Supply Response and Investment in Agriculture in Andhra Pradesh

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ABSTRACT

The study explored the response of aggregate farm output, input use, and farm investment decisions to output and input prices, wages, technological change, public investments, and climatic factors using district-level panel data of over 39 years from Andhra Pradesh. It confirms the low, short-run aggregate output supply elasticity of Indian agriculture as found in the literature. It validates the hypothesis that the relationships between public investment, financial institutions, and farm investment of labor and capital in agriculture have not changed over the years. The empirical estimates of aggregate output supply elasticity with respect to output price (0.2), roads (0.2), markets (0.11), and net irrigated area (0.05) are higher than previous findings for selected states in India. Aggregate agricultural output responds positively to credit availability (represented by banks) and canal irrigation, each with an elasticity of 0.01. The wage elasticity (0.3) on aggregate output is higher than price elasticity (0.2), indicating that the effects of rising wages outweigh the incentives offered by output price support. Climatic factors (e.g., rainfall) significantly affect fertilizer use and aggregate output while deviation from normal rainfall adversely affects aggregate output. The study substantiates previous findings that public investment in infrastructure and financial institutions respond to the agriculture potential and agro-climatic endowments of an area. A renewed focus, therefore, is required for better targeting of public investments in areas that are relatively resource poor and have harsh agro-climatic conditions for a more inclusive growth and rural poverty reduction.

Key words: agriculture, aggregate output, supply response, public and private investments
JEL Classification: C23, C33, Q11

INTRODUCTION

Economic reforms initiated in 1991 in India induced rapid economic growth and transformation of the Indian economy. There have been, however, severe disparities in sectoral growth performances. Despite increases in public and private investment in agriculture, the growth rate of this sector has been below 3 percent in more than the past decade; the overall economic growth of the country is being driven by the non-agricultural sectors. Urbanization, income growth, and dietary change coupled with the continuous population growth are expanding demand for food. Yet the performance of the agriculture sector is lagging behind. The farm economy has failed to exploit its full potential and the opportunities for growth from the demand-side forces. Ensuring agriculture's steady growth along with the other sectors of the economy is critical since agriculture's performance is linked to the livelihood and welfare of the masses of rural population. The performance of agriculture and the rural economy urgently needs to be enhanced in order to improve food security and alleviate rural poverty as well as to sustain overall growth of the economy.

Farm production is experiencing the challenges that come with rising rural wages as economic growth accelerates and declining farm size along with a growing rural population. Given these, the responses of farm output, input use, and farm investment to changes in output and input prices, technical change, climate, and public investments need to be examined. The estimation results may be used to evaluate consequences on farm profits, output supply, input demand, and farm investments if present trends in wages, prices, technology, and infrastructure continue. Information on the agricultural sector's long-run supply response to changes in incentives, technology, climatic factors, and rural infrastructure may help policy makers to advance the process of modernization, provide incentives to farmers to invest their labor and capital in agriculture, increase total factor productivity, and reduce rural poverty.

Earlier studies have explored the long-run aggregate supply response and public investment in Indian agriculture. Fan and Hazell (1997) analyzed and compared rates of returns from public investments in less-favored and favored areas of the country. Their study recommends more public investments in less-favored regions to achieve further productivity growth and rural poverty reduction. Fan (2008) concluded that investment in rural roads yields high returns in poverty reduction by improving rural access to key services. Binswanger, Khandekar, and Rosenzweig (1993) used district-level data from India to estimate the response of aggregate crop output and private agricultural investment to government policies and public investment. Providing long-run perspectives to aggregate agricultural productivity growth and farm supply response, their study considered all factors affecting real farm profit. It found that farm investment and aggregate output supply are determined through a complex interactive process among farmers, government, and intermediaries responding to the same factors. This finding compels the use of econometric techniques that can solve the problems of endogeneity and unobserved factors during the analysis of aggregate output supply.

Objectives and Hypothesis of the Study

The study aims to understand the effect of economic transformation and infrastructure investment on the long-run supply responsiveness of the agricultural sector under new agricultural policies. In the long-run, farmers' investments of labor and capital assets in agriculture will depend on farm profits, relative wages, non-farm and urban economy, technology adoption, and availability of infrastructure and public goods and services in the village. The study tested whether or not the relationship between public investment and financial institutions has changed over time and how it differs between areas of high and low agro-climatic potential as well as between irrigated and non-irrigated areas. It examined the responses of farm output, input use, and farm investment to output prices and rising wages, technological change, public investments, and climate change in Andhra Pradesh, India.

Andhra Pradesh state was chosen as study site because a complete data set for the districts in the state is readily available at the International Crop Research Institute for Semi-Arid Tropics (ICRISAT). District-level panel data from 1970 to 2008 were used to analyze the aggregate supply response for major crops. Exogenous non-price factors and endogenous price factors were integrated and linked to study long-run aggregate agricultural supply response. The fixed effects model specification that was used addresses the endogeneity problem by capturing different responses to own- and cross-prices and spatial and temporal variations from the panel data.

It was hypothesized that the relationship between public investment and financial institutions has not changed over time and that it differs between areas of high and low agro-climatic potential as well as between irrigated and non-irrigated areas.

