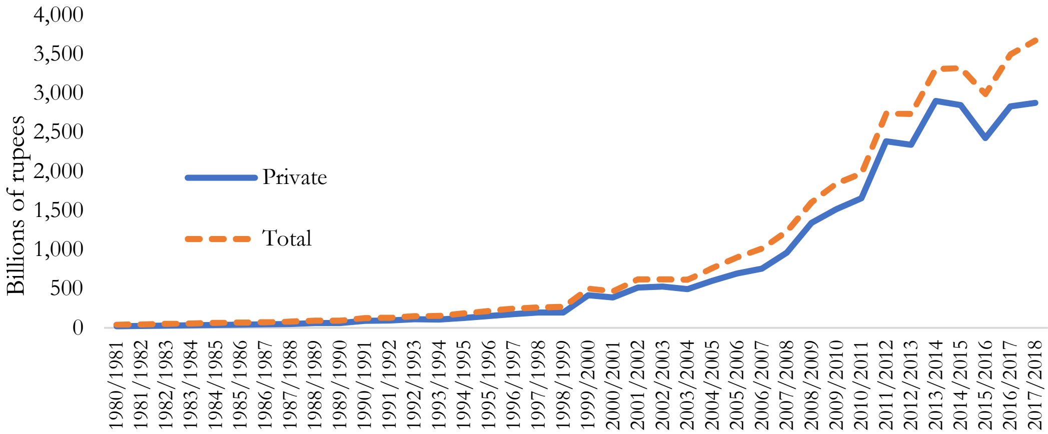
$$Z = \Delta_y \mu + \tau, \text{ for the endogenous variables,} \quad (6)$$

in which X and γ are column q vectors related to the observed exogenous variables and errors, respectively; Δ_x is a $(q \times n)$ structural coefficient matrix for the effects of the latent exogenous variables on the observed variables; Z and τ are column p vectors related to the observed endogenous variables and errors, respectively; Δ_y is a $(p \times m)$ structural coefficient matrix for the effects of the latent endogenous variables on the observed ones. Finally, although model goodness-of-fit measures are an important part of any statistical model assessment, one of the most common goodness-of-fit measures is the standardized root mean square residual (SRMR), which is an index of the average of standardized residuals between the observed and the hypothesized covariance matrices. Values of the SRMR range between zero and one, with well-fitting models having values < 0.04 (Annex Table 2).

3. COMPOSITION OF FIXED CAPITAL EXPENDITURE IN FARM BUSINESS

Investment in agriculture is done by both the public and the private (household and corporate) sectors. The public sector's share in agricultural gross capital formation has been declining over time, moving from 52 percent in 1980/1981 to about 19 percent in 2017/2018 (Figure 1).

Figure 1. Gross capital formation in agriculture and the allied sector



Source: India, Ministry of Statistics and Programme Implementation (n.d.)

Total investments in agriculture are comprised of 78.2 percent from households and only 19.4 percent from public investments (Table 1); the private corporate sector accounts for less than 2.5 percent of investment in the agricultural sector. Out of the total corporate investment of about INR 18,759 billion (US$ 280) in the economy during 2016/2017, agriculture received only about INR 80 billion (only 0.42 percent); furthermore, the investment-to-GDP ratio in agriculture is low, standing at only about 13 percent, as compared to 35 percent in the case of the non-agricultural sector. The capital investment as a proportion of overall GDP is 31 percent.

