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Role of Infrastructure in Productivity and Diversification of Agriculture

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1. Introduction

Efficiency and competitiveness needs to be the cornerstone in any agricultural development strategy in the liberalized economic environment. This question is particularly relevant to the small farmers in developing countries where size of holdings are very small and traditional crops with low productivity are not capable of providing sufficient income and employment to the population dependent on agriculture sector. In the State of Tamil Nadu, 74 per cent of the holdings are below one hectare in size and nearly 90 per cent of them are below 2 hectares. Productivity is decelerating for most of the crops in 90s at low levels of average productivity compared to world average. Securing the livelihood security for this large number of farmers involve increasing the productivity and diversification of crops. Significant increases in investment in rural infrastructure would help increase production and consumption, decrease malnutrition, and increase livelihood security. In the emerging global order, farmers need to invest, innovate and take risks for increasing productivity in small farms in the developing countries. For which, assured market for produces and easy access to input market is a precondition. Poor transport infrastructure limits market access for many farmers in the developing countries. Producers need to be better linked to markets through investment in infrastructure aimed at reducing transport and marketing costs to realize the market potential. But public investment in agriculture has been declining in real terms in the 90s. Institutional rigidities and infrastructural deficiencies need to be addressed to make the agriculture competitive. But the survey of literature clearly demonstrates there are limited studies on the role of infrastructure in enabling agriculture to respond the challenges of globalization. Most of the studies consider only road and irrigation in rural infrastructure, leaving other important productivity enabling infrastructure. This study besides irrigation and road also takes into account input and output markets and commercial vehicles as infrastructural variable. Earlier studies on agricultural productivity and infrastructure considered output growth while in the present study productivity is analyzed through Total Factor Productivity (TFP). TFP is conceptually superior measure to study the contribution of infrastructural variables, as it explains the growth in output which is not explained by the growth in the traditional production inputs.

2. Survey of Literature

Research in Asia found that in villages with better access to roads, fertilizer costs were 14 percent lower, wages were 12 percent higher and crop output was 32 percent higher (IFPRI,1990). In Africa, rural road construction has been found to be associated with increases in agricultural production, especially in non-food export crops, expanded use of agricultural credit, increases in land values, proliferation of small shops and expansion of rural markets (Anderson et al., 1982). Numerous sources of such "horizontal" impacts of policy reform can be found in developing country settings. For example, geographic disparities in access to human and physical infrastructure affect prospects for participating in the opportunities created by greater openness to external trade (Ravallion, 2004). Infrastructure helps poorer individuals and underdeveloped areas to get connected to core economic activities, thus allowing them to access additional productive opportunities (Estache, 2003). Similarly, infrastructure development in poorer regions reduces production and transaction costs (Gannon and Liu, 1997). For example, in poor rural areas infrastructure expands job opportunities for the less advantaged by reducing the costs to access product and factor markets (Smith et al. 2001). The fixed transaction costs (those not dependent on commercialized volume) of subsistence farmers' to access product markets are equivalent to a value-added tax of approximately 15 percent, illustrating the potential for raising producer welfare with effective infrastructure investments. (Renkow, Hallstrom, and Karanja, 2004). Estache and Fay (1995) found that enhanced access to roads and sanitation has been a key determinant of income convergence for the poorest regions in Argentina and Brazil. Infrastructure access can raise the value of the assets of the poor. Improvements in communication and road services imply capital gains for these poor farmers (Jacoby, 2000). Some research studies consider the issue of infrastructure efficiency. Hulten (1996) finds that differences in the effective use of infrastructure resources explain one-quarter of the growth differential between Africa and East Asia, and more than 40 percent of the growth differential between low- and high-growth countries. Esfahani and Ramirez (2002) report significant growth effects of infrastructure in a large panel data set in which the contribution of infrastructure is affected by institutional factors. Ferreira (1995) presents a model of public-private capital complementarity in which expanding public investment reduces inequality. Another strand of recent literature analyzes the role of infrastructure on income inequality. Infrastructure development can have a positive impact on the income and welfare of the poor over and above its impact on average income (Lopez 2004). César Calderón (2004) found that inequality declines not only with larger infrastructure stocks but also with an improved quality of infrastructure services regardless of the econometric technique and the inequality measure employed (Gini coefficients or income shares). The links between infrastructure services and inequality were also discussed by Estache, Foster and Wodon (2002), Estache (2003) and World Bank (2003).

The present study aims at answering the research questions such as (1) what is the role of infrastructure in agricultural productivity? (2) To what extent infrastructure development in public sector affects efficiency and diversification in crop production? (3) Whether infrastructure has differential impact on profitability of agriculture among different size groups of farmers? And (4) what kind of relationship exists between public and private investment in agricultural infrastructure? The specific objectives of the study are:

3. Objectives of the study

i. To estimate the productivity gains from infrastructure investments in agriculture,

ii. To analyze the role of infrastructure in crop diversification and efficiency of crop production,

iii. To study the private infrastructural investment under differential public investment; and

iv. To identify the constraints in fostering public investments in agriculture and suggest policies to augment them

4. Methodology

a. Infrastructure and productivity

Total Factor Productivity (TFP) is defined as growth in output which is not explained by input growth but a combined result of technical progress and technical efficiency or the efficiency with which factors are used, given the technical progress, to produce output (Fan, 1991). It is a conceptually superior measure to gain richer insights into the sources and efficiency of agricultural production growth. For example, Fan and Hazell (2000) modeled agricultural output as a function of traditional farm inputs, technology, infrastructure and time. The significant and positive time trend in the model suggested the existence of important but missing technology and infrastructure variables in the model. These may include the impacts of agricultural research not captured by the High Yielding Varieties variable (eg research on improved husbandry practices), agricultural extension and so on. TFP captures all such variables as it is defined as growth in output which is not explained by the growth in input. TFP indices are constructed to compare performance of a given system at two points in time (inter-temporal TFP indices) or to compare two systems at a given point in time (interspatial TFP indices). If the ratio of total outputs to total inputs is increasing, then the ratio can be interpreted to measure that more outputs can be obtained for a given input level. Differences in TFP over time or across farming types can result from several factors (Ahearn et al. 1998), such as: (i) differences in efficiency (less than the maximum output is produced from a given input bundle), (ii) variation in scale or level of production over time, as the output per unit of input varies with the scale of production or (iii), technical change. TFP is achieved over time on account of the farmer's rationality in resource use and as a follow up of the economic policies and environment (Kaur and Sekhon, 2005) and infrastructure like markets, roads and vehicles not only aids in making such rational choices but also in achieving them. Surprisingly, one rather neglected determinant of productivity growth is public infrastructure (Mamatzakis, 2003) even though agriculture is an economic activity in which the role of public infrastructure is particularly influential. Public infrastructure is one of the productive inputs for Greek agriculture (Fousekis and Pantzios, 2000) and it is positively correlated with the Total Factor Productivity of Greek agriculture (Mamatzakis, 2003). Aschauer (1989) finds that the stock of public infrastructure capital is a significant determinant of aggregate TFP.