This paper is structured as follows: the second section presents the performance of agriculture sector in Andhra Pradesh, the third section describes and discusses the data and variables, the fourth section tackles the estimation equations, the fifth section discusses the results, and the final section provides the summary and conclusions of the study.

Performance of Agriculture in Andhra Pradesh

The performance of the agriculture sector in Andhra Pradesh is shown in Table 1. Growth rates for two periods—period I: triennium ending (TE) 1982–83 to TE 1993–94, and period II: TE 1993–94 to TE 2005–06—were calculated. The productivity growth of rice, the most staple crop, has been steady; the annual yield growth rate is around 1.5 percent. On the other hand, higher growths rates have been observed in recent years for maize (4.08%), pulses (chickpea, 5.7%; pigeon pea, 4.7%), and oilseeds (safflower, 5.7%). Annual yield growth of cotton has increased from 0.8 percent in period I to about 3 percent in period II. Similarly, the positive and impressive growth recovery in sugarcane was observed in period II as compared to the negative growth in period I. The growth rates indicate a reasonably successful diversification of agriculture toward pulses, oilseeds (despite slower growth in groundnut yields), and cotton and the revival of agriculture in Andhra Pradesh.

In TE 1982–83, the agriculture and allied sector constituted around 45 percent of the total economy in terms of share in the net state domestic product (NSDP) (Table 2). Over the years the rest of the economy grew faster than agriculture. The share of agriculture and allied sector in NSDP declined steadily from 45 percent in TE 1982–83 to 27 percent by TE 2007–09. Consequently, the share of the rest of the economy in NSDP increased from 55 percent in TE 1982–83 to 73 percent by TE 2007–08.

The agriculture and allied sector grew at the rate of 3.6 percent per annum during 1980–81 to 1989–90, declining to 2.5 percent during 1990–91 to 1999–2000. The period 2000–01 to 2007–08 saw a revival of agriculture; agriculture and allied sectors grew at 4.3 percent per annum. Overall, this

Table 1. Annual compound growth rates (%) of yield of major crops, 1980-81 to 2007-08

Crops	TE 1982–83 to TE 1993–94 (Period I)	TE 1993–94 to TE 2007–08 (Period II)	TE 1982–83 to TE 2007–08 Overall
Rice	1.55	1.67	1.55
Sorghum	1.74	3.63	2.58
Pearl millet	0.77	2.52	1.58
Maize	0.92	4.08	2.40
Finger millet	0.64	0.51	0.56
Small millets	3.33	-0.89	1.15
Chickpea	4.20	5.68	4.75
Pigeon pea	3.13	4.67	3.75
Groundnut	1.07	0.14	0.58
Sesamum	2.44	0.73	1.53
Safflower	0.19	5.69	2.80
Sunflower	4.05	1.84	2.83
Sugarcane	-0.40	0.63	0.11
Cotton	0.81	2.97	1.81

Source: Computed from data from *Statistical Abstract of Andhra Pradesh*, Government of Andhra Pradesh, Hyderabad, various issues

Table 2. Growth and composition of agriculture in total NSDP, 1980-81 to 2007-08

Particular/Period	Agriculture and Allied Sectors	Rest of Economy
Share in NSDP (%)		
TE 1982–83	44.73	55.27
TE 1992–93	36.17	63.83
TE 2002–03	29.43	70.57
TE 2008–09	26.67	73.33
Annual compound growth rates (%)		
1980–81 to 1989–90	3.59	9.33
1990–91 to 1999–00	2.50	6.56
2000–01 to 2007–08	4.31	8.40
1980–81 to 2007–08	3.50	8.05

Source: Computed from data from *National Accounts Statistics*, Government of India, New Delhi, various issues

sector grew annually by 3.5 percent during 1980-81 to 2007-08, despite decreases in yield of many crops. This was mainly due to allied sectors particularly livestock, fishery, and horticulture (fruits and vegetables), whose annual growth in output value was at the impressive rates of 7.24 percent, 6.63 percent, and 5.39 percent, respectively (Table 3).

It is noted that the revival and growth of these subsectors occurred despite the relatively hostile weather conditions and poor technology used in the production of most crops in Andhra Pradesh. It is thus interesting to know the extent to which incentives, public investment in infrastructure, financial institutions, human capital, and technology helped agricultural productivity growth and increase in the aggregate output of agriculture in this state. On the other hand, the growth rate of the rest of the economy during the same period was more than double that of the agriculture and allied sectors.

Table 3. Annual compound growth rates in value of output of agriculture sub-sectors, 1990-91 to 2005-06

Growth Rate (%)	TE 1982–83 to TE 1993–94 (Period I)	TE 1993–94 to TE 2007–08 (Period II)	TE 1982–83 to TE 2007–08 Over All
Crops	1.54	2.43	1.82
Fruits & vegetables	2.62	5.39	4.92
Livestock	5.35	7.24	6.20
Fisheries		6.63	

Source: Computed from data from *National Accounts Statistics*, Government of India, New Delhi, various issues