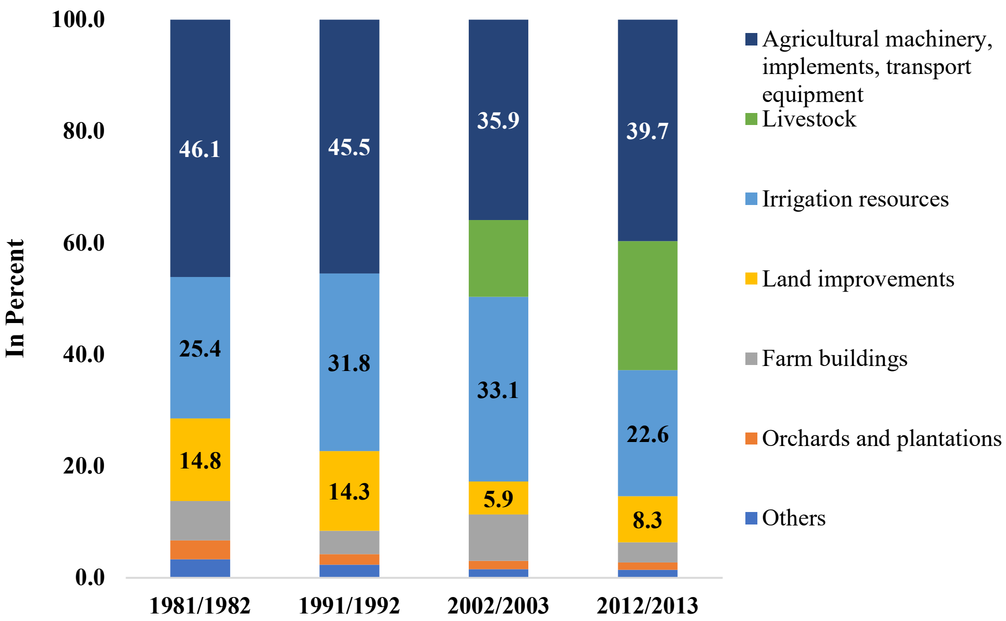
Table 1. Share of various sources in gross fixed capital formation in agriculture and in the total economy, 2016/2017

Sector	Capital investment (in INR billion)	Capital investment as percent of GVA	Share in total gross capital formation in sector (percent)		
			Private corporate	Public sector	Households
Agriculture	3,316	13.3	2.4	19.4	78.2
Non-agri	40,209	35.4	46.4	25.5	28.0
Economy	43,524	31.4	43.1	25.1	31.8

Source: India, Ministry of Statistics and Programme Implementation.
Note: Gross Value Added (GVA) = Gross Domestic Product + Subsidies on products – Taxes on products

Figure 2 provides an interesting insight into changes in the composition of fixed capital expenditure (FCE) in farm business. As shown, the most important investment items in agriculture for rural households turn out to be machinery, implements, and transport equipment; these are followed by irrigation resources, livestock, and land improvement works. Together, they account for more than 85 percent of FCE in farm business among rural households. These patterns hold true over time, though there are variations in their proportionate share; for instance, the share of agricultural machinery implements and transport equipment declined from 46.1 percent in 1981/1982 to 39.7 percent in 2012/2013; similarly, irrigation maintained the second position, though its share has fluctuated over time.

Figure 2. Trends in composition of fixed capital expenditure in farm business among rural households, 1981/1982 to 2012/2013

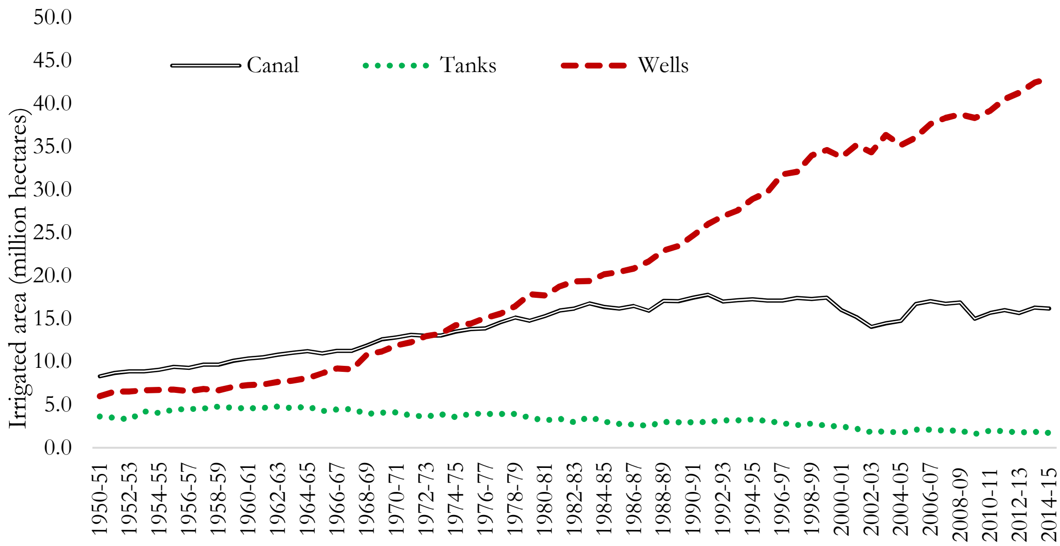


Source: India, Ministry of Statistics and Programme Implementation, All India Debt & Investment (37th, 48th, 59th and 70th Rounds).