TFP is the ratio of aggregate outputs to aggregate inputs used in the agricultural production process. Total output and total input are measured in an index form. A Torngvist-Theil index is used to aggregate both inputs and outputs. The major problem with the index number approach lies in deriving aggregate output and input measures that represents the numerous outputs and inputs involved in most production processes. The most popular indexing procedure is the Divisia index. As Richter (1966) has shown, the Divisia index is desirable because of its invariance property: if nothing real has changed (for example, i f the only input quantity changes involve movements along an unchanged isoquant), then the index itself is unchanged (Alston, Norton, and Pardey 1998). The formula for the index of aggregate production is

$$\ln YI_t = \Sigma_i \, 1/2(S_{i,t} + S_{i,t-1}) \ln(Y_{i,t} / Y_{i,t-1}) \qquad -1$$

where In YI_t, is the log of the production index at time t, $S_{i,t}$ and $S_{i,t-1}$, $_I$ are output i's share in total production value at time t and t-1, respectively, and $Y_{i,t}$ and $Y_{i,t-1}$, are quantities of output i at time t and t-1, respectively. Farm prices are used to calculate the weights of each crop in the value of total production. Five cereal crops (rice, jowar, bajra, ragi, and maize), 2 pulse crops (black gram and green gram), 4 vegetable crops (onion, brinjal, lady's finger and tomato), 2 oil seed crops (groundnut and gingelly) and 4 commercial crops (Cotton, sugarcane, turmeric and chillies) were included in this measure of total production. The formula for the index of aggregate input is:

$$\ln XI_t = \Sigma i \, 1/2(W_{i,t} + W_{i,t-1}) \ln(X_{i,t} / X_{i,t-1}) \qquad -2$$

$W_{i,t}$ and $W_{i,t-1}$ are cost shares of input i in total cost at time t and t-1, respectively; and $X_{i,t}$ and $X_{i,t-1}$ are quantities of input i at time t and t-I, respectively. Five inputs (labor, land, fertilizer, machine labour, and pesticides) are included.

Labor input is measured as the total number of hours of male and female labor employed in agriculture at the end of each year; land is measured as gross cropped area; fertilizer input as the total amount of nitrogen, phosphate, and potassium used; machine labor is measured in number of hours. The wage rate for agricultural labor is used as the price of labor to aggregate total cost for labor, the costs of machine labor, plant protection chemicals are taken directly from the production cost surveys, and the fertilizer cost is the product of total fertilizer use and fertilizer price calculated as a weighted average of the prices of nitrogen, phosphate, and potassium. The land cost is measured as the residual of total revenue net of measured costs for labor, fertilizer, machine labor and plant protection chemicals. Therefore, the cost share of each input is calculated by its respective cost divided by total production cost.

Total factor productivity (TFP) is defined as aggregate output minus aggregate inputs.

$$\ln TFP_t = \Sigma_i\ 1/2(S_{i,t} + S_{i,t-1}) \ln(Y_{i,t} / Y_{i,t-1}) - \Sigma i\ 1/2(W_{i,t} + W_{i,t-1}) \ln(X_{i,t} / X_{i,t-1}) \qquad -3$$

Where ln TFP, is the log of the TFP index

The following model is proposed to identify the factors contributing the TFP growth in agriculture. This model include infrastructure variable like irrigation, road density, research institutes, markets and other production related variables like Area under High Yielding Varieties and rainfall. All the variables in the model are in logarithm.

$$TFP = \alpha + \beta_1\, irri + \beta_2\, roadesity + \beta_3\, mkts + \beta_4\, ComVec + \beta_5\, pumset + \beta_6\, HYV + \beta_7\, Rfall + \beta_8\, Lit + \eta_i + u \qquad -4$$

Where,

TFP	=	Total Factor Productivity
Infrastructure Variables		
Irri	=	Irrigation intensity
Roadesity	=	Road density
mkts	=	Number of input and output marketing centers
ComVec		Number of Commercial vehicles
Pumset	=	Number of pumpset /hectare

Other Variables

HYV	=	Area under High Yielding Varieties
Rfall	=	Annual rainfall
Lit	=	Rural Literacy rate
η_i		To capture district specific fixed effects

Variables used in the above model are discussed below.

1. Irrigation intensity

Irrigation intensity is the ratio of gross irrigated area to net irrigated area. Most of the irrigation infrastructure is created through public investment.

2. Road density

Road density is the ratio of total road length to the geographical area of the district. The road density augments the location advantage of farms with respect to transport of input and output and access to markets. World Development Report (2005) argues Roads and commercial vehicles increase the choices of farmers not only in the selection of better and appropriate inputs but the selection of efficient product markets also. Roads allow farmers to move their goods more often and more cheaply. In some cases the time it took to get to rural markets fell by half. In the areas benefiting from the road upgrading, the land is more productive, and the volume and value of agricultural produce is higher. As it became easier to ship produce quickly without damaging it, farmers shifted from low-value cereals to high-value fruit. As the price of bringing goods to the farms fell, farmers used more fertilizer.

3. Input and Output markets

The number of dealers of fertilizers, pesticides and seeds are includes in input markets. Output markets include the number of rural shandies, farmers' markets, regulated markets, co operative marketing societies.