DATA AND VARIABLES

This study used district level panel data covering 20 districts of Andhra Pradesh for the years 1970–71 to 2007–08. The aggregate crop output is an index of 15 major crops, with the district specific prices of 1970–71 as base. Multilateral price and quantity indices for each district were constructed using the method discussed by Binswanger, Khandekar, and Rosenzweig (1993). This method aims to compute aggregate quantity and price indices that reflect both the variation in prices and quantities across and within districts over time. The Laspeyres output and price indices for each district were computed as follows: let i stand for commodity, $j = 1\dots n$ for district j, and t for time. For each commodity, the state base price P_{io} and state reference quantity Q_{io} (i.e., average production of commodity i per district) were defined as:

$$P_{io} = \frac{\left(\Sigma_j p_{ijo} q_{ijo}\right)}{\left(\Sigma_j q_{ijo}\right)} \; ; \; Q_{io} = \frac{\left(\Sigma_j q_{ijo}\right)}{n}$$

where $t = 0$ (base year = 1970–71). After substituting the state prices and reference quantities, the district-level indices were then defined, for use in comparing cross-district differences in price and quantity indices as well as in differences over time, as follows:

$$q_{jt} = \frac{(\Sigma_j q_{ijt} P_{io})}{(\Sigma_i Q_{io} P_{io})} \; ; p_{jt} = \frac{(\Sigma_i q_{ijt} p_{ijt})}{(\Sigma_i Q_{io} P_{io})}.$$

These are the multilateral Laspayres quantity and price indices, respectively, for district j in time t. The aggregate output index reflects both variation over time in each district relative to its base year (1970–71) and variations in output across districts relative to the average of all districts during the base period.

International prices are food price indices provided by the International Monetary Fund (IMF); these were converted into base 1970–71 prices. Fertilizer prices are all-India average prices of urea, super phosphate, and murate of potash weighted with yearly total consumption of nitrogen (N), phosphorus (P), and potash (K). The aggregate output price indices, weighted fertilizer prices, and international price indices were deflated using all-India wholesale price index (WPI) for primary commodities. Similarly, wage rates are daily district wages for agricultural laborers for field labor, which were deflated using the consumer price index of agricultural laborers (CPAL) for food.

Government infrastructure consists of total road length, canal irrigation, number of schools and rural literacy, number of regulated markets, and number of scheduled commercial bank branches. These variables were standardized by district-wise net cropped area (NCA) and converted into natural log values.

Private agricultural investments include tractors, pumpsets, net irrigated areas (NIA), and labor force. Agricultural intensification and technology adoption variables are represented by cropping intensity and area under high-yielding varieties. Data on tractors and pumpsets are from five yearly agricultural censuses while data on labor force are from 10 yearly population censuses. Census year data for 1972, 1977, 1982, 1987, 1992, 1997, 2002, and 2007 were used to estimate investment equations. The total number of observations was 160.

Climatic variables include rainy season (June to September) rainfall and deviations from normal rainy season rainfalls.

Estimation of Equation

Aggregate agricultural output and investments are determined jointly by actions undertaken by farmers, government agencies, and business and financial institutions in response to agricultural and economic opportunities offered by technological development and the agro-climatic endowments of a region. As output prices are jointly determined with output quantities, this study used an instrumental variable technique, where the output price as a function of the district variables and the international price index were first predicted. The same applies to the district agricultural wage, which is instrumented by the agricultural and urban populations in the district. The problem of endogenous determination of distribution of public infrastructure and banking institutions occurs as government and banks also respond to agricultural opportunities (Binswanger, Khandekar, and Rosenzweig 1993). The impact of public infrastructure on farm investment and aggregate output was expected to be high in regions with better agro-climatic endowments. Agriculturally advanced and agro-climatically well-endowed regions are likely to attract more public and private resources and capital investment and, therefore, better supply response. It is, however, hard to quantitatively characterize a regional agro-climatic potential and implied agricultural opportunities, and these are often unobserved. To avoid problems of observation and endogeneity in econometric estimation, fixed and random effects methods were applied in various studies (Binswanger et al. 1987; Lau and Yotopolous 1989; Bapna, Binswanger, and Quizon 1984; McGuirk and Mundlak 1991; Binswanger, Khandekar, and Rosenzweig 1993). The methodological superiority and relevancy of the Binswanger, Khandekar, and Rosenzweig (1993) methodology with panel data lie in its better handling of exogenous shocks, which occur simultaneously and regularly, using hybrid estimation technique that combines systems of equation and fixed effects model.

In this study, aggregate supply response regressions were estimated using single-equation fixed effects model with group dummies as well as systems of equations using three-stage least square methodology with year dummies and regional dummies for coastal Andhra, Rayalaseema, and Telangana. The latter methodology provides improved estimates of parameters over the former, hence retained for discussion. Equality constraint was imposed on coefficients of fertilizer prices in the aggregate output equation and predicted farm harvest prices in fertilizer prices equation. The specification of the model and selection of variables were primarily guided by the economic theory, past studies on the subject, and performance of the regression results. Some of the highly correlated variables were excluded from the estimation equation at the final stage. Stepwise regression was also run to select the set of variables providing best fit of the data. Since only fertilizer costs were available to calculate net revenue, the net revenue equation was not estimated and, hence, excluded from the system.

The investment regression equations were estimated using only fixed effects methodology and single-equation models. Limdep software was used in the analysis. Natural logarithmic transformations of variables were used to estimate the equations; data were corrected for first-order autocorrelation. The estimated coefficients of the explanatory variables were elastic since double logs were used. The estimated equations along with the expected sign of the explanatory variables are presented in Tables 4 and 5.

