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Productivity and Resource Structure : Underlying Dimensions of Agricultural Development in Gujarat

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Sardar Patel Institute of Economic & Social Research
Thaltej Road, Near TV Tower, Ahmedabad - 380054.
Phone : (079) 26850598,26851428, Fax : +91-79-26851714
E-mail : info@spiesr.ac.in • Website : www.spiesr.ac.in

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Abstract

The paper provides an analysis of factors responsible for agricultural sector growth in Gujarat in 2000s. Relationship between productivity and resource structure is quantified and related with agricultural output. Factor analysis gives considerable weight to availability of water and technical inputs aiding productivity growth. Regional ecological variation emerged as an important factor for land productivity analysis. Behaviour of districts reinforces the classical inverse size-productivity debate in the presence of land fragmentation. Besides water, infrastructural and technological variables, structural parameters i.e., human capital, and climate have begun to appear as far more important for agricultural growth.

Key words: Productivity, Agriculture, Resource use, Factor Analysis

JEL Classification: C38, O13, O47, Q15.

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* Professor, SPIESR, Thaltej, Ahmedabad. niti@spiesr.ac.in

Productivity and Resource Structure: Underlying Dimensions of Agricultural Development

1. Introduction

Gujarat witnessed a turnaround in growth of the primary sector and agriculture in particular after 1999-2000. Between 1981-83 and 1991-93 agricultural output declined at 2.1 per cent from 3.6 per cent growth recorded in the green revolution phase. After 1980-83 crop output stagnated. The period between 1997-2000 and 2007-10 recorded unprecedented output acceleration at 8.05 per cent, leading to growth in land productivity at 7.5 per cent, rising from 0.14 per cent recorded in 1990s (Mehta, 2011). Agricultural growth also has played a dominant role in recent growth acceleration. Contribution of the agriculture sector to gross state domestic product (GSDP) after 2004-5 has stabilized at 17-19 per cent. The correlation between income from agriculture and GSDP which was 0.48 in the 1980s and 0.52 in the 1990s, stands now at 0.85.

Remarkable growth in agriculture sector in recent decades is intact even after two years of consecutive droughts in the state. The pattern of growth deserves further attention and explanation on casual linkages. The lessons learnt can be used for replication in other states. General consensus is that productivity growth in agricultural sector is essential if agricultural output is to grow at a sufficiently rapid rate to meet demands of food and raw materials accompanying urbanization and industrialization. Failure to achieve rapid growth in agricultural productivity can lead to drain of foreign exchange or shifts in internal terms of trade against industry, impeding industrial production.

Productivity as defined by the output flow per unit of resource input is the result of interaction of mutually reinforcing forces of agrarian structure, resource endowments, technology, human capital and institutional dimensions (Hayami and Ruttan, 1970). Out of all technology is likely to have the most direct impact on productivity. The quality of resource endowments, however, constrains application of technology. Resource endowments in turn are conditioned by the agrarian structure. Each of these dimensions connotes a complex phenomenon. Further, depending on resources, institutional and social context, the development process may either strengthen or weaken the resource structure affecting behaviour of productivity growth. Existence of linkages between resource structure and infrastructure and output growth has been well documented in empirical research[1]. Rural infrastructure such as, irrigation, electrification, roads, markets, credit, literacy, extension etc. play a key role in determining agricultural output in India. Irrigation infrastructure enhances intensity of land use and the cropping intensity resulting in higher output. Rural electrification enhances energisation of pump sets that helps to increase ground water usage, reliable source of irrigation for rainfed areas. Rural roads diffuse agricultural technology, improve access to markets and help farmers to realize better input and output prices. Further, rural-urban linkages are fostered through road development. Institutional factors such as credit facility reduces the borrowing costs and enhance farmers' ability to invest in production durables, tractors for instance. Rural markets too bolster the productivity and profitability of farmers. Some elements of the entire gamut of rural infrastructure may be more important than the others; but the overall impact on output is more pronounced in a better endowed region (Narayanamoorthy and Hanjira, 2006). For example, it has been ascertained that states with better initial physical endowments achieved higher rates of agricultural output growth than states with poor resource endowments (Dutt and Ravallion, 1998). Fan et.al (2000) studying the relation between government expenditure on research and rural infrastructure concluded that improved rural infrastructure and technology contributed to agricultural growth, but the impacts varied by settings. They also found that expenditure on road and R & D had highest impact on agricultural productivity and poverty reduction and were 'win-win' strategies. Education and irrigation also had modest impact on productivity growth. Studies on impact of such variables on land productivity growth at district level are few and far between. Secondly, since cultivable area cannot be expanded much further, yields have to increase to realize the plan targets. There is thus a need to examine carefully the conditions associated with high/rising productivity so that workable strategies for future growth may be developed for the state. Such an exploration is also desired, keeping in view the long history of instability in agricultural growth from which the state suffers.