4. Commercial vehicles

The bulkiness of the agricultural outputs and inputs is an inherent characteristic which limits the access to efficient markets. The easy access and cheap transport overcome this limitation in achieving efficiency and increasing the total factor productivity.

5. Pump set

Ratio total pump set to the cropped area of the district indirectly measure the electricity consumption, an important infrastructural variable in agricultural production.

6 High Yielding Varieties

High yielding varieties represent technological improvement and contribute for total factor productivity in agriculture.

7. Rain fall

Rain fall has significant influence on crop growth and agricultural productivity and hypothesized to have major influence on total factor productivity.

8. Rural literacy rate

Education of the farmer plays vital role in efficiency in production, e.g., a better educated farmer will do better in growing a crop than the less educated farmer growing the same crop.

b. Infrastructure and Diversification

There is a strong evidence that it is not the farm size, but infrastructure like access to motorable road, market and irrigation which determine the extent, success and profitability of diversification through high paying crops like off-season vegetables (Chand 1995). Timmer (1997) stylizes the contrast between the diversification of national food production and that of farm-level production for Asian agriculture. He speculates that, as agricultural transformation continues further, the diversification level of national production might go up again because improved commercialization of agriculture allows ecologically diverse regions to pursue their comparative advantage. But the diversification level at the farm level is likely to go down, since the principle of comparative advantage continues to work, driving each farm to specialize in the activity it can perform the best. But some studies report mixed effects of infrastructural variables on crop diversity. A study in Ethiopia finds households farther away from an all-weather road grow more diverse barley and maize, but less diverse teff. Households in communities located farther away from the district town have less diverse maize (Benin et al, 2004). Similarly another study in West Punjab reports opposite influence of irrigation and road density on crop diversity in two periods. In general, irrigation development makes it technically feasible to grow diverse crops. During the colonial period, when large-scale irrigation was first introduced, crop shifts to high value-added crops implied a more diversified cropping pattern, thereby contributing to an increase in the diversification index. In contrast, after the early 1950s, when large-scale canal irrigation was becoming an obsolete technology, further shifts to high value-added crops in highly irrigated districts implied more specialization. The coefficient on road density also takes opposite signs-districts with better road net-works are associated with moderately positive trends before 1952, whereas they are associated with substantially negative trends after 1952. The strongly negative effect in the second period seems to suggest that the road infrastructure helps specialization in agriculture when specialization occurs all over the districts. We can interpret this as the effect of reduced transportation costs in narrowing the gap between the market price of a commodity and its farm-gate price. The positive effect in the first period (although its significance level is only marginal) seems to suggest that the initial development of roads occurred only locally so that its impact on district-level specialization was weak (Kurosaki, 2003). The significance of crop shifts in the process of agricultural transformation can be understood through the development of rural markets. If all producers choose crops on the principle of comparative advantage, and all producers face the same relative prices land reallocation occurs only when technology or relative prices change. In agriculture, however, the assumption that all producers face the same relative prices is not justifiable because spatial dimensions and transportation costs are important in crop production (Takayama and Judge, 1971; Baulch, 1997).

Specialization or diversification is measured through indices like Herfindal index, Simpson index and Entropy index (Kelly Ryan and Patel 1995, Pandey and Sharma 1996, Chand 1996). Simpson Index of Diversity (SID) would be used to capture the diversification of agriculture as it provides a clear dispersion of crops in a geographical area. The following model is specified with all the variables in logarithm.

$$SID = \alpha + \beta_1\, irri + \beta_2\, roadesity + \beta_3\, mkts + \beta_4\, ComVec + \beta_5\, pumset + \beta_6\, HYV + \beta_7\, Rfall + \beta_8\, Lit + \eta_i + u \qquad -5$$

Where,

SID	=	Simpson Index of Diversity
		$SID = 1- \sum(a_j/A)^2$
		Where, aj = Area under jth crop; A = Gross cropped area

Infrastructure Variables

Irri	=	Irrigation intensity
Roadesity	=	Road density
mkts	=	Number of input and output marketing centers
ComVec	=	Number of Commercial vehicles
Pumset	=	Number of pumpset /hectare

Other Variables

HYV	=	Area under High Yielding Varieties
Rfall	=	Annual rainfall
Lit	=	Rural Literacy rate (Percentage)
η_i		To capture district specific fixed effects

c. Infrastructure and Efficiency in production

The efficiency in agricultural production for major crops will be studied under different infrastructural endowments. Primary data on agricultural production will be collected from 60 farmers each from two districts Viz., with highest and lowest infrastructural endowment.

i. Infrastructure Index

An infrastructure index was constructed to identify the districts with high and low infrastructure. Adopting the methodology of Iyengar and Sudarshan (1982) an Infrastructure index was constructed. Let X_{id} represent i^{th} infrastructure in d th district.

$$Y_{id} = (X_{id} - Min\ X_{id}) / (Max\ X_{id} - Min\ X_{id}) \qquad -6$$

Where Min X_{id} and Max X_{id} are respectively, the minimum and maximum of X_{i1}, X_{i2}, ….. $X_{in.}$ The scaled values, Y_{id} vary from 0 to 1. Accordingly, Namakkal and Ramanathapuram districts were selected to represent high and low infrastructural endowed districts respectively.

ii. Technical Efficiency in agricultural production: Stochastic Production Frontier Estimation

Since Farrell (1957) seminar paper, there has been a growing body of literature in the methodology and their applications to efficiency measurement. While early methodologies were based on deterministic models that attribute all deviations from the maximum production to efficiency, recent advances have made it possible to separately account for factors beyond and within the control of firms such that only the latter will cause inefficiency. Aigner et al. (1977), Meeusen and Van Den Broeck (1977) independently proposed the stochastic frontier production function with two independent error components. The one accounts for the presence of technical inefficiencies in production and the other accounts for measurement errors in output, weather, etc and the combined effects of unobserved inputs in production. This methodology was used in number of studies to measure the technical efficiency (Tzouvelekas et al..2001, Wadud and White 2000, Sharma et al., 1999, Battese and Coelli 1995). Using a two-stage procedure, the predicted efficiency indices were regressed against a number of household/farm characteristics, in an attempt to explain the observed differences in efficiency among farms (Nkamleu, 2004; Nyemeck et al., 2003; Bravo-Ureta and Pinheiro, 1997). Although this exercise has been recognized as a useful one, the two-stage estimation procedure is inconsistent in its assumptions regarding the independence of the inefficiency effects in the two estimation stages. The two-stage estimation procedure is unlikely to provide estimates which are as efficient as those that could be obtained using a single-stage estimation procedure. Coelli (1996) and Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm specific characteristics. The advantage of Battese and Coelli (1995) model is that it allows estimation of the farm specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure

(Rahman, 2003). In this study the general stochastic production function (Battese and Coelli, 1993, 1995), with inefficiency effects is defined as:

$$y_i = f(x_i; \beta) \exp(v_i - u_i) \qquad i = 1,\ldots,n \qquad (1)$$

where *yi* denotes the output quantity of the *i*th farm, *xi* is a (1 x *J*) vector of input quantities and β is a (*J* x 1) vector of unknown parameters to be estimated. The *vi* are two-sided random variables associated with measurement errors in output and other noise in the data which are beyond the control of firms. *vi* are assumed to be independently and identically distributed *N*(0, σ *v*2) and independent of the *ui*. In the absence of the stochastic term *ui*, the model in (1) reduces to a purely deterministic (mean) production function. The *ui* are defined as non-negative random variables which account for technical inefficiency effects in production and are independently distributed as truncations at zero of the *N*(*μi*,σ *u*2) distribution, where:

$$\mu_i = \delta_0 + \sum_{k-1}^{k} \delta_k z_{ik} + \omega_i \qquad (2)$$

and *zi* is a (1 × *K*) vector of farm characteristics that affect efficiency and δ is an (*K* × 1) vector of parameters to be estimated. The *ωi*'s are random variables generally defined by the truncation of the normal distribution with zero mean and variance σ2, with the point of truncation as *ωi* ≥ - δ *zi*.

Maximum likelihood methods are used to simultaneously estimate the stochastic frontier and technical inefficiency effects models. For the likelihood function the variance terms are parameterized as:

$\sigma^2 = \sigma^2_u + \sigma^2_V$ and $\gamma = \sigma^2_u / (\sigma^2_u + \sigma^2_V)$, with $0 \leq \gamma \leq 1$ (Battese and Coelli,1995)

Technical inefficiency for the *i*-th farm is estimated as the expectation of *ui*, conditional on the observed value of (*vi* - *ui*):

$$TEi = E[\exp(-u_i) \mid v_i - u_i] = E[\exp(-\delta_0 - \sum_{k-1}^{k} \delta_k z_{ik} - \omega_i \mid v_i - u_i]$$

iii. Empirical model

We use a Cobb-Douglas functional form to specify the stochastic production frontier. Taylor et al. (1986) argued that as long as interest rests on efficiency measurement and not on the analysis of the general structure of the production technology, the Cobb-Douglas production function provides an adequate representation of the production technology. Moreover examining the impact of functional form on efficiency Kopp and Smith (1980) concluded '….that functional specification has a discernible but rather small impact on estimated efficiency". That is why the Cobb-Douglas functional form has been widely used in farm efficiency analyses both in developing and developed countries (Battese. 1992: Bravo-Ureta and Pinheiro, 1993). The specific model estimated is given by:

$$\text{In } Y = \beta_0 + \sum_{i=1}^{5} \beta_i \ln X_i + r_i - u_i \qquad - (1)$$

Where

Y	=	Yield in Kgs
X_1	=	Fertilizer in kgs
X_2	=	Manure in kgs
X_3	=	Labour in man days
X_4	=	Machinery in hours
X_5	=	Irrigation in nos

The technical inefficiency is modelled as:

$$u_i = \delta + \sum_{m=1}^{7} \delta_m Z_{mi} \qquad - (2)$$

Where,

Z_1 = Education in years

Z_2 = Access to road in kms

Z_3 = Credit, 1 if availed credit /0 otherwise

Z_4 = Extension contact in nos/month

The computer package developed by Coelli for Stochastic Frontier Production, FRONTIER Version 4.1, is used for estimation of the above model.

d. Infrastructure and private capital formation

Public investment in agriculture has been declining since mid-1980s which is likely to have adverse impact over the longer term because investments in irrigation, roads, and education have been shown to significantly contribute to agricultural productivity growth and the reduction of rural poverty in India. This trend has not been offset by an increase in private investment. It is very pertinent to note the observation of Sawant,et al (2002) on investment by cultivator households. In cultivator households, proportion of investing households was as low as 19.3 per cent in 1971-72 and came down to just 11.89per cent in 1991-92. One of the enabling factors for creation of an environment for private investment is increasing public investment in infrastructure, though there is differing views on the complementarity between public and private investments in agriculture. By and large the general observation in the literature is that the public sector investment has an inducement effect on private investment. Nevertheless, movement of public and private investments in diverse directions since mid-1980s instigated a controversy regarding the weakening of the complementarity between the two (Mishra and Chand 1995; Misra and Hazell 1996; Mitra 1996). In this study the impact of differential public infrastructure on private capital formation in Tamil Nadu is analyzed in two districts one with high infrastructure endowment namely, Namakkal and the other with low infrastructure endowment, namely Ramanathapuram district by specifying the following log –log model:

$$PCF = \alpha + \beta_1 \text{ irri Area} + \beta_2 \text{ Accesroad} + \beta_3 \text{Accesresinst} + \beta_4 \text{ nonfamincome} + \beta_5 \text{ SID} + u$$