The estimation equations are as follows:

Supply response estimation equation

$$P_{ij} = \alpha_1 + \beta_{11} * TLG + \beta_{12} * RLS + \beta_{13} * FP_{ij} + \beta_{14} * PW_{ij} + \beta_{15} * I_{ij} + \beta_{16} * R_{ij-1} + \beta_{17} * M_{ij-1} + \beta_{18} * RK_{ij} + \xi_1 \quad (1)$$

$$W_{ij} = \alpha_2 + \beta_{21} * TLG + \beta_{22} * RLS + \beta_{23} * PP_{ij-1} + \beta_{24} * FP_{ij} + \beta_{25} * R_{ij-1} + \beta_{26} * B_{ij-1} + \beta_{27} * M_{ij-1} + \beta_{28} * C_{ij} + \beta_{29} * L_{ij} + \beta_{210} * Y_i + \beta_{211} * H_{ij} + \beta_{212} * IR_{ij} + \beta_{213} * T_{ij} + \beta_{214} * RW_{ij} + \beta_{215} * UP_{ij} + \beta_{216} * RK_{ij} + \xi_2 \quad (2)$$

$$Q_{ij} = \alpha_3 + \beta_{31} * {}^{TLG} + \beta_{32} * {}^{RLS} + \beta_{33} * PP_{ij\_1} + \beta_{34} * FP_{ij} + \beta_{35} * PW_{ij} + \beta_{36} * R_{ij\_1} + \beta_{37} * B_{ij\_1} + \beta_{38} * M_{ij\_1} + \beta_{39} * C_{ij} + \beta_{310} * L_{ij} + \beta_{311} * Y_i + \beta_{312} * H_{ij} + \beta_{313} * IR_{ij} + \beta_{314} * T_{ij} + \beta_{315} * DK_{ij} + \xi_3 \quad (3)$$

$$F_{ij} = \alpha_4 + \beta_{41} * TLG + \beta_{42} * RLS + \beta_{43} * PP_{ij-1} + \beta_{44} * FP_{ij} + \beta_{45} * PW_{ij} + \beta_{46} * R_{ij-1} + \beta_{47} * B_{ij-1} + \beta_{48} * M_{ij-1} + \beta_{49} * C_{ij} + \beta_{410} * L_{ij} + \beta_{411} * Y_i + \beta_{412} * H_{ij} + \beta_{413} * IR_{ij} + \beta_{414} * T_{ij} + \beta_{415} * RK_{ij} + \xi_4 \quad (4)$$

Equality Constraint: $\beta_{34} = \beta_{43}$

Real investment estimation equation

$$T_{ij} = \alpha + \beta_1 * P_{ij-1} + \beta_2 * PW_{ij} + \beta_3 * R_{ij} + \beta_4 * B_{ij} + \beta_5 * M_{ij} + \beta_6 * C_{ij} + \beta_7 * L_{ij} + \beta_8 * Y_i + \xi \quad (5)$$

$$PS_{ij} = \alpha + \beta_1 * P_{ij-1} + \beta_2 * PW_{ij} + \beta_3 * R_{ij} + \beta_4 * B_{ij} + \beta_5 * M_{ij} + \beta_6 * C_{ij} + \beta_7 * L_{ij} + \beta_8 * Y_i + \xi \quad (6)$$

$$IR_{ij} = \alpha + \beta_1 * P_{ij} + \beta_2 * PW_{ij} + \beta_3 * R_{ij} + \beta_4 * B_{ij} + \beta_5 * M_{ij} + \beta_6 * C_{ij} + \beta_7 * L_{ij} + \beta_8 * Y_i + \xi \quad (7)$$

$$AW_{ij} = \alpha + \beta_1 * P_{ij} + \beta_2 * P_{ij-1} + \beta_3 * PW_{ij} + \beta_4 * R_{ij} + \beta_5 * B_{ij} + \beta_6 * M_{ij} + \beta_7 * C_{ij} + \beta_8 * L_{ij} + \beta_9 * Y_i + \xi \quad (8)$$

$$CR_{ij} = \alpha + \beta_1 * P_{ij} + \beta_2 * R_{ij} + \beta_3 * B_{ij} + \beta_4 * M_{ij} + \beta_5 * C_{ij} + \beta_6 * L_{ij} + \beta_7 * Y_i + \xi \quad (9)$$

$$H_{ij} = \alpha + \beta_1 * P_{ij} + \beta_2 * PW_{ij} + \beta_3 * R_{ij} + \beta_4 * B_{ij} + \beta_5 * M_{ij} + \beta_6 * C_{ij} + \beta_7 * L_{ij} + \beta_8 * Y_i + \xi \quad (10)$$

where, subscripts *i* denote districts 1 …… 20, and *j* denote years 1 ……39.