The spatial variability of output and yield growth in Indian agriculture has been the subject of intense research. At the district level studies (such as Brown 1971, Bhalla and Alagh, 1979) were noteworthy in identifying patterns of agricultural development in India and growth for crops and districts. Some of the recent studies (Joshi et.al, 2006, Vaidyanathan, 2010, Chand 2005, Chand et.al, 2011, Bhalla and Singh, 2009, Birthal et.al, 2011) too permit identification of higher output and faster growing areas and the special characteristics of these areas can be examined in order to determine the elements aiding success. Recent studies (Shah et.al., 2009, Kumar et.al. 2010) have gone a long way in unraveling the drivers of Gujarat's agricultural success story. Shah et.al (2009) have identified several factors that caused the miracle, notably, above normal rainfall after 1999-2000, favourable market environment for cotton, wheat and other crops and availability of reasonably priced Bt cotton seed amongst exogenous drivers. Gujarat specific factors include policy initiatives of the government. These are measures to improve farmers' market access, promote diversification to high value crops and strengthen backward linkages (research, credit, input supply). Gujarat's rural road network is ahead of other states pushing its dairying activity further. Drawing from the above framework the present paper provides an in-depth analysis of underlying factors responsible for growth in the agricultural sector. Adopting a comprehensive methodology, the relationship between productivity and resource structure is examined and related with agricultural output.

Besides introduction the paper is organized into four sections. The second section gives a description of the methodology. Section three highlights the variables and sources of data. Fourth section presents the results and attempts interpretation of the results. Last is the concluding section.

2. Methodology and Database

Agricultural growth and development process is known for intricate mutual interdependence in behaviour of underlying situations. In the light of this, use of multi-variate analysis (the pre-requisite of which is absence of interdependence in independent causal variables) has to be treated with caution. Technique of factor analysis is used extensively as an alternative. Factor analysis helps in analyzing a mass of data by virtue of its capacity to rearrange a large correlation matrix into smaller number of common factors (Adams and Bumb, 1973). It is a collection of statistical methods used to a) analyze patterns in a correlation matrix,b) explore observed data for presence of theoretical underlying structural dimensions and c) to observe the relation of observed variables with the underlying dimensions. Factor analysis can be classified as exploratory or confirmatory. The former is used to give insight into the structure or underlying processes explaining collection of variables (Pohlmann, 2004). These processes are reflected by a set of indices. The four mathematical principles that help form these factors (or dimensions) from the observable variables are – i) those variables that are correlated are combined within a single factor. These variables are also correlated with the underlying dimension and are hence clubbed together. ii) variables correlated with a given factor are nearly independent of variables correlated to other factors iii) factors are delineated in a manner that maximizes the percentage of total variance attributable to each successive factor and iv) the underlying factors are independent (uncorrelated) (Singh, 1978, 1980). The factor indices may be obtained by a number of standard techniques; the principal factor technique and varimax rotation procedure being widely used to get unique factor indices.[2]

The objective of the final unique solution referred to as matrix A in the literature is to estimate the pattern co-efficient (a_{ij}) that will best account for the correlations among observed variables. The a_{ij}^{th} coefficient also shows the net correlation (called factor loading) between the j^{th} factor/dimension and the i^{th} observed variable. The factor loading (a_{ij}) square represents proportion of the total unit variance of the variable i which is explained by factor j after allowing for contribution of other factors.[3] The sum of square factor loadings or "communality" of each variable denoted as h^2 indicates proportion of the total unit variance explained by all the factors taken together[4]. The sum of the effect of all variables belonging to a factor shows the proportion of the total variance explained by that factor. The grouping of variables into common factors can be done by assigning each variable to that factor with which it shows the closest linear relationship, in other words that factor in which it has the highest loadings. If the loadings of a variable are very close in two factors than variable may be assigned to the factor with which on *a priori* grounds may be judged to have closest affinity (Ibid). However, prior research and theory may be used as basis for the number of factors decision[5].

The agricultural resource structure basically comprises of four key resource inputs: land, labour, capital and water. These inputs are manifested in the form of a number of variables depending on the prevailing mix of natural conditions, institutions and state of development in an economy. We have selected variables to capture these resource inputs. Of course choice of variables is further constrained by the availability of data for all districts (old) of Gujarat around the triennium ending1999-2000 and 2009-10. These are two reference points chosen for the purpose of comparative static district analysis of factors underlying the high growth of Gujarat agriculture in recent period.

In all 18 variables are chosen to represent Gujarat's resource structure. The variables are listed in Table 1.

Variable one is the value of output per hectare. Variables 4, 5, 6, 7, 11 (landholding size, rainfall, irrigation, farm labour) are traditional inputs. New mechanical devices (pumpsets, tractors, seed/fertilizer drills), fertilizers, literacy, high yielding seeds are measured by variables 9,15,14,12,10 and 13. Cropping practices are represented by cropping intensity (2) and commercial cropping (variable 3). Infrastructure is represented by variables 16, 17, 18 (agricultural credit, roads, and markets). It needs