Where,

PCF	=	Private Capital Formation in Rs
irri Area	=	Irrigated area in ha
Accesroad	=	Access to Road in Kms
Accesresinst	=	Access to Research institutes, Krishi Vigyan Kendras and other extension agencies (Very good, good, poor)

nonfamincome	=	Non farm income in ‘000 Rs
SID	=	Simpson index of diversification

5. The Study Area

Tamil Nadu is India’s seventh largest state with a population of about 62 million and with a geographical area of 130 million hectares. The Gross State Domestic Product (GSDP) growth rate was 6.3per cent during the 1990s, ahead of the all India average of 6.1per cent. Tamil Nadu’s performance with respect to the Human Development Index (HDI) is also impressive; it ranks third among 29 states. This is especially true for human development indicators like female life expectancy, female mortality rate, and access to safe drinking water etc. Notwithstanding these achievements, Tamil Nadu is still a low-income state and has a relatively high incidence of poverty (20 per cent) and unemployment (14 per cent) in the country. There are intra-state disparities in key poverty and social indicators. About 12 million people live in poverty, and inequality in Tamil Nadu is higher than the all-India average, and is in fact, the highest among the fifteen major states. This uneven improvement in the quality of life has left a large section of the population which has consistently failed to benefit from the economic and social development that the state has achieved. Sixty-five percent of the States population is living in rural areas, with agriculture as the main profession. Agricultural land holdings in the state are very small in size along with high degree of fragmentation, with 74 per cent of the holdings below one hectare in size and nearly 90 per cent of them below 2 hectares. The net sown area in the State is 5.09 m ha and 50.97 per cent of the net sown area is irrigated. About 30 per cent of the net irrigated area is irrigated by canals, 21 per cent by tanks and 49 per cent is fed by wells. Rain fed agriculture employing about 25 per cent of farmers accounts for 46 per cent of the net sown area of 5.5 million hectares. Rural poverty is concentrated among those with marginal landholdings and dependent on rain-fed agriculture. Recurring droughts and price crashes due to seasonal gluts increase the vulnerability of these sections due to income variations. Investment in infrastructure like irrigation, road, education, markets, etc., would in the long run reduce these vulnerability and enable the small and marginal farmers to participate in the new development process ushered in by the liberalization and globalization of the economy.

6. Data source and analysis

District wise panel data was collected for 5 years from 1998-99 to 2003-04. Due to reorganization of districts, the data set could not be collected for earlier years. Also the spatial variation in infrastructure is more significant than the temporal variation. For example, the irrigated area was 2.71 million ha in 1971-72 and 2.801 million ha in 2001-02. Similarly the density of road per '000 sq km of geographical area was 1117 km in 97-98 and 1384 km in 2002-03. But there is spatial variability in irrigation intensity and road density among the 28 districts in the state as evidenced from the coefficient of variation. Coefficient of variation was 74 per cent for irrigation intensity and 38 per cent for road density in the state.

Table. 1. Sample size distribution

Districts	Villages	Sample Farmers
Namakkal	1.Maravapalayam	10
	2.Kakkaveri	10
	3.Pettai	10
	4.Mulasi	10
	5.Eraiyamangalam	10
	6.Alankadu	10
Ramanathapuram	7.Pottithatti	10
	8.Devipattinam	10
	9.Peruvayyal	10
	10.Pichakuruchi	10
	11.Cholandur	10
	12.Cheenganankudi	10
	Total	**120**

The data was collected from various issues of Season &Crop Report of Tamil Nadu, Economic Appraisal of Tamil Nadu, Annual Statistical Abstract of Tamil Nadu, Statistical Handbook of Tamil Nadu, and web site of the Government of Tamil Nadu. The data was also collected from Commissionerate Agricultural Marketing and Agri

Business, Commissionerate of Agriculture, District Rural Development Agency, and Tamil Nadu Co-Operative Union. Primary data for the study pertains to the farm-survey of two districts, each representing differential infrastructural endowments. Samples were collected from six villages in Namakkal district and six villages in Ramanathapuram district. A total of 120 farmers from these 12 villages were selected following random sampling procedure (vide table.1). Technical efficiency analysis was carried out for paddy crop which is major crop in Namakkal and in Ramanathapuram district.

7. Results

a. Infrastructure and productivity

The influence of infrastructural variables on Total Factor Productivity is modeled in equation-4. The important infrastructural variables included in the model are irrigation intensity, road density, markets and commercial vehicles. Other production related variables like percent of area under High Yielding Varieties and rain fall were included to isolate the effect of theses variables on TFP. The descriptive statistics of the variables used in the model is presented in the table.2

The equation-4 is estimated under three assumptions about the intercept of the model.

a. The usual OLS regression using pooled data (OLS-PD), ignores space and time dimension and hence it is highly restricted. It assumes intercept value is same for all the districts (OLS-PD).
b. The Fixed Effects Model (FEM) or Least Square Dummy Variable (LSDV) model overcomes this limitation through differential intercept dummies. In this model intercept may vary across districts but each district's intercept does not vary over time. It means intercept is time invariant.
c. Just as dummy variables are used to account district effect, dummy variables are used to account for time effect, making the intercept time variant (LSDV-TV).

Table.2. Determinants of Total Factor Productivity -Mean and Standard deviation of variables

Variables	Variable description	Mean	Standard deviation
Infrastructural variables			
Irri	Irrigation intensity (%)	117.0	20.0
Roadesity	Road density (Ratio of road length in km to geographical area in Sq.Km)	0.0046	0.0016
mkts	Number of markets per sq. km	0.0069	0.0032
pumset	Number of pumpset /hectare of cultivated area	0.36	0.0079
ComVec	Number of Commercial Vehicles per Sq. Km	0.0286	0.0151
Other Variables			
HYV	Ratio of High Yielding Varieties to Net Sown Area	0.4976	0.2767
Rfall	Annual Rainfall in mm	819.65	274.34
Lit	Rural Literacy rate	56.53	14.20

The results of the model are presented in tables 3. Among the three models estimated, the results of the Time Variant Least Square Dummy Variable (LSDV-TV) model is discussed as this model excludes spatio-temporal effects in the data and have the better fit with the highest R^2. In this model, the R^2 is 0.47 and five out of the eight independent variables turned out to be statistically significant in influencing on TFP (For estimates of OLS-PD and FEM model Vide appendix –I).