TLG	= Dummy for Telangana districts
RLS	= Dummy for Rayalaseema districts
P_{ij}	= Real aggregate agricultural output price (index)
PP_{ij}	= Predicted real aggregate agricultural output price (index)

Table 4. Estimation of supply response equations

Abbreviation	Aggregate Output Price	Agricultural Wage	Aggregate Output	Fertilizer Use
Lagged year predicted real aggregate output price (index)		X+	X+	X+
Real price of fertilizer (index)	X−	X	X−	X−
Predicted real agricultural wage (index)	X−		X−	X
Real international food price (index)	X+			
Lagged year total road length (km per NCA)	X−	X	X+	X+
Lagged year commercial bank branches (no. per NCA)		X	X+	X+
Lagged year market density (no. per NCA)	X−	X	X+	X+
Canal irrigated area (% of NCA)		X	X+	X+
Rural literacy (% of total rural population)		X	X+	X+
Area under high yielding varieties (HYV) as % of gross cropped area (GCA)		X	X+	X+
Net irrigated area (% of NCA)		X+	X+	X+
Tractors (no. per NCA)		X	X+	X+
Agricultural population (no. per sq. km.)		X−		
Urban population per district (% of district total population)		X+		
Rainy season rainfall (millimeter)	X−	X	X+	X+
Deviation in rainy season rainfall from normal	X+	X−	X−	X−
Year (1970–71 to 2007–08)	X−	X	X+	X+

Table 5. Estimation of real investment equations

Abbreviation	Tractors	Pumpset, NIA	Agricultural Labor Force	Cropping Intensity	HYVs
Current year real aggregate output price (index)			X+	X+	X+
Lagged year real aggregate output price (index)	X+	X+	X+		
Predicted real agricultural wage (index)	X−	X−	X+		X−
Total road length (km per NCA)	X+	X+	X	X+	X+
Commercial bank branches (no. per NCA)	X+	X+	X+	X+	X+
Market density (no. per NCA)	X+	X+	X+	X+	X+
Canal irrigated area (% of NCA)	X+	X+	X+	X+	X+
Rural literacy (% of rural population)	X+	X+	X+	X−	X−
Year (1972 to 2007)	X+	X+	X+	X+	X+

$PP_{ij\text{-}1}$ = Predicted lagged year real aggregate output price (index)
FP_{ij} = Real fertilizer price (index)
W_{ij} = Real agricultural wage (index)
PW_{ij} = Predicted real agricultural wage (index)
I_{ij} = Real international food price (index)
Q_{ij} = Aggregate agricultural output (index)
F_{ij} = Fertilizer use (NPK, kg per ha)
$R_{ij\text{-}1}$ = Lagged year total road length (km per NCA)
$B_{ij\text{-}1}$ = Lagged year commercial bank branches (no. per NCA)
$M_{ij\text{-}1}$ = Lagged year regulated markets (no. per NCA)
C_{ij} = Canal irrigated area (% of NCA)
L_{ij} = Rural literacy (% of rural population)
Y_i = Year (1970–71 to 2007–08)
H_{ij} = Area planted to HYVs, (% of GCA)
IR_{ij} = Net irrigated area (% of NCA)
T_{ij} = Tractor (no. per NCA)
PS_{ij} = Pumpset (no. per NCA)
CR_{ij} = Cropping intensity (%)
AW_{ij} = Agricultural workers (no. per NCA)
RW_{ij} = Rural work force (no. per square kilometer geographical area)
UP_{ij} = Urban population (% of total population)
RK_{ij} = Rainy season, June to September, rainfall (millimeter)
DK_{ij} = Deviation in rainy season rainfall from its normal

The system of supply responses comprises four equations estimated simultaneously. Aggregate output prices, agricultural wages, aggregate output supply, and fertilizer use were determined simultaneously using a set of variables consisting of input and output prices, infrastructure, rural literacy, technology, and climate factors.

The estimated investment equations consist of tractor, pumpset, irrigated area, agricultural workers, cropping intensity, and area under high-yielding varieties. Explanatory variables are the same across all the investment equations and include aggregate output prices, predicted wages, road length, area under canal irrigation, rural literacy, number of bank branches, and regulated markets.

RESULTS AND DISCUSSION

This section presents and discusses the data and results of the econometric analysis. The descriptive statistics of the variables are provided in Table 6.

Determinants of Aggregate Output Prices, Wage Rates, Aggregate Output Supply, and Fertilizer Use

The regression results of the aggregate supply response equations (aggregate output prices, agricultural wages, aggregate output supply, and fertilizer use) using three-stage least squares are shown in Table 7.

Aggregate Output Price

Aggregate output price is determined by input prices influencing input use and cost of production, international food prices, infrastructure, and weather variables. These factors combined explain 59 percent of the variations in aggregate output prices in Andhra Pradesh. As expected, wage rate and international price have positive and significant effects on aggregate output price, with elasticities of 0.488 and 0.054, respectively. Fertilizer price has a weak and negative (−0.067 elasticity) effect on output price, which is not statistically significant. Road development has a strong negative effect on prices (−0.236 elasticity); it reduces transaction and transportation cost and

Table 6. Descriptive statistics of the variables (n = 740)