Table 1: Variables

No.	Name	Specification	Mean TE 2000-01	TE 2009-10
1.	Agricultural * Productivity	Crop value/ha.(Rs)	15480	27698
2.	Cropping Intensity	Double cropped area/Net Cultivated area (%)	112.7	116.5
3.	Commercial Cropping	Non-foodgrain area/Gross cropped area (%)	69.3	65.2
4.	Agrarian Structure	Average size of holding(ha)	2.78	2.41
5.	”	Share holdings < 2 ha (%)	78.9	83.6
6.	Rainfall	Annual Rainfall (mm)	925	911
7.	Irrigation	Gross irrigated area/ total cropped area (%)	34.0	45.7
8.	Groundwater	Ground water irrigated area/net sown area(%)	30.6	36.5
9.	Electrification	Pumpsets / 00 ha of net area sown (No.)	41.1	69.4
10.	Literacy	Rural male literates (%)	80.5	87.2
11.	Farm Labour	Agricultural workers/ 00 ha of NSA (No.)	64.7	75.9
12.	Fertilizer	Fertilizer/00 ha GCA(kg/ha)	8056	14818
13.	Technology	HYV area/total cropped area (%)	80.4	87.6
14.	Mechanization	Fertilizer & seed drills/00 ha NSA (No.)	3.7	7.1
15.	”	Tractor/00 ha of NSA (No.)	1.5	2.1
16.	Credit **	Institutional agricultural credit/00 ha NSA (Rs. lakhs)	5.8	31.5
17.	Infrastructure	Road length/ sq. km. of sown area (Km)	0.76	0.77
18.	”	Average area served by regulated market (sqkms)	494	489

* Base Prices.

** Credit at current prices.

to be mentioned that the reference period of these variables varies with the nature of variables- flow or stock. For some flow variables such as fertilizers consumption, irrigation, etc., annual information is available, hence triennial annual averages of years around 2000 and 2010 are estimated. This minimizes the effect of weather/climate variations etc. For stock variables such as mechanical devices, land holdings, farm labourers, literacy, infrastructure variables, information pertains to the year in the vicinity of these periods from which information is available, e.g., census, livestock census, etc.

With regard to estimation of agricultural productivity, some explanation is desired. Since crop cultivation traditionally holds the dominant position in agriculture, it is used as a proxy for agricultural production for the purpose of analysis. Notwithstanding data limitations, we have to content with sum total value of production for 24 important crops. Four of these are important cereals-rice, jowar, bajra, maize, wheat and ragi. Amongst pulses, tuar, gram, mung, and urad are considered. Four important oilseeds considered are groundnut, sesame, castor, rape and mustard seed. Cotton, sugarcane, tobacco, guar and spices (chilly, cumin) and fruits and vegetables (onion, potato, banana, sapota and mango) were used for calculation of value of output. To account for product quality variations,location-specific (district) triennial average prices are multiplied with corresponding production figures. Agricultural productivity per hectare was obtained by dividing sum of total value of these crops by the corresponding cropped area. Comparability is ensured by using constant prices, or triennial averages of 1999-2000, 2000-01 and 2001-02.

3. Results and Interpretation

In a stepwise regression analysis, using agricultural productivity and six independent variables, for four points of time showed that in initial phase (1960s) male agricultural worker productivity, pump sets and rudiments of mechanization were crucial determining land productivity.[6] Fertilizer consumption emerged as a crucial factor during eighties. The results were quite unsatisfactory for the nineties. Introduction of policy changes and sudden rise in fertilizer prices may have led to fall in productivity levels in the state for most crops. Excluded variables and the effect of "other crops" that were more input intensive and had become important in the cropped area, could have affected the performance of the estimated equation. The exercise repeated for early 2000's showed the dominant effect of water availability. The explanatory power of equation improved considerably. Irrigation extent, rainfall and pump sets enabling ground water extraction enveloped the other variables. These variables are separately related to agricultural productivity and to irrigation and each other.

The results of factor analysis computed with principal factor technique and varimax rotation are highlighted in Table 2 for triennium ending 2000-01 and in Table 3 for 2009-10. In Tables 2 and 3, listing of variables is according to their (rotated) factor loadings, except for agricultural output per hectare which being of primary interest is allocated to the first row. The last column gives the "communality" of each variable and the last row provides the percentage variation explained by each factor. The set of five factors, it needs to be noted, explained more than 62% of the variations in agricultural productivity in early 2000's. By 2010, these explained nearly 85% of the variations in land productivity.

Changing nature of the emerging underlying factors/dimension is summarized in Table 4. As can be seen from Table 4 the factor components have altered somewhat in the course of the decade. Changes are also discernable in the relative importance of factor roles during the 2000s decade. In TE 2000-01 agrarian structure and human capital emerged as independent factors or dimensions. In TE 2009-10, while agrarian structure was part of first factor, human capital and ecological dimension emerged as independent factors. The results make overt the pattern of mutual interdependence and provide a clue to some of the existing relationships. Unlike regression that attributes virtually all the enhanced output to irrigation alone, the multi-variable

Table 2: Rotated Factor Loadings for Agricultural Productivity with Agricultural Input Variables, Gujarat, TE 2000-01