Livestock was included only in the last two National Sample Survey (NSS) rounds on agriculture; due to this, agricultural machinery, implements, and transport equipment showed a declining trend. Investment in irrigation resources gained substantially in importance during the 1990s and the 2000s. Its share in capital formation in agriculture grew from 25.4 percent in 1981/1982 to 31.8 percent in 1991/1992, and then to 33.1 percent in 2002/2003; thereafter, it declined steeply to 22.6 percent in 2012/2013. Investments in orchards and plantations declined consistently during this period. The strong propensity of farmers toward asset creation is shown by the high weightage of agricultural machinery, implements, and transport equipment; irrigation resources; and land improvement works. Notably, livestock is included as an asset from 2002/2003 and captured a considerable share of fixed capital expenditure in farm business between 2002/2003 and 2012/2013, moving from 13.8 to 23.1 percent.

Between the 1950s and the 1970s, India's irrigation development took place in several phases; this led to a rapid increase in the area under large public irrigation schemes. This development can be partially attributed to India's response to the imminent danger of a food crisis during the 1960s. From the late 1970s onward, however, there was a rapid increase in the area under groundwater irrigation (Figure 3). The groundwater irrigation boom brought large benefits to millions of farmers, but also led to overexploitation and depletion of water resources. The emphasis has now shifted toward the development of micro-irrigation methods such as drip and sprinkler irrigation.

Figure 3. Net irrigated area by source of irrigation (million hectares)



Source: India, Ministry of Agriculture and Farmers Welfare (2017).

Private investment in irrigation showed an increase across states; the interstate variations, however, were stark. As shown in Table 2, in 2002/2003, private investment in irrigation varied from a meagre INR 2/hectare (ha) in West Bengal to as high as INR 1,129/ha in Haryana; similarly, in 2012/2013, investment in private irrigation ranged from INR 30/ha in West Bengal to INR 2,531/ha in

Himachal Pradesh. Investment in irrigation also depicts considerable variation across the states in terms of percentage. It accounted for about 65 percent of private investment in agriculture in Tamil Nadu in 2002/2003; this was followed by Maharashtra (53 percent), Rajasthan (53 percent), Haryana (49 percent), Andhra Pradesh (44 percent), Karnataka (37 percent), Madhya Pradesh and Chhattisgarh (32 percent), Punjab (30 percent), Kerala (24 percent), Gujarat (22 percent), and Jammu and Kashmir (12 percent). Private investment in irrigation got less weightage in Uttar Pradesh and Uttarakhand, Bihar and Jharkhand, Assam, West Bengal, Odisha, and Himachal Pradesh; in those states, it accounted for only in the range of 0.1 to 7.5 percent. These large interstate variations in private irrigation investment are attributed to different factors, including agro-climatic conditions and the status of public investment.

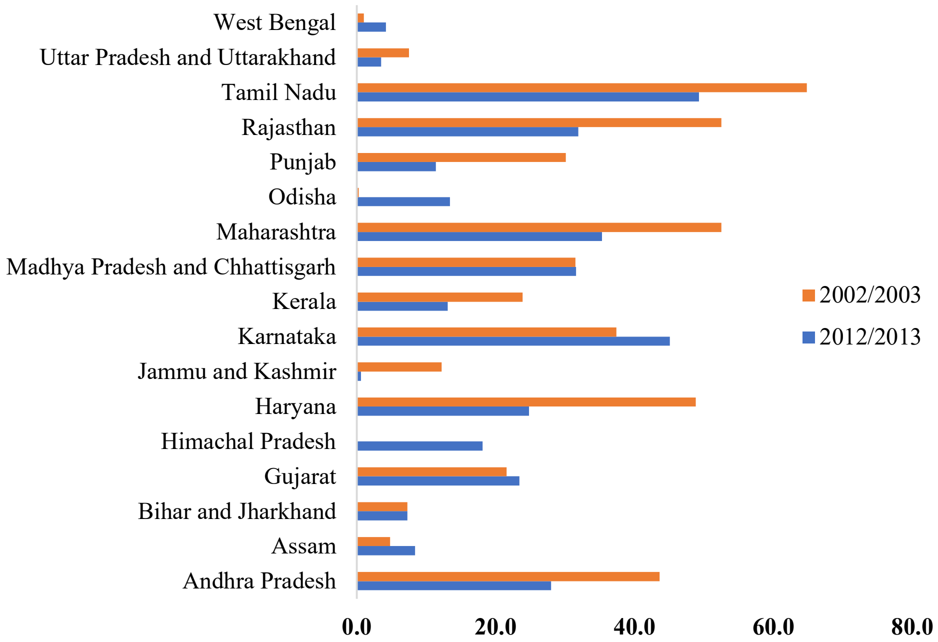
In 2012/2013, however, there was a decline in the share of irrigation investment in total private investment in agriculture. In Tamil Nadu, irrigation accounted for 65 percent of private investment in 2002/2003, but by 2012/2013 its share in agriculture investments had decreased to 49 percent; the share of irrigation investment in other states had also declined, including in Haryana (25 percent), Rajasthan (32 percent), Punjab (11 percent), Maharashtra (35 percent), Andhra Pradesh (28 percent), Jammu and Kashmir (1 percent), Kerala (13 percent), and Uttar Pradesh and Uttarakhand (4 percent). In some states, however, the share in irrigation had increased substantially between 2002/2003 and 2012/2013; these states included West Bengal (4 percent), Assam (8 percent), Odisha (13 percent), Karnataka (45 percent) and Himachal Pradesh (18 percent). In three states (Gujarat, Bihar and Jharkhand, and Madhya Pradesh and Chhattisgarh) the share remained almost constant (Figure 4).