Variables	Mean	Standard Deviation
Aggregate agricultural output (index)	1.646	0.826
Fertilizer use (NPK kilograms per hectare NCA)	130.824	110.045
Pumpset (no. per thousand hectare NCA)	109.285	107.394
Tractor (no. per ten thousand hectare NCA)	54.436	54.985
Real agricultural wage (index)	0.043	0.015
Real aggregate agricultural output price (index)	0.017	0.009
Real international food price (index)	0.602	0.425
Real fertilizer price (index)	15.156	4.605
Agricultural workers (no. per hectare NCA)	1.827	0.588
Agricultural population (no. per square kilometer)	188.333	75.502
Urban population (% of total population)	22.640	13.085
Rural literacy (% of rural population)	34.021	15.442
Commercial bank branches (no per hundred thousand ha NCA)	41.501	24.055
Regulated markets (no. per hundred thousand hectare NCA)	8.127	3.470
Total road length (kilometer per thousand ha NCA)	14.589	7.209
Canal irrigated area (% of NCA)	15.636	16.611
Cropping intensity (%)	121.569	17.586
Net irrigated area (% of NCA)	39.468	20.167
Area under high yielding varieties (% of GCA)	35.598	18.518
Rainy season (June to September) rainfall (mm)	636.503	257.683

facilitates spatial movement of commodities. Elasticity of output price with respect to market is strong and positive (0.170). This indicates that producers can sell their output at their desired location and get better price when there is availability and connectivity with markets for their commodities. *Kharif* or rainy season rainfall has a significant though weak effect on aggregate output price (−0.003 elasticity). Similarly, trend elasticity of real aggregate output price is rather weak (0.014) though highly significant.

Agricultural Wages

The wage equation is identified by urbanization and rural population density. Other explanatory variables in the wage equation are output price, fertilizer use, roads, markets, banks, rainfall, HYV, irrigation, and tractor use. These explain about 75 percent of the variations in agricultural wages. Wage rate has a positive elasticity (0.10) on the output price and is significant at 1 percent level. Fertilizer price has a non-significant effect on wage, which may be because prices are controlled. Coefficients of road (0.086) and banks (0.034) are positive and significant. These factors are conducive to agricultural intensification and facilitate movement of labor force. The effect of market on wage is not different from zero. Wage elasticities with respect to canal irrigation and rural literacy are 0.045 and 0.084, respectively. Areas under HYV and rainfall have a positive but non-significant effect on agricultural wages. Net irrigated area has a significant and positive

Table 7. Regression estimates of aggregate supply response model (three stage least squares)

Variables	Aggregate Output Price	Agricultural Wage	Aggregate Output	Fertilizer Use
Constant	-2.026* (0.402)	-3.906* (0.339)	1.412* (0.335)	-0.645 (0.633)
Dummy for Rayalaseema	-0.0769*** (0.042)	0.028 (0.028)	-0.102* (0.035)	0.031 (0.047)
Dummy for Telangana	-0.545* (0.031)	0.166* (0.032)	-0.417* (0.028)	0.154** (0.058)
Predicted real aggregate output price for lagged year		0.099* (0.031)	0.200* (0.015)	0.007 (0.048)
Real price of fertilizer	-0.067 (0.065)	-0.048 (0.049)	-0.007 (0.048)	0.023 (0.106)
Predicted real agricultural wage	0.488* (0.101)		0.289* (0.081)	0.669* (0.118)
Real international food price	0.054* (0.017)			
Total road length in lagged year	-0.236* (0.034)			
Total road length in 2 lagged year		0.086*** (0.046)	0.209* (0.030)	0.729* (0.079)
Commercial bank branches in lagged year		0.034**** (0.021)	0.010 (0.009)	0.286* (0.036)
Market density in lagged year	0.170* (0.042)	-0.022 (0.025)	0.112* (0.033)	-0.036 (0.045)
Canal irrigation		0.045* (0.007)	0.009* (0.003)	-0.063* (0.013)
Rural literacy		0.084*** (0.050)	-0.065* (0.022)	0.307* (0.086)
HYV area		0.001 (0.026)	0.033* (0.011)	0.419* (0.047)
Net irrigated area		0.088* (0.029)	0.049* (0.012)	0.262* (0.048)
Tractors		-0.037** (0.015)	-0.005 (0.007)	0.196* (0.027)
Agricultural population		-0.003 (0.027)		
Urban population		0.096* (0.019)		
Rainy season rainfall	-0.033* (0.009)	0.003 (0.018)		0.106* (0.032)
Deviation in rainy season rainfall			-0.006** (0.002)	
Year (1970–71 to 2007–08)	0.014* (0.003)	0.016* (0.002)	0.011* (0.003)	0.006**** (0.004)
R^2	0.603	0.749	0.726	0.915

Note: *, **, ***, **** are level of significance at 1,5,10, and 15 percent, respectively.
Figures in parentheses are the standard errors

(0.088 elasticity) effect on wage, whereas that of tractor is negative but also significant (-0.037 elasticity). This may be because tractors have a labor-saving and/or labor-displacing effect on agricultural operations. As expected, agricultural population has a negative effect (−0.003 elasticity) while urban population has a much larger positive and significant effect (0.10 elasticity) on agricultural wage. The wage trend coefficient is positive and significant (0.016).