Table.3. Determinants of Total Factor Productivity – LSDV-TV model

Variables	Coefficient	Std. error	t- value	Significance
Constant	-3.798	196194.44	0.000	1.000
Irri	0.3276*	0.1863	1.758	0.0820
Roadesity	0.2002***	0.6386	3.135	0.0023
Mkts	0.1732***	0.4830	3.586	0.0005
ComVec	0.0041	0.4318	0.095	0.9242
Pumpset	-3.060	190189.63	0.000	1.0000
HYV	-0.2529	0.4237	-0.597	0.5520
Rfall	0.2373***	0.8987	2.641	0.0097
Lit	0.1901**	0.9556	1.989	0.0495
R^2	0.467			
F-value	5.13			
N	104			

***significance at 1 percent level, **significance at 5 percent level & * significance at 10 percent level.

Irrigation, roads, markets and literacy are the important infrastructural variables which had significant positive influence on total factor productivity. These infrastructure are created mostly through public investment and indirectly contribute to productivity growth. The results show that the density of commercial vehicles and agricultural pumpsets did not have statistically significant influence total factor productivity. This is probably because the impact of agricultural pumpsets is more systematically captured by irrigation variable and the commercial vehicles by the road density variable. Among the infrastructure variable, the marginal impact of irrigation infrastructure was higher as shown by the regression coefficient, while the impact of roads, literacy and markets followed in that order. As Tamil Nadu has a very moderate rainfall with high variability in distribution, irrigation plays a crucial role in increasing and stabilizing agricultural productivity in many parts of the state. Hence, improving irrigation infrastructure shall continue to be the major priority for public investment. Among the non-infrastructural variables affecting total factor productivity, rainfall alone turned out to be significant. The variable high yielding variety was not significant probably due to the fact that the coverage of high yielding varieties is limited to few important crops and the area under high yielding varieties remained more or less stable over the period of study. The results clearly demonstrate the role of infrastructure in increasing the total factor productivity in agriculture.

b. Infrastructure and diversification

In the early stages of agricultural development with very low level of infrastructure, any increase in the stock of infrastructure represents wider choices to the farmers with regard to inputs, crops, markets etc. At this stage, there bound to be more diversification of crops with the increase in infrastructure. In advanced stages of development, when infrastructure integrates markets and farmers attempt to reap the comparative advantage, infrastructure growth leads to specialization. The equation-5, try to capture the nature of influence the infrastructure have on crop diversification in the study region. The results of the model are presented in Tables 4.

Table.4. Determinants of diversification – LSDV-TV model

Variables	Coefficient	Std. error	t- value	Significance
Constant	-3.2039	258573.48	0.000	1.0000
Irri	0.6475***	0.2456	2.636	0.0098
Road density	-0.2398***	0.0842	-2.849	0.0054
Mkts	0.1992***	0.0637	3.130	0.0023
ComVec	0.1610***	0.0569	2.829	0.0057
Pumset	-1.4569	250659.48	0.000	1.0000
HYV	0.0084	0.0558	0.150	0.8811
Rfall	-0.0770	0.1184	-0.650	0.5170
Lit	0.0045	0.1259	0.036	0.9716
R^2	0.2969			
F-value	2.48			
N	104			

The result of the time variant Least Square Dummy Variable (LSDV-TV) model is discussed as this model excludes spatio-temporal effects in the data (For estimates of OLS-PD and FEM model Vide appendix –II). . Except pumpsets, all the other four infrastructural variables turned out to be statistically significant. Irrigation intensity, input-output markets and commercial vehicles had significant positive influence on crop diversification. But road density has significant negative influence on diversification. As some of the earlier studies suggested (For example, Kurosaki, 2003; Benin et al, 2004) this may be due to the fact that the road infrastructure helps specialization in agriculture to exploit the comparative advantage.

c. Rural Infrastructure and Efficiency in agricultural production

A summary of the values of the variables used in the analysis is presented in .Table 5 and 6.

Table.5. Stochastic frontier production function -Mean and Standard deviation of variables in Namakkal

Variables	Average	Standard deviation
Yield in kgs per ha	1967.92	339.95
Fertilizer in kgs	275.92	67.08
Manure in kgs	3072.11	995.59
Human labour in hours	58.65	17.37
Farm machinery in hours	15.86	8.24
Irrigation in nos	8.07	1.77
Education in years	8.20	3.60
Access to road in kms	1.68	0.66
Credit, 1 if availed and 0 otherwise	0.62	0.49
Extension contact in nos	4.95	3.28

Table.6. Stochastic frontier production function -Mean and Standard deviation of variables in Ramnad

Variables	Average	Standard deviation
Yield in kgs per ha	1393.22	554.80
Fertilizer in kgs	271.55	143.29
Manure in kgs	2216.67	1059.13
Human labour in hours	48.72	7.70
Farm machinery in hours	11.74	5.25
Irrigation in nos	8.48	1.89
Education in years	5.82	3.69
Access to road in kms	1.89	1.08
Credit, 1 if availed and 0 otherwise	0.65	0.48
Extension contact in nos	1.70	0.96

Farmers in Namakkal obtained higher average crop output per hectare of land compared to Ramnad. Similarly it is interesting to note that manure use, which is a bulky input; and machinery use, mostly tractor for which road access is necessary, is more in Namakkal district. Similarly the standard deviation in input use is also relatively small in Namakkal diatrict except for labour. Good infrastructural facilities could be one of the reasons for labour migration resulting in instability in availability for agriculture.

Farmers in both the districts have comparably the average level of credit availability while the educational status was higher in Namakkal district with an average level of 8 years of schooling compared to the 6 years of schooling in Ramanathapuram district. The access to road from the farm was on an averge 0.62 kms in Namakkal while it was 1.89 km in Ramanathapuram district. The extension contacts were observed to be more with an average of nearly 5 per month in Namakkal compared to the mere 1.70 in Ramnad district.

The maximum-likelihood estimates (MLE) of the parameters of Cobb-Douglas stochastic frontier function were obtained using maximum-likelihood procedures through FRONTIER 4.1 package. The results are presented in the Table 7 and 8. The homogeneity of the two data set were tested through a pooled regression with dummy variable and found that the dummy variable was significant (vide appendix -3). Hence the the regressions for two districts were estimated separately.