No.	Description	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Communality
1	Productivity per hectare (Rs) (2000-02)	-0.110	-0.029	-0.205	-0.711	0.252	0.624
		(0.012)	(0.001)	(0.042)	(0.505)	(0.064)	
2	Irrigated area by ground water to sown area (%)	[0.929]	-0.139	-0.044	-0.028	0.121	0.899
3	Male agricultural workers per 00 ha of NSA (no.)	[0.899]	0.248	-0.077	0.004	0.044	0.878
4	Tractors per 00ha of NSA (no.)	[0.894]	-0.126	-0.102	-0.004	0.263	0.894
5	Gross irrigated area to gross cultivated area (%)	[0.803]	-0.058	-0.760	-0.525	-0.005	0.929
6	Cropping Intensity (%)	[0.801]	0.007	-0.212	-0.225	-0.37	0.874
7	Instt. Credit per ha of sown area (Rs.lakh)	[0.720]	-0.264	-0.304	0.072	0.394	0.841
8	Average rainfall (mm)	-0.166	[0.924]	-0.114	0.152	-0.005	0.918
9	Roads per sq.km of NSA (km)	0.277	[0.911]	0.107	0.043	0.050	0.923
10	Fertilizer consumption per 00 ha of GCA (kg)	-0.225	[0.748]	-0.116	0.005	0.200	0.664
11	Pumpsets per 00 ha of net irrigated area (no.)	-0.357	[0.649]	-0.033	0.615	0.013	0.928
12	Non foodgrains area share in GCA (%)	0.033	[-0.746]	0.016	0.257	0.379	0.767
13	Area under HYV of foodcrops to cropped area (%)	0.024	[-0.779]	0.261	-0.053	0.346	0.798
14	Seed/fertilizer drills per 00ha of NSA (no.)	-0.051	-0.121	[0.979]	-0.039	-0.086	0.985
15	Average area served by regulated markets (sq.km)	-0.252	-0.054	[0.931]	0.223	-0.059	0.987
16	Average size of landholdings (ha)	-0.505	0.057	0.443	[0.575]	-0.172	0.814
17	Rural literacy rate (%)	0.365	-0.069	-0.250	-0.290	[0.800]	0.924
	Percent Variation explained	30.6	24.5	14.6	10.8	8.7	

Note: Figures within brackets indicate the factor to which each variable is assigned.
Percentage of overall variance explained by factors is 89.1%.
Figures in parentheses of first row are respective square values.

Sources:
For landholding related data: Agricultural Census, 1995-96 and 2005-06.
For landuse, irrigation, and HYV area: Crop & Season reports, various years, Government of Gujarat; www.agricoop.nic.in
For pumpsets, tractors, seed/fertilizer drills: Directorate of Agriculture; Bureau of Economics & Statistics, GoG; Livestock Census, 1993 & 1997, Transport Statistics (BE&S), 2007.
For fertilizer consumption: Fertilizer Statistics, Fertilizer Association of India, Various years
For roads, regulated market: Statistical Abstracts, BE&S, Various years.
For agricultural workers & literacy: Census of India, 2001 & 2011.
For agricultural credit: State level Bankers' Committee, Ahmedabad.

Table 3: Rotated Factor Loadings for Agricultural Productivity with Agricultural Input Variables, Gujarat, TE 2009-10

No.	Description	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Communality
1	Productivity per hectare (Rs)	0.350	-0.181	0.059	-0.073	0.831	0.854
		(0.123)	(0.033)	(0.004)	(0.005)	(0.690)	
2	Gross irrigated area to gross cultivated area (%)	[0.880]	0.000	0.241	0.339	0.120	0.961
3	Tractors per 00ha of NSA (no.)	[0.854]	0.135	0.175	0.194	0.080	0.822
4	Area under HYV of foodcrops to cropped area (%)	[0.749]	-0.531	0.081	-0.144	0.129	0.886
5	Fertilizer consumption per 00 ha of GCA (kg)	[0.737]	0.092	0.174	0.164	0.542	0.901
6	Irrigated area by ground water to sown area (%)	[0.628]	-0.201	0.400	0.224	-0.307	0.739
7	Pumpsets per 00 ha of net irrigated area (no.)	[-0.783]	0.091	0.211	-0.246	0.257	0.793
8	Average size of landholdings (ha)	[-0.632]	-0.128	-0.628	-0.084	-0.201	0.857
9	Roads per sq.km of NSA (km)	-0.128	[0.854]	-0.278	0.157	0.171	0.877
10	Male agricultural workers per 00 ha of NSA (no.)	0.394	[0.839]	0.252	-0.171	0.132	0.970
11	Non foodgrains area share in GCA (%)	0.110	[-0.961]	-0.144	-0.009	0.160	0.981
12	Cropping Intensity (%)	0.337	-0.020	[0.708]	0.006	-0.317	0.716
13	Average area served by regulated markets (sq.km)	-0.133	-0.091	[-0.765]	-0.288	-0.260	0.761
14	Seed/fertilizer drills per 00ha of NSA (no.)	-0.129	0.097	[0.604]	-0.66	-0.094	0.835
15	Rural literacy rate (%)	0.333	0.162	0.140	[0.803]	0.166	0.830
16	Instt. Credit per ha of sown area (Rs.lakh)	0.284	-0.056	0.261	[0.732]	-0.223	0.737
17	Average rainfall (mm)	-0.305	0.485	-0.105	0.193	[0.674]	0.832
	Percent Variation explained	28.5	18.26	14.62	12.67	12.01	

Note: Figures within brackets indicate the factor to which each variable is assigned.
Percentage of overall variance explained by factors is 86.1%.
Figures in parentheses of first row are respective square values.
Sources: Same as Table 2.