Table 2. Trends in private investment in agriculture and irrigation and governance index, across the Indian states

States	Private investment in agriculture (INR/hectare)		Private investment in irrigation (INR/hectare)		Governance index	
	2002/2003	2012/2013	2002/2003	2012/2013	2002/2003	2012/2013
Andhra Pradesh	681	1,250	297	333	2.81	1.63
Assam	172	512	8	46	0.25	0.25
Bihar and Jharkhand	127	540	9	44	1.32	0.71
Gujarat	751	1,762	162	416	3.16	1.50
Himachal Pradesh	2,508	7,772	2	2,531	0.33	0.17
Haryana	2,312	1,611	1,129	370	2.65	2.29
Jammu and Kashmir	966	2,273	118	9	1.55	1.40
Karnataka	386	1,659	144	765	2.47	1.15
Kerala	1,532	5,447	366	667	1.46	0.54
Madhya Pradesh and Chhattisgarh	161	1,173	51	374	1.55	1.20
Maharashtra	664	1,843	348	622	3.05	1.75
Odisha	374	558	1	112	1.37	0.80
Punjab	1,376	2,799	414	285	1.82	2.11
Rajasthan	970	1,256	509	379	2.21	1.22
Tamil Nadu	1,427	1,076	925	514	2.86	1.94
Uttar Pradesh and Uttarakhand	1,184	2,791	88	91	1.71	1.15
West Bengal	262	593	2	30	0.94	0.59
All India	**932**	**2,054**	**269**	**446**	**1.85**	**1.20**

Source: India, Ministry of Statistics and Programme Implementation (n.d.). and Author's calculation.

Figure 4. Percentage share of irrigation investment in total agricultural private investment



4. RELATIONSHIP BETWEEN PUBLIC IRRIGATION GOVERNANCE AND PRIVATE INVESTMENT IN IRRIGATION

Table 2 gives an overview of trends in the irrigation governance index between 2002/2003 and 2012/2013; Annex Table 3a shows the details of year-to-year scores. At the all-India level, the governance index scores (based on weighted averages) slightly improved between 2000/2001 and 2009/2010, moving from 2.05 to 2.33; they then fell to 1.37 in 2015/2016. Among the states, only Punjab, Haryana, and Tamil Nadu have relatively higher scores.

Table 3 tabulates the state-wise governance index and private investment in irrigation. In 2002/2003, the states where both the governance index and investments were reported as being low included Assam, Bihar and Jharkhand, Himachal Pradesh, Odisha, and West Bengal; only in Kerala was the governance index low and private investment in irrigation high. Nine states had a high governance index and high private investment in irrigation; these states included Andhra Pradesh, Haryana, Karnataka, Madhya Pradesh and Chhattisgarh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh and Uttarakhand. Gujarat, Jammu and Kashmir, and Uttar Pradesh and Uttarakhand showed a high governance index and low private investment in irrigation.