Aggregate Output

The explanatory variables in the output equation account for about 73 percent of the variations in the aggregate output. Output price has a significant and positive effect (0.2 elasticity) on aggregate output. This supply elasticity is higher than the aggregate elasticity found in an earlier study by Binswanger, Khandekar, and Rosenzweig (1993) (0.06 using domestic prices and 0.13 using international prices). This result confirms earlier findings that aggregate supply elasticity in the short-run is small, hence inelastic. The elasticity of output with respect to fertilizer price has the expected sign but is not significant. This may be due to endogeneity problem when estimating fertilizer price elasticity with domestic output price in which fertilizer price does not appear to affect aggregate output. While the coefficient of agricultural wage is significant, it unexpectedly has a positive sign (0.289 elasticity). As expected, the effects of infrastructure such as road (0.21 elasticity), market (0.112 elasticity), and irrigation canal (0.01 elasticity) are positive and highly significant. It may be noted that wage elasticity for the aggregate output exceeds the output supply elasticity, supporting the results of a similar analysis by Binswanger et al. (2011) using microdata of the National Council of Applied Economic Research (NCAER), New Delhi. There is a possibility of households releasing more labor and utilizing more efficiently with the increase in the opportunity cost of labor. Urbanization and rapid expansion of the non-farm sector would have positive effects on agricultural production and household labor income along with wage rise. This is achieved through the positive effects on agricultural investment, intensive cultivation, and improved resource use efficiency in the production. Binswanger et al. (2011) highlighted the reversal of linkages between urbanization and non-farm economy and agricultural growth and the positive effects of wages on agricultural output. This study's findings confirm the overwhelming impact of infrastructure on aggregate crop output found in Binswanger et al. (1987) using international data and Binswanger, Khandekar, and Rosenzweig (1993) focusing on India.

The effect of banks on aggregate output is positive as well (0.010 elasticity) though non-significant. The trend elasticity of output is positive and highly significant (0.011). Deviation of *kharif* rainfall from normal has a negative and significant (−0.006 elasticity) effect on output while technological factors such as HYV and NIA have a positive and highly significant effect (elasticity of 0.033 and 0.049, respectively). The coefficient of tractor use is negative (−0.005 elasticity) and not significant. The zero impact of tractors is consistent with the fact that tractors are a labor substitute, thus not an output enhancer.

Fertilizer Use

The demand for fertilizer is influenced by output price and its own price, agricultural wage, rural infrastructure, rural literacy, rainfall, and technological factors like HYV and irrigation. These factors combined explain around 92 percent of the variations in fertilizer use. The coefficients of output and fertilizer prices are non-significant, indicating that fertilizer demand increases with the rise in infrastructure investments, except for canal irrigation which has a negative coefficient. The following have positive and significant effects on fertilizer demand as indicated by their elasticities: road (0.729), bank (0.286), technology variables such as HYV (0.419) and NIA (0.262), tractor use (0.196), rural literacy (0.307), and rainfall (0.106). Similarly, the trend coefficient of fertilizer use is positive and significant (0.006). Moreover, the significant and positive (0.669 elasticity) effect of agricultural wage on fertilizer demand confirms that fertilizer and labor are substitutes.

These results validate the findings of other studies on the growth of fertilizers and influence of agro-climatic endowments on the potential of green revolution technologies. They also confirm the results of Binswanger, Khandekar, and Rosenzweig (1993) on the influence of banks on demand for fertilizers.

Determinants of Real Investments in Agriculture

The results of the estimated fixed effects model on the determinants of investment are given in Table 8. Census year data were used. The results relate to average annual levels of investment for each of the inter-census intervals.

Aggregate output price index has positive and significant effects on investments in irrigation (0.11 elasticity), cropping intensity (0.04 elasticity), and area planted to high-yielding varieties (0.2 elasticity). However, it negatively affects agricultural work force (−0.12 elasticity). The lagged aggregate output price index indicates an increasing investment in tractor (0.3 elasticity) and agricultural workforce (0.07 elasticity). The effect of aggregate output price on investments in pumpset is positive but not significant (0.04 elasticity).

Agricultural wage influences positively and significantly investment in tractors; the elasticity of stock of tractor is high (1.755) and significant. This indicates the presence of a strong response and substitution effects of tractors on agriculture labor with rising wages. Similarly, agricultural wage affects positively and significantly investments in irrigation (net irrigated area) and areas planted to high-yielding varieties. Its effects on investments in pumpset and agricultural work force are positive but not significant.

Road has a positive and significant effect on agricultural workforce (0.2 elasticity) and areas planted to high yielding varieties (0.7 elasticity). Its effects on real investments in tractors, pumpsets, and cropping intensity, however, are not significant. This indicates that public investment on roads has a relatively better impact in terms of technology adoption and labor movements. The implication is that such public investments are likely to be more effective in technically-advanced agricultural regions.

Banks increase private investments in tractors (0.46 elasticity elasticity), pumpsets (0.61), agricultural work force (0.16 elasticity), and areas planted to high-yielding varieties (1.34 elasticity). As in the case of roads, the results for banks indicate that the impact of banks is most pronounced in agriculturally better-to-do areas. Similarly, intensity of market has positive and significant effects on private investments. However, banks and market do not significantly affect net irrigated area and cropping intensity. Canal irrigation also has increasing effects on private investments in agriculture, though its impact on tractor use, cropping intensity, and areas planted to HYV is not significant. Rural literacy increases investment in irrigation (pumpset, 0.5 elasticity; net irrigated area, 0.33 elasticity), and adoption of high-yielding varieties (1.16 elasticity). This finding is consistent with those of other studies and current development literature on education's positive effect on adoption of new technology.