Table 4: Changing Nature of Underlying Factors, TE 2000-01& TE 2009-10

TE 2001			TE 2010		
Factors	**% Variation explained in resource structure**	**% Variation explained in Agri Prod.**	**Factors**	**% Variation explained in resource structure**	**% Variation explained in Agri Prod.**
(1) & (3) Water availability, technology &Insttnal support	30.6 14.6	1.2 4.2	(1) Water availability, technology & Agrarian structure	28.5	12.3
(2) Landuse, Crop Pattern and Ecological dimension	24.5	0.1	(2) & (3) Insttnal support, Landuse and Crop pattern	18.3 14.6	3.3 0.4
(4) Agrarian Structure	10.8	50.5	(4) Human Capital Development	12.7	0.5
(5) Human Capital Development	8.7	6.4	(5) Ecological dimension	12.0	69.0
Total	89.1	62.4	Total	86.1	85.5

Source: Tables 2 and 3

dimension recognizes the intertwined nature of variables in agricultural production process in Gujarat.

(1) Water availability, technology advancement and credit: Five factors have emerged from the factor analysis. Agricultural productivity is unrelated to any other factor, but the fourth and fifth factors for the two time points of time. About a third of the variation is explained by set of variables representing the effects of irrigation and tractors. The state government has devoted substantial budgetary resources for major and medium canal irrigation projects. Project such as Mahi, Ukai, Karjan and Damanganga provide water to Central and South Gujarat. Nearly five lakh small water harvesting structures mostly in Kutch and Saurashtra region (December 2008) have enabled cultivation of rabi wheat and irrigated cotton. Massive rural

electrification programme and subsidy for electricity has encouraged private investment for ground water irrigation. Tubewell irrigation has seen explosion in alluvial areas of the state, while in hard rock areas of Saurashtra and Kutch energized open wells have helped expand ground water irrigation. Although command area of SSP is nearly 100 thousand ha., but gross area irrigated by Narmada Canal System (till March 2008) could be around 2.4. – 3.27 lakh ha. Farmers lift canal water by putting up engines to transport it to their fields. This has aided the dramatic increase in area under wheat and cotton in area around Narmada Main Canal. The Narmada Canal also discharges water into several rivers of Central and North Gujarat that has replenished aquifers and raised water tables (Shah et.al., 2009; Kumar et.al., 2010; Mehta, 2011). SSP canals that are now supplying water to water scarce regions of Gujarat have played a major role in productivity enhancement, especially in districts of South Gujarat (Bharuch, Baroda, Narmada) and North Gujarat (Ahmedabad and Gandhinagar). Lastly, initiatives of state government to promote micro-irrigation systems (through Gujarat Green Revolution Company) also paid dividends.

In the earlier period, factor one also combined the influence of other farm inputs/production factors such as farm labour and credit availability that influence the nature of cropping intensity. Availability of farm credit enables the purchase of modern implements as well as improves the access to ground water. This is particularly relevant to districts of North Gujarat, where the outreach and access of ground water is often restricted to smaller peasants as tubewells require considerable initial investments. Furthermore, the availability of irrigation makes intensive agricultural activities possible owing to multiple cropping, thereby providing far greater opportunities for farm employment. It has been stated that initiative of the government in providing good quality power to farmers under Jyotigram scheme was a step for deriving maximum economic benefit from energy use in agriculture. New power connection for agro-wells in farms to install meters is another step that would improve physical efficiency of water use. Farmers allocate water to a crop which gives higher return per unit of water (Ibid).

Three of the variables in this factor that remain highly correlated during TE 2000-01 and 2009-10 are per cent gross irrigated area, extent of area irrigated by ground water sources and tractor usage. In TE 2009-10, apart from the irrigation variables and mechanization, the other two input variables that become associated with this factor are consumption of fertilizers and area under HYV of food crops. Possibly adoption of HYV is prevalent to a greater extent in areas having these features. Fertilizer use is far more effective when irrigation is assured and timely. The undercurrents of this factor tend to highlight the salient characteristics of the situation in a state where agricultural economy and cropping pattern respond to availability of water, leading to intensive cropping. In the more recent period inputs, particularly fertilizers and tractors, are being used widely to enhance production of foodgrains, such as, wheat and rice, hence this variable appears as a part of the first factor. The negative response to use of pumpsets per 00 ha of NSA in the second time point perhaps captures the picture of varying agro-climatic conditions and irrigation pattern across districts. In southern and middle Gujarat districts surface irrigation is dominant. The first factor has a noticeable association with agricultural productivity, although, only 12.3 % of the variations in agricultural productivity was being explained by this factor at the end of last decade. This also tends to corroborate the fact that increases in agricultural output are largely the feat of irrigation availability and recently diversion of inputs towards wheat and rice. Replacement of cropped area by cotton from other crops forming the largest chunk of output value, has also been enabled by increased availability of water as a consequence to the Sardar Sarovar project.