In 2012/2013, we found some of the states to be in the same low–low matrix, including Assam, West Bengal, Bihar and Jharkhand, and Odisha; Himachal Pradesh, on the other hand, had shifted from low–low to low–high, meaning a low governance index with high private investment in irrigation. Kerala had moved from a low–high to a low–low matrix; this suggests that investment in irrigation had declined from 2002/2003. Among states in the high–low matrix, all shifted to other matrices; for instance, Jammu and Kashmir, and Uttar Pradesh and Uttarakhand, had moved to a low–low matrix, while Gujarat had moved to a high–high matrix. This suggests that between 2002/2003 and 2012/2013, Gujarat had done more to invest in private investment in irrigation and had improved its governance index. By 2012/2013, Maharashtra, Rajasthan, and Karnataka had shifted from a high–high to low–high matrix; this suggests that these states had maintained their private investment in irrigation in the decade since 2002/2003, but that there had been a decline in the governance index. Punjab and Haryana moved from a high–high to high–low matrix, meaning that they had sustained their governance index but had declined in private investment in irrigation from 2002/2003.

Table 3. Relationship between governance index and private investment in irrigation

2002/2003			
		Share of irrigation in agriculture (private investment)	
		Low (< 23.5)	**High (> 23.5)**
Governance index	**Low (< 1.5)**	Assam, Himachal Pradesh, West Bengal, Bihar and Jharkhand, and Odisha	Kerala
	High (> 1.5)	Jammu and Kashmir, Uttar Pradesh and Uttarakhand, and Gujarat	Maharashtra, Punjab, Rajasthan, Karnataka, Haryana, Andhra Pradesh, Tamil Nadu, and Madhya Pradesh and Chhattisgarh
2012/2013			
		Share of irrigation in agriculture (private investment)	
		Low (< 23.5)	**High (> 23.5)**
Governance index	**Low (< 1.5)**	Assam, Kerala, West Bengal, Bihar and Jharkhand, Odisha, Uttar Pradesh and Uttarakhand, and Jammu and Kashmir	Himachal Pradesh, Karnataka, Maharashtra, and Rajasthan
	High (> 1.5)	Punjab and Haryana	Gujarat, Andhra Pradesh, Madhya Pradesh and Chhattisgarh, and Tamil Nadu

Source: Authors' calculation

From this tabulation, we can infer that the first priority should be given to states where both the governance index and private investment in irrigation are low; however, in states where private investment in irrigation is high and governance index is low, more attention needs to be paid to improving governance, which will help promote efficient use of irrigation resources. The matrix does not clearly decipher the degree of relationship between governance index and private investment in agriculture; we therefore estimated the correlation coefficient between the two. An improvement in irrigation governance is expected to induce private investment in agriculture and irrigation. The correlation coefficient of the governance index is statistically positive with private investment in agriculture

(0.22) and in irrigation (0.18), though the magnitude is not very high (Table 4). These coefficients indicate that there is a significant positive relationship between irrigation governance index and investments. These relationships were subsequently further explored with regression analysis.

Table 4. Correlation coefficient

	Governance index	Private investment in agriculture	Private investment in irrigation
Governance index	1.00		
Private investment in agriculture	0.22	1.00	
Private investment in irrigation	0.18	0.59	1.00

Source: Authors' calculation

5. DETERMINANTS OF PRODUCTIVITY AND PRIVATE INVESTMENT IN IRRIGATION

This section focuses on the relationship between private investment in agriculture and irrigation, and governance and agricultural productivity. In recent years, several researchers have pointed out that even if a country or a state has the potential to develop and use modern technologies, its economic performance may not be satisfactory if it is not backed by appropriate and adequate institutions; this is even more evident in the case of agriculture. In recent years, China and Vietnam have demonstrated that governance reforms can lead to remarkable agricultural development and that governance can significantly influence a country's agricultural productivity. Hayami and Ruttan (1985) suggest that in agriculture, poor institutions and policies impede both the adoption of appropriate technology and the outcome of organizational innovation; the World Development Report (World Bank, 2007) argues that governance is essential to agricultural development.