Table.7. Maximum likelihood estimates of stochastic frontier production function: Namakkal district

Independent variables		**Coefficient**	**t ratio**
Production function			
Intercept	$\beta0$	5.2638***	17.0260
Fertilizer	$\beta1$	0.2399***	7.3480
Manure	$\beta2$	-0.0080	-0.2822
Human	$\beta3$	0.2693***	4.5794
Farm machinery	$\beta4$	0.0242***	2.8173
Irrigation	$\beta5$	0.0036	0.0861
Variance of parameters			
$\sigma^2 = (\sigma^2_v + \sigma^2_u)$		0.0616	2.6213
$\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$		0.9853	84.6156
Log likelihood		65.3688	
χ^2		78.6816	
Inefficiency effects			
Constant	$\delta0$	-0.1233	-0.7351
Education	$\delta1$	-0.1943***	-3.6802
Access to road	$\delta2$	0.9060***	6.5706
Credit	$\delta3$	-0.7520***	-4.3796
Extension contact	$\delta4$	0.0024	0.0480

Table.8. Maximum likelihood estimates of stochastic frontier production function: Ramanathapuram district

Independent variables Production function		Coefficient	t ratio
Intercept	$\beta 0$	6.0854***	8.1673
Fertilizer	$\beta 1$	0.3026***	4.5769
Manure	$\beta 2$	-0.0799	-1.6130
Human	$\beta 3$	-0.2008	-1.2690
Farm machinery	$\beta 4$	0.0300	1.0742
Irrigation	$\beta 5$	0.4615***	3.3494
Variance of parameters			
$\sigma^2 = (\sigma^2_v + \sigma^2_u)$		0.2992	4.2976
$\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$		0.9350	35.7670
Log likelihood		7.4301	
χ^2		51.687	
Inefficiency effects			
Constant	$\delta 0$	0.3718	1.0913
Education	$\delta 1$	-1.6166**	-2.0720
Access to road	$\delta 2$	2.0547***	2.7551
Credit	$\delta 3$	-0.8049	-1.6310
Extension contact	$\delta 4$	0.6663	1.3367

The parameter, $\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$, which is the ratio of the errors tests the hypothesis that the efficiency effects jointly estimated with the production frontier function are not simply random errors. γ is bounded between zero and one, where if $\gamma = 0$, inefficiency is not present, and if $\gamma = 1$, there is not random noise (Battese and Coelli. 1995). The estimated value of γ is close to 1 in the two models and is significantly different from zero, thereby, establishing the fact that inefficiencies exists in these two districts. Further, Likelihood Ratio (LR) test statistic was used to test different inefficiency specifications. The null hypothesis that $\gamma = 0$ is rejected at the 5%, level of significance confirming that inefficiency exit and are indeed stochastic (LR statistics 78.68 and 51.69 $>\chi^2 = 3.32$).

Table.9. Frequency distribution and summary statistics of efficiency estimates in Namakal district

Efficiency (%)	Number of farms	Percent
>90	42	70.00
>80 ≤ 90	8	13.33
>70 ≤ 80	3	5.00
>60 ≤ 70	2	3.33
>50 ≤ 60	4	6.67
>40 ≤ 50	1	1.67
Mean		88.94
Minimum		49.19
Maximum		99.08

Table.10. Frequency distribution and summary statistics of efficiency estimates in Ramanathapuram district

Efficiency (%)	Number of farms	Percent
>90	21	35.00
>80 ≤ 90	20	33.33
>70 ≤ 80	10	16.67
>60 ≤ 70	3	5.00
>50 ≤ 60	4	6.67
>40 ≤ 50	2	3.33
Mean		82.30
Minimum		17.43
Maximum		95.73

The results also indicate that technical efficiency (TE) indices range from 49.19 per cent to 99.08 per cent in Namakal district, with an average of 88.94 per cent (Table 9). This indicates that, if the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a 10 per cent (1-[88.94/99.08]) cost savings. Similarly in Ramanathapuram district, technical efficiency (TE) indices range from 17.43 per cent to 95.73 per cent, with an average of 82.30 per cent (Table 10). An average farmer could realize a 14 per cent cost savings (1-[82.30/95.73]) if he was to achieve the TE level of his most efficient counterpart.

Factors explaining inefficiency

The parameter estimates of the inefficiency effects stochastic production frontier model employed to identify the factors influencing farmers' levels of technical inefficiency are given by δs in Table 7 & 8. The results show that education, the distance of the plot from the main access road and credit access have a significant impact on technical inefficiency of farmers in Namakkal district while education and the distance of the plot from the main access road have significant inefficiency effect in Ramanathapuram district. Access to road is an important variable in determining the technical efficiency in agricultural production as it facilitates movement of bulky farm inputs and outputs in a cost effective way. It also enables the use of heavy machinery like tractors and combined harvesters which result in timely agricultural operations. The results clearly establish that technical inefficiency increases with the distance of the plot from the main access road and underscores the importance of better infrastructure in agricultural development. Similarly an icrease in education significanly reduces the inefficiency. The negative and significant impact of credit on technical inefficiency in Namakkal district implies that access to cash credit is likely to enhance the technical efficiency of farmers in this district. The agricultural extension system did not influence technical efficiency significantly.

d. Infrastructure and private capital formation

The impact of public infrastructure on private capital formation in Tamil Nadu is analyzed in two districts, one with high infrastructure endowment and the other with low infrastructure endowment. The pooled data of the two districts was first estimated to test the homogeneity of the data. The district dummy variable was not statistically significant implying that the two data sets are homogenous. This implies that the differential public infrastructure endowment is not significantly influencing private capital formation in agriculture. The mean and standard deviation of the explanatory variables in the capital formation function is given in table. 11.

Table.11. Mean and Standard deviation of variables

Variables	Average	Std deviation
SID	-0.88	0.87
Accesroad	0.44	0.55
Accesresinst	0.19	0.34
nonfamincome	2.78	0.50
irri area	0.54	0.71
Dummy	0.50	0.50

The model specified to analyze the determinants of private capital formation at farm level have shown that non – farm income, irrigated area and access to road are the important variables that affected capital formation at farm level. The results are presented in the table. 12. It is important note that non farm income significantly influences the capital formation in agriculture. Agricultural income alone is not generating sufficient surpluses for investment in farming. The next important variable that affects capital formation is irrigation. Recurrence of drought and monsoon failure results in spending off one or two years' savings in a drought year. Irrigated agriculture to some extent protects crops from monsoon failure and produce sufficient surpluses for investment in the farm. Access to road influences capital formation (significant at 10 per cent level of probability), as the distance of the farm increase

Table.12. Determinants of private capital formation in agriculture in sample households

Variables	Coefficient	T Ratio
Constant	7.91***	12.13
SID	-0.03	-0.23
Accesroad	-0.23*	-1.67
Accesresinst	0.00	0.00
nonfamincome	1.06***	4.39
irri area	0.57***	5.06
District dummy	0.25	0.99
R-squared = 0.59***, $F_{[6,113]}$ = 26.95		

***significance at 1 percent level, **significance at 5 percent level & * significance at 10 percent level.

from road, the capital formation declines. Access to agricultural research institutes and farm level diversification have not influenced capital formation in a significant way.