(2) <u>Land Use and Cropping Pattern:</u> The second factor/dimension in declining order of structural importance accounted for nearly a quarter of variation in early 2000s. This factor is identifiable with the pattern of land use and cropping that is dependent on land augmenting investments – such as fertilizers, HYV and infrastructural support. A closer examination of variables having high correlation with this factor in TE 2000-01 highlight the additional salient characteristic of Gujarat's economy. These variables were average rainfall, use of pumpsets, road development and proportion of cropped area under non-food crops. Surprisingly, two of the variables namely preponderance of commercial crops and HYV under foodcrops are inversely related. The rationale behind this apparently unexpected relationship lies in the fact that most of the commercial crops (notably cotton, groundnut, spices, tobacco, etc.) and food crops such as jowar and rice are cultivated in the kharif season, coinciding with monsoon months. Further it has been noted that most of the wells, canals and tanks have little water during the rabi season. Steep decline in depth of wells has been reported during relatively wet periods too (Lall et.al, 2011). With failure of monsoon, drought situation prevails even in the kharif season. Given the scarcity of water resources, its allocation favours such crops that are less water intensive, grown when water availability is dependable and are more productive. On these counts, it is the non-food crops that command top priority and stake the first claim on water resource. Secondly, the rapid expansion in area under Bt cotton and wheat explains

most of the agricultural output value after 2000. After 2004-05 foodgrain area has hardly expanded, on the other hand, rabi wheat now accounts for major share of foodgrains area. Use of land augmenting investment, such as fertilizer is related to availability of irrigation and has favourable influence on agricultural productivity. As and when additional water becomes available, it is allocated to crops in order of their declining productivity level. Economic rationality of farmers underscores the complex relationship between landuse and productivity and variables representing capital inputs.

The situation prevailing in drier parts of Gujarat needs to be highlighted in the context of second factor. Northern Gujarat districts as well as Saurashtra and Kutch have been for long utilizing the ground water resource to cultivate a variety of crops with the support of government in the form of subsidized inputs (such as electricity for pumping ground water, price and marketing support). Agriculture in these regions is being sustained by depleting aquifers. Most of the accumulated ground water deficit is concentrated in these regions (GoG, 2009). These regions account for 75% of electricity used for ground water extraction. However, owing to low level of recharge, groundwater situation now in North Gujarat is critical threatening the very sustainability of farming activity. Farmers suffer as they have to continually invest in deepening wells and powerful pumps to irrigate, but face a decline in quality and quantity of water that is pumped out. Farmers respond to this situation by migrating or restricting crop cultivation to rainy season (Lall et.al., 2011). This possibly adversely affects farmer's income.

By TE 2009-10 the variation explained by second factor reduced to 18.3%. Only 3.3% of the variation in agricultural productivity was explained by this factor. The high cost of irrigation by ground water (on account of high cost of electricity) offsets the modest yield increases accruing from cultivation of commercial crops; thus income generated or revenue from irrigated crops has not risen significantly in the drier regions of Gujarat. If this situation continues, agriculture may turn into a net economic losses for large sections of farming community in arid parts of the state.

(3) Agrarian Structure: The third important factor is identifiable with agrarian structure represented by scale of operation or size of cultivating unit. This was interpreted as a separate factor (No.4) in TE 2000-01, and land productivity per hectare was the other variable showing correlation with this factor. In early 2000s the factor's role as agricultural productivity determinant was very significant (50.5%).As a structural dimension its role was far less important accounting for 10.8% of the total variation in resource structure. An increase in size of cultivating unit is accompanied by investments for irrigation augmentation, especially when ownership of land lies with cultivating unit. Segments of farmers favourably placed in terms of ownership and access to resource have far greater opportunities for diversifying out of low value crops into commodities with greater demand potentials. This notion is corroborated by high secondary factor loading that availability of pump sets enjoy for the third factor in the early 2000s.[7] The obvious outcome is assured and timely irrigation supply. Thus the amalgamation of these set of conditions form the building block for agricultural production. Probably such conditions get strengthened in a situation where land is relatively evenly distributed among cultivating units and there is less preponderance of small holdings.[8]