Table 5 presents estimated results for the determinants of agricultural productivity and private investment in agriculture. Our results show that the governance index has a positive and significant influence on private investment in agriculture and that the latter in turn has a positive and significant impact on agricultural productivity. Other factors that were found to have a significant impact on agricultural productivity include fertilizer consumption and the proportion of labor employed in agriculture; literacy was also found to have a small but significant influence on agricultural productivity. Besides the governance index, other factors that were found to have positive and significant impacts on private investment include the state's per capita income and the level of its public expenditure. This is consistent with Bathla, Kumar, and Joshi (2020), who found that private investment in irrigation had the highest marginal return in augmenting agricultural income in India, in the context of the existing level of groundwater use.

Table 5. Determinants of productivity and private investment in agriculture using a structural equation model

Structural equation model	Coeff	SE
Dependent variable—productivity		
Private investment in agriculture	0.152***	(0.030)
Fertilizer consumption	0.315***	(0.035)
Agricultural employment	0.646***	(0.047)
Literacy rate	0.582***	(0.140)
Constant	5.580***	(0.494)
Dependent variable—private investment		
Governance index	0.195***	(0.059)
Share of public expenditure to GDP	1.321***	(0.127)
Per capita income	1.171***	(0.133)
Literacy rate	1.529***	(0.352)
Constant	-15.438***	(1.142)
Latent endogenous variables		
Variance of productivity	0.086***	(0.008)
Variance of private investment	0.267***	(0.025)
Observations	221	221

Source: Authors' calculation

Note: SE = standard error; Coeff = coefficient; *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels.

To complement these results and for a robustness check, we used high frequency data collected at the household, individual, and plot levels under an ICAR–ICRISAT collaborative project entitled, "Tracking Changes in Rural Poverty in Household and Village Economies in South Asia".[7] Using this data, which included 6,768 observations, we employed an instrumental variable model to estimate the effect of investment in irrigation on net farm income.

The effect of private investment in irrigation on net farm income among agricultural households showed a significant positive effect (Table 6). The results suggest that a 10 percent increase in capital formation in irrigation at the farm level will lead to 2.7 percent increase in net farm income. Other factors which were shown to affect farm income included farm size, possession of livestock, education, and occupation.

[7] Village-level studies (VLSs) are longitudinal surveys that were initiated by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in 1975; they were carried out in 10 semi-arid tropical Indian villages. The surveys continued for the next 10 years, formally ending in 1985 in response to budgetary pressures; they were resumed in 2002 in the initial six villages starting with low-frequency rounds, with higher-frequency interviews beginning in 2005/2006. In 2010, the program was redesigned under the title, "Village Dynamics in South Asia (VDSA)" and its activities were extended to eastern India and Bangladesh. This initiative was funded by the Bill & Melinda Gates Foundation and was implemented in India in collaboration with the Indian Council of Agricultural Research (ICAR), state agricultural universities, and other local organizations. Due to the relatively small sample coverage, however, VLS data cannot be treated as representative of the districts, states, or agro-climatic regions within which the villages are located.

Table 6. Impact of irrigation assets on net return of agriculture

Dependent variable—Net return from agriculture (ln)	Instrumental Model				Ordinary least squares	
	First stage		Second stage			
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Irrigation assets value (ln)			0.277**	0.145	0.104***	0.013
Operated land (ln)	1.234***	0.063	1.500***	0.202	1.823***	0.073
Livestock value (ln)	0.111***	0.012	0.139***	0.021	0.132***	0.013
Household head illiterate	-0.251**	0.131	-0.337**	0.143	-0.378***	0.162
Base: Caste: SC and ST						
Caste: OBC	0.776***	0.149	0.706***	0.194	0.800***	0.178
Caste: FC and NT	1.772***	0.191	0.294	0.332	0.628***	0.235
Age (ln)	0.310	0.189	-0.082	0.201	0.091	0.215
Household size	0.506***	0.126	0.453***	0.155	0.612***	0.146
Agriculture main occupation	1.055***	0.116	1.421***	0.202	1.327***	0.127
Instrumental variable—share of institutional credit	0.175***	0.024				
Constant	-1.213	0.741	0.789	0.784	0.160	0.845
sigma_u	2.367		2.516			
sigma_e	3.889		2.747			
Rho	0.270		0.456			
N	6765		6765			
State control	Yes		Yes			

Source: Authors' calculation

Note: SC = Scheduled Caste; ST = Scheduled Tribe; OBC = Other Backward Classes; FC = Forward Caste; NT = Nomadic Tribes; *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels.