Table 8. Regression estimates of real investment model (single equation fixed effects)

Variables	Tractor	Pumpset	Net Area Irrigated	Agricultural Work Force	Cropping Intensity	Area planted to HYV
Real aggregate output price			0.107** (0.053)	-0.115* (0.037)	0.037** (0.018)	0.201* (0.072)
Real aggregate output price in lagged year	0.299** (0.117)	0.041 (0.088)		0.067**** (0.041)		
Predicted real agricultural wage	1.775* (0.921)	0.521 (0.693)	1.574* (0.418)	0.201 (0.309)		-1.109* (0.652)
Total road length	-0.315 (0.23)	-0.221 (0.173)	-0.248** (0.104)	0.198** (0.077)	-0.015 (0.038)	0.661* (0.164)
Commercial banks	0.459* (0.127)	0.613* (0.095)	0.059 (0.057)	0.162* (0.041)	0.013 (0.018)	1.344* (0.089)
Market density	0.561** (0.217)	0.472* (0.163)	0.199*** (0.102)	0.049*** (0.074)	0.013 (0.039)	0.045 (0.149)
Canal irrigation	0.049 (0.061)	0.069**** (0.046)	0.064** (0.028)	-0.035*** (0.020)	0.003 (0.011)	0.100 (0.042)
Rural literacy	-0.292 (0.303)	0.493** (0.233)	0.328** (0.137)	0.076 (0.098)	0.022 (0.049)	1.162* (0.206)
Year (1970–71 to 2007–08)	-0.074 (0.074)	-0.044 (0.056)	-0.302* (0.034)	0.011 (0.024)	0.009 (0.010)	0.174* (0.051)
R^2	0.959	0.958	0.959	0.941	0.852	0.936

Note: *, **, ***, **** are level of significance at 1,5,10, and 15 percent, respectively.
Figures in parentheses are standard errors

SUMMARY AND CONCLUSIONS

India's economic reform and structural transformation are passing through a phase wherein farm production is experiencing the challenges that come with rising rural wages as economic growth accelerates and declining farm size along with a growing rural population. Using data on Andhra Pradesh, this study focused on how to promote overall agriculture growth and efficiency of farm production. It examined the responses of aggregate farm output, input use, and farm investment to increasing output prices and rising wages, technological change, public investments, and climate change. The inter-relationships among the investment decisions of government, financial institutions and farmers and their joint effects on agricultural investment and output were quantified. Enhancing the long-run production frontier and aggregate output growth of agriculture through strengthening public infrastructure and other factors that affect real farm profit and incentives are considered to be the a viable option and possible solution.

The aggregate output supply response with respect to price is 0.2. This confirms the fact that aggregate agriculture supply is inelastic in the short run, though this study's estimates are significantly higher than those in the literature. Binswanger, Khandekar, and Rosenzweig (1993) calculated the aggregate crop output supply elasticity for India to be 0.06 using domestic price and 0.13 using international price. Similarly, the aggregate output supply elasticities in this study with respect to infrastructure such as roads (0.21), markets (0.11), and net irrigated area (0.05) are higher than those of Binswanger, Khandekar, and Rosenzweig (1993). The wage elasticity of the aggregate output supply (0.3) also exceeds the supply elasticity with respect to output price found in the present study, supporting the results of Binswanger et al. (2011), which used microdata from the NCAER.

Fertilizer use increases with wages (0.67 elasticity), roads (0.7 elasticity), and banks (0.3 elasticity). This result confirms the findings of Binswanger, Khandekar, and Rosenzweig (1993) that, with the availability of a bank in the locality, fertilizer use increases and substitutes for labor. Similarly, it increases with adoption of HYV (0.4 elasticity), NIA (0.3 elasticity), and tractor (0.2 elasticity). This indicates that fertilizer use responds more to Green Revolution technologies in areas with irrigation. Commercial bank increases investments in tractors (0.5), pumpsets (0.6), agricultural workforce (0.2), and areas planted to HYV (1.34).

It may be concluded that the relationships between public investment, financial institutions, and farm investment of labor and capital in agriculture have not changed over the years. These actors respond to the agriculture potential and agro-climatic endowments of the area. As such, there is a need for renewed focus and better targeting of public investments in areas that are relatively resource poor and have harsh environmental conditions for a more inclusive growth and poverty reduction. Climatic factors such as rainfall significantly affect fertilizer use and aggregate output. Similarly, output price, wages, input use, and aggregate output are influenced by level of infrastructure development and availability of banks. The empirical results from this study illustrate the potential to increase aggregate crop output through improvement of investment priorities and proper government policies on output and input prices. That output responds more to its own price than to input prices (e.g., fertilizer) suggests that agricultural policy should also focus on improved input supply such as access to credit and market. The development of roads, banks, markets, canals, and rural literacy increases fertilizer use and aggregate output; these variables are highlighted as major drivers for aggregate output increase. Investment in irrigation and other infrastructure may help to mitigate the adverse effects of climate change on aggregate output and supply response.

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