In TE 2009-10, the dimension of agrarian structure was also represented by the first factor. Structurally, cultivation base of agrarian structure, namely land and water, was identifiable with this factor. The land size variable depicts a negative association in Gujarat by end of 2000's decade. The overall variation in resource structure explained by this dimension has declined (from 30 to 28%), but its role as productivity determinant has significantly improved (from 1.2 to 12.3%). Possibly the objective conditions may have improved due to strengthening of hold of agrarian structure. The existence of agricultural dualism is apparent in the state, whereby the traditional small peasant is assumed to be well endowed with plentiful labour, even though facing several constraints on credit. On the other hand large farmers would employ labour to the point where wage rate equalled marginal product. This could explain declining productivity co-existing with increasing profitability. Earlier studies (Sen 1966; Bardhan 1973; Saini 1971) have provided convincing evidence on inverse relationship between crop productivity per unit of land and increase in farm size, thereby providing strong support for land reforms and support policies for small holders on grounds of efficiency and growth.[9] Studies have also noted that adjustment to land quality (soil quality) diminishes the inverse relation and it is argued that the inverse relations between farm size and land productivity is a spurious result caused by bias due to non-inclusion of land quality parameter (Bhalla & Roy, 1988). It is also argued that villages with small holdings may have cheap abundant labourers, allowing farmers to employ more labour/ha, resulting in higher farm productivity. Either way, after controlling for village factors inverse relationship may disappear/diminish. The diversity in climatic conditions prevailing in Gujarat (and water availability) reinforces such a notion. It has been argued that with the advances in technology the inverse relationship will vanish (Ghose, 1979). Punjab may be taken as an example, where in dynamic agro-climatic zones inverse and Sengupta (1997) in the context of West Bengal have reported that inverse relation between farm size and productivity was far stronger in agriculturally developed regions.

In Gujarat small and marginal holdings (less than 2 ha) have increased from 80 to 86 % of total operational holdings as per the last agricultural Census (2005). The average size of land holding is getting progressively reduced due to marginalization process and currently it is 2.4 ha (declining from 2.6 ha in 1995-96). The aggregate figure hides inter-district variations in the agrarian structure. The experience of Gujarat in 2000s decade shows that preponderance of small/marginal holdings did not constrain the attainment of high level of productivity and growth. Apparently, size advantage in access to irrigation facilitated productivity enhancement. Studies show that as farm size declined, (at country level), use of fertilizer per hectare of land increased even under unfavourable conditions and this relationship was found to remain intact over time (Chand, 2011). In Gujarat on the other hand, the inverse relationship between scale of farming and input intensity is greater in small farms. Relationship between farm size and fertilizer use has increased in strength during the course of the last decade, from 0.085 to -0.70 (significant at 5%). The inverse relationship between scale of farming and overall irrigation development was increasing in Gujarat (from – 0.71 to -0.75) between 2000-01 to 2009-10. Similarly, groundwater usage and average land holding size showed negative relationship that increase from -0.52 to -0.55 in the 2000s decade (Appendix 1). These trends co-exist with biotechnology revolution specific to cotton and increased HYV use for foodgrains. Thus in Gujarat smaller holdings have been making more intensive use of land, using higher doses of inputs (water, manual labour and mechanization). This trend is against the conventional argument that large farms have better access to credit necessary to purchase yield increasing inputs. It is possible that with changes in labour market and rising demand for labour such advantages would further increase.

The process of growth in 2000s decade has improved these conditions in a significant way. That land marginalization process is accompanied by improvement in land productivity can be corroborated by following facts: 1) more cultivated area is reported to be under irrigation. 2) Inter-district variations in access to irrigation facilities have declined. 3) Access to ground water has increased with its share in

irrigation increasing by nearly 6 percent points. Dependence on pump sets for lifting water (ground water or procuring water from canals) has increased and inter-district variation in mechanized water lifting has reduced considerably. 4)Tractorization is gaining strength and regional disparities in farm mechanization are on the wane (Table 5).

It is of little wonder that agricultural miracle and unprecedented growth in overall productivity has much to do with agrarian structure.[11] Evidence on spatial distribution of income shows that rural areas in Gujarat are shifting substantially towards secondary and tertiary activities and away from primary activities, as is expected in development theory. Interestingly of late registered manufacturing has become predominantly a rural activity in Gujarat, while unregistered manufacturing is predominantly an urban activity (Dholakia and Pandya, 2011). Possibly larger farmers (having better access to education and skills) are coming out of agriculture in favour non-farm activities and it is the small size category of farmers that remain in agriculture. Major advances in labour productivity are dependent on absorption of higher percent of agricultural workforce into non-agricultural sector. Ongoing trends suggest that the state needs to consolidate its role in making small holder agriculture more productive and surplus yielding.[12]

Table 5: Selected set of Variables relating to Agrarian structure and Input use

No	Description	Mean Value TE 2000-01	Mean Value TE 2009-10	t test for mean value	P value (α=.05)
1	Size of landholding (ha)	2.78	2.41	8.94	0.000
		(35.3)	(37.8)		
2	Share of holdings < 2 ha (%)	78.89	83.6	-7.95	0.000
		(14.4)	(12.7)		
3	Cropping Intensity (%)	112.79	116.74	-1.86	0.080
		(10.2)	(9.7)		
4	Ground water irrigated	30.58	36.45	-1.75	0.096
	area to NSA (%)	(75.6)	(48.3)		
5	Share of gross irrigated area	33.95	45.74	-5.18	0.000
	to gross cropped area (%)	(53.3)	(38.1)		
6	Fertilizer consumption	8.72	14.75		0.008
	per 00ha GCA (tonne)	(48.9)	(48.2)		
7	Use of Tractors per	1.49	2.14	-3.64	0.002
	00ha NSA (nos.)	(72.5)	(31.8)		
8	Use of pumpsets per 00 ha	41.11	69.38	-3.352	0.004
	of NIA (nos)	(142.6)	(98.0)		

Note: Figures in brackets are corresponding values of coefficients of variation.