6. CONCLUDING REMARKS

This study examined Indian state-level trends in the interlinkages between private investment in agriculture, irrigation governance, and agriculture productivity between 2001/2002 and 2015/2016. Data was sourced from the unit-level All-India Debt and Investment Survey of the 59th and 70th Rounds of the National Sample Survey; data on public expenditure on irrigation and other variables was also sourced from the Finance Accounts (India, Ministry of Statistics and Programme Implementation. National Accounts Statistics) and from the Indian government's Agriculture Statistics at a Glance (India, Ministry of Agriculture and Farmers Welfare 2015) . A governance index was constructed by taking a set of public irrigation water and infrastructure variables that also capture key dimensions of governance; these included institutions and regulatory mechanisms, participation and accountability, and service delivery. The results obtained from the structural equation model and from the instrumental variable method indicated a positive impact of governance on private investment in agriculture; an increase in private investment can, in turn, augment agriculture productivity and net returns earned by farmers.

The findings validate the existing literature on the importance of governance in the agricultural sector and the need for improvements in irrigation governance. With the exception of Punjab and Haryana, the estimated governance index is very low and has been on a declining trend since 2001/2002. Among 20 selected states, high governance and high investment in irrigation by farm households are found only in Haryana, Gujarat, Andhra Pradesh, Maharashtra, Rajasthan, and Tamil Nadu. Low governance and low investment in irrigation, as are found in Assam, Odisha, West Bengal, Kerala, Bihar and Jharkhand, Uttar Pradesh and Uttarakhand, suggest the need for improvements in governance in these states. Madhya Pradesh, Chhattisgarh, Himachal Pradesh, and Karnataka are low in governance but high in irrigation investment; these states should also thus improve governance in order to enable the efficient use of irrigation resources. In order to incentivise farmers for higher asset formation, states should make concerted efforts to more rapidly complete major to medium irrigation projects, maintain them adequately, and ensure timely delivery of water and infrastructure development.

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7. ANNEX

Table 1a. List of indicators and data sources

S. No.	Indicators	Unit	Data sources
1.	Agricultural productivity	Indian rupees/hectare (INR/ha)	Agricultural Gross Domestic Product (Agricultural Gross Domestic Product, *National Accounts Statistics* (India, Ministry of Statistics and Programme Implementation.)
2.	Fertilizer consumption	per ha	Fertilizer Association of India
3.	Agricultural employment	per ha	Agricultural Statistics at a Glance 2015 (India, Ministry of Agriculture and Farmers Welfare 2015)
4.	Private investment in agriculture	INR/ha	India, Ministry of Statistics and Programme Implementation. 2012. All India *Debt and Investment Survey (various rounds)*
5.	Share of expenditure to GDP	Share	India, Ministry of Agriculture and Farmers Welfare. 2012
6.	Per capita income	INR per capita	India, Ministry of Statistics and Programme Implementation. (n.d.) *National Accounts Statistics*.
7.	Literacy rate	Rate	India, Office of the Registrar General & Census Commissioner, India, Census, 2011

Table 1b. List of indicators for construction of governance index and data sources

S.No.	Dimensions	Variable	Unit	Data sources
1	Institutions and regulatory mechanisms	Irrigation receipts in major, medium, and minor irrigation	At 2011/2012 prices, INR/ha	India, Comptroller and Auditor General of India. (n.d.)
2		Rural teledensity	Per 100 individuals	India, Telecom Regulatory Authority of India (n.d.)
3		Length of rural roads	Kilometers per 100,000 population	India, Ministry of Road Transport and Highways (n.d).
4		Electricity tariff for agriculture	Paisa/kWh	India, Ministry of Agriculture and Farmers Welfare. 2012.

5		Water rate flow	INR	India, Central Water Commission, 2012
6	Participation and accountability	Revenue and capital expenditure in major, medium, and minor irrigation and command area development (CAD)	INR per ha at 2011/2012 prices	India, Comptroller and Auditor General of India. (n.d.)
7		Consumption of electricity for agricultural purposes	KWh/ha	India, Ministry of Agriculture and Farmers Welfare. 2012.
8	Service delivery	Net area irrigated by canals and tanks	Per 1,000 ha	India, Ministry of Agriculture and Farmers Welfare. 2012.
9		Area irrigated by other sources of water	Per 1,000 ha	India, Ministry of Agriculture and Farmers Welfare. 2012.
10		Cropping intensity	Ratio	India, Ministry of Agriculture and Farmers Welfare. 2012.

Note: paisa = INR .01.