8. Conclusion

Cereal based small farm agriculture in the State of Tamil Nadu in India is facing the challenge of accelerating crop productivity and diversification of crops in the context of declining public investment and in the globalizing economy. The results of the study clearly establish that the investments in rural infrastructure like irrigation, rural markets, and roads increase the total factor productivity in Tamil Nadu agriculture. But public investment in agriculture has been declining in real terms in the 90s. It is imperative that stepping up investment in rural infrastructure is not only essential to accelerate agricultural productivity but also to secure livelihoods for two-third of the population in the State in the emerging global economic order. The results show the effect of infrastructure on diversification is mixed. While irrigation intensity, the markets and commercial vehicles had positive significant influence on crop diversification, road density had significant negative influence on diversification.

Some earlier studies also reported that road infrastructure was instrumental in specialization of agriculture for reaping the benefits of comparative advantage, thus reducing diversification. Stochastic frontier production function estimation revealed that higher infrastructure endowments aid in achieving higher level of technical efficiency in agricultural production. The inefficiency in production is explained by deficiency in some of the factors like education, the distance of the plot from the main access road and access to credit. The analysis of private capital formation in Tamil Nadu revealed that the differential public infrastructure endowment was not significantly influencing private capital formation in agriculture. The important determinants of private capital formation at farm level were non – farm income, irrigated area and access to road.

Ways to enable the small and marginal farmers in developing countries are being increasingly debated among academicians and policymakers. The results clearly establish the rural infrastructure are important determinants of total factor productivity and efficiency in agricultural production. Since significant increases in public investment in rural infrastructure seem unlikely, Governments will have to give greater emphasis in using their public investment resources more efficiently. This requires better targeting of investment to achieve better efficiency. The results of the study would be a step in this direction.

9. References

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APPENDICES

Appendix -1

A. Determinants of Total Factor Productivity – OLS-PD model

Variables	Coefficient	Std. error	t- value	Significance
Constant	1.4599	1.1250	1.298	0.1975
Irri	0.3131*	0.1753	1.787	0.0772
Roaddensity	0.2055***	0.0602	3.416	0.0009
Mkts	0.1596***	0.0431	3.703	0.0004
ComVec	0.0033	0.3668	0.091	0.9276
pumset	2.0221**	0.9717	2.081	0.0401
HYV	-0.0247	0.0373	-0.663	0.5091
Rfall	0.2606***	0.0745	3.501	0.0007
Lit	0.1397**	0.0792	1.763	0.0812
R^2	0.455			
F-value	9.91			
n	104			

***significance at 1 percent level, **significance at 5 percent level & * significance at 10 percent level.

B. Determinants of Total Factor Productivity Growth – FEM model

Variables	Coefficient	Std. error	t- value	Significance
Constant	-2.87	190315.49	0.000	1.0000
Irri	0.3155*	0.1773	1.779	0.0783
Roadesity	0.2008***	0.0626	3.208	0.0018
mkts	0.1747***	0.04517	3.868	0.0002
ComVec	0.0040	0.04250	0.095	0.9248
pumset	1.8455*	0.9885	1.867	0.0650
HYV	0.2703	.0384	-.704	0.4833
Rfall	0.2429***	.07657	3.174	0.0020
Lit	0.1855**	.08897	2.086	0.0397
R^2	0.465			
F-value	7.29			
n	104			

***significance at 1 percent level, **significance at 5 percent level & * significance at 10 percent level.

Appendix -1I

A. Determinants of diversification – OLS-PD model

Variables	Coefficient	Std. error	t- value	Significance
Constant	-1.6027	1.5607	-1.027	0.3071
Irri	0.5992**	0.2431	2.464	0.0155
Roadesity	-0.2136**	0.0835	-2.559	0.0121
mkts	0.1452**	0.0598	2.429	0.0170
ComVec	0.1361***	0.0509	2.674	0.0088
pumset	-0.1078	1.3481	-0.080	0.9364
HYV	0.0296	0.0518	0.572	0.5689
Rfall	-0.0098	0.1033	-0.095	0.9247
Lit	-0.1285	0.1099	-1.169	0.2453
R^2	0.2038			
F-value	3.04			
n	104			

***significance at 1 percent level, **significance at 5 percent level & * significance at 10 percent level.

B. Determinants of diversification – FEM model

Variables	Coefficient	Std. error	t- value	Significance
Constant	0.2901	0.2205	1.315	0.1915
Irri	0.6422***	0.2335	2.750	0.0071
Roadesity	-0.2395***	0.0824	-2.905	0.0046
mkts	0.1999***	0.05949	3.361	0.0011
ComVec	0.1610***	0.0560	2.877	0.0050
pumset	-0.6883	1.3017	-0.529	0.5982
HYV	0.0076	0.0506	0.150	0.8810
Rfall	-0.0745	0.1008	-0.739	0.4617
Lit	0.0025	0.1172	0.022	0.9828
R^2	0.2968			
F-value	3.53			
n	104			

***significance at 1 percent level, **significance at 5 percent level & * significance at 10 percent level.

Appendix -1II

Homogeneity test for stochastic frontier production function: Pooled Regression

Variables	Coefficient	T Ratio
Intercept	5.18***	7.754
Fertilizer	0.33***	4.929
Manure	-0.16***	-2.785
Human labour	0.28**	2.174
Farm machinery	0.05*	1.708
Irrigation	0.09	0.755
Dummy	0.38***	6.522
R-squared= .514853, $F_{[6,113]}$ = 19.99		

***significance at 1 percent level, **significance at 5 percent level & * significance at 10 percent level.