Table 2: Goodness-of-fit and other diagnostics

Description	Fit Statistics	2001–2013
Chi-square	Chi-square	90.37
Null: Model fits as well as the saturated model	LR p-value	0.000
Null: Baseline model fits as well as the saturated model	LR p-value	0.000
Good fit if ≤ 0.05	90 percent CI of RMSEA, lower bound	0.230
Good fit if close to 1	Comparative fit index	0.850
Good fit if close to 1	Tucker-Lewis index	0.610
Good fit if < 0.08	SRMR	0.048
Good fit if close to 1	CD	0.857
Eigenvalue stability	Stability index	0.000

Source: Authors' calculation

Note: LR = likelihood ratio; CI = confidence interval; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; CD = coefficient of determination.

Table 3a. Governance index

State	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Andhra Pradesh	2.78	2.81	2.22	2.61	2.79	2.74	2.08	2.60	2.74	1.67	1.09	1.63	1.54	1.64	2.12
Assam	-0.18	-0.25	-0.44	-0.36	-0.41	-0.24	-0.42	0.04	0.70	0.21	-0.49	-0.25	-0.34	-0.67	-0.18
Bihar	1.83	1.72	1.81	1.92	1.92	1.74	1.45	1.75	1.88	1.00	0.54	0.64	0.39	0.19	0.83
Gujarat	2.87	3.16	2.36	2.58	2.64	2.65	2.11	2.74	2.81	1.51	1.04	1.50	1.21	1.11	1.77
Haryana	2.82	2.65	2.44	2.67	2.64	2.72	2.28	2.55	2.46	2.20	2.36	2.29	2.21	2.09	2.30
Himachal Pradesh	0.46	0.33	-0.25	0.26	0.39	0.50	0.06	0.32	0.44	0.37	0.10	0.17	0.10	-0.14	-0.10
Jammu and Kashmir	1.48	1.55	1.37	1.72	1.65	1.75	1.50	1.75	1.66	1.27	1.17	1.40	1.31	1.21	2.06
Karnataka	2.42	2.47	1.86	2.03	2.16	2.16	1.65	2.20	2.49	1.23	0.68	1.15	0.86	0.50	1.33
Kerala	1.46	1.46	1.05	1.29	1.35	1.36	0.94	1.48	1.83	0.79	0.32	0.54	0.41	0.08	0.47
Madhya Pradesh	1.84	1.77	1.37	1.63	1.66	1.70	1.42	1.75	2.15	1.14	0.71	1.06	0.82	0.81	1.40
Maharashtra	2.67	3.05	2.52	2.87	2.91	2.78	2.39	2.87	2.78	1.81	1.32	1.75	1.40	1.09	1.75
Odisha	1.33	1.37	0.96	1.34	1.35	1.45	1.10	1.56	2.18	0.86	0.31	0.80	0.50	0.83	1.38
Punjab	1.47	1.82	1.54	2.14	1.89	2.37	1.93	1.55	1.77	2.10	1.85	2.11	1.96	0.65	1.22
Rajasthan	1.99	2.21	1.70	1.92	1.92	2.00	1.68	2.09	2.46	1.43	0.94	1.22	0.98	0.42	0.88
Tamil Nadu	2.56	2.86	2.37	2.42	2.59	2.78	2.29	2.74	2.89	2.13	1.56	1.94	1.75	0.46	0.79
Uttar Pradesh	1.93	1.96	1.85	2.05	2.13	2.24	1.94	2.24	2.31	1.52	1.10	1.28	1.39	1.37	1.72
West Bengal	1.24	0.94	1.06	1.25	1.30	1.45	1.10	1.39	1.85	1.02	0.57	0.59	0.54	0.04	0.40
Chhattisgarh	0.82	1.32	1.04	1.56	1.44	1.52	1.24	1.73	1.79	1.27	0.90	1.33	1.02	1.10	1.44
Jharkhand	1.13	0.92	1.34	1.40	1.48	1.17	1.21	1.18	0.94	0.73	0.50	0.77	0.61	1.48	1.68
Uttarakhand	1.13	1.45	0.97	1.47	1.44	1.42	0.82	1.23	0.87	0.90	0.76	1.01	0.75	0.99	1.28
All states (weighted average)	2.05	2.16	1.77	2.04	2.09	2.12	1.74	2.14	2.33	1.43	0.97	1.30	1.09	0.84	1.37

Source: Authors' calculation