(4) Human Capital Development: In addition to use of technical inputs, irrigation and resource endowments, modern agriculture technology concomitant of dynamic agriculture is also embodied by human capital or literacy rate of rural population, particularly males. An interesting study of 148 countries has shown that improving water security improves the human development in a region (Kumar and

Mudgerikar, 2009). Male literacy in Gujarat has reported significant strides in the decennial census, increasing from 80.5 to 87% of the population. Literacy level of rural males has recorded an improvement from 74 % in 2001 to 83% in 2011. Inter-district variations in human capital in rural Gujarat have registered decline; the coefficient of variation is rural male literacy declined from 9.8 to 6.9% in 2011.

Human capital development was embodied in factor five in TE 2000-01 and by factor four in TE 2009-10. This factor is broadly conceived to include education, skill/knowledge and capacity to develop and adopt productive technologies. Human capital development enables farmers to use knowledge for decision making related to allocative and technical matters. It opens channels for using institutional credit reducing dependency on informal credit sources. Labour productivity levels in agriculture can be improved (in presence of varying resources) through improvement in quality of labour force. Human capital is also a proxy for capacity of a region to engage in research and extension. In TE 2000-01 institutional credit together with literacy get related to this factor. Higher literacy standard is positively associated with credit use for acquiring capital inputs, farm machinery, use of HYVs and fertilizers. Gujarat's agriculture is subscribing increasingly to this factor – it explained 8.7% of variation in resource structure of agricultural sector in early 2000 and by the end of 2000s decade, its role increased to 13%. Due to the capital intensive and commercialized nature of agriculture, the weight of this dimension in explaining resource base variations recorded a rise. It needs to be noted that since human capital development creates conditions for access and use of modern agricultural practices, its uniform spread across districts is bound to lower its share in explaining inter-district productivity variations, chiefly as land productivity is recording increase with land constraint, higher levels of education is possibly reducing the productivity differentials across regions. Historically European countries, New Zealand, South East Asian countries have achieved highest level of productivity by complementing favourable resource endowments with high investments in rural education (Hayami and Ruttan, 1970; Mellor and Johnston, 1984). Recent studies on India (Kumar, 1999; Mittal and Kumar, 2000) have shown that literacy accounts for nearly 13% growth in total factor productivity and 74% in adoption of HYVs for rice.

(5) Ecological Dimensions: In TE 2009-10, regional ecological condition emerged as the fifth factor or dimension accounting for 12% of total variance in resource structure; the bellwether of this being rainfall. (In 2000 ecological dimension was related with factor two). Land productivity per hectare was also related to factor five in TE 2009-10 and showed a high factor loading of 83%. As much as 69% of the variation in agricultural productivity is explained by this factor. Considering the structural importance of this factor, the result corroborate the belief that despite technological advancement and feats achieved in terms of productivity enhancement, the effect of rainfall and other natural parameters on Gujarat's agriculture is undeniable. Rainfall is crucial in determining the cropping pattern and output per unit of land. Further exploitation of groundwater for expanding irrigation is not possible in the water scarce arid and semi-arid regions of Gujarat. In fact during periods of drought, irrigated agriculture can show a decline as recharge of aquifer is severely impaired. High growth in agriculture observed in the recent period followed a period when there occurred a major dip in production during drought of 1999-2000. After 2000, the state witnessed occurrence of four successful monsoons. This helped in steady expansion in cropped area and/or yield increases. It may be noted

that during bad monsoon years agriculture is marked by shrinkage in area under irrigated winter crops and reduction in yields of kharif crops (notably cotton, groundnut).

In other words: …..“Critically” of rainfall for Gujarat to sustain its agriculture production has even gone up as compared to the pre-green revolution period. The four consecutive years of good rainfall, remarkably improved groundwater recharge, increased storage in surface reservoirs throughout the state, and improved soil moisture conditions. The reduced pressure on aquifers for irrigation due to availability of water from reservoirs reduced irrigation water requirement for crops due to improved soil moisture condition and increase in replenishment together made a huge positive impact on groundwater balance, making more water available for subsequent years.” (Kumar et. al, 2010, p.14).

As is expected, the secondary factor loading for ground water irrigation is negative. Use of groundwater in Gujarat is limited in areas receiving higher average rainfall and this confirms the commonplace observations about geographic characteristics of Gujarat. The ecologically advanced districts also benefit by greater fertilizer use (high secondary factor loading), canal irrigation than those receiving scanty rainfall supplemented by groundwater irrigation and provision of institutional credit. Second clear reasoning of this result can be arrived at by recognizing that in districts with low rainfall land is sown with non-food crops that are less water intensive. In the correlation matrix the negative relationship of commercial farming with fertilizer use and rainfall and overall irrigation lends further credence to this argument. By 2010, some of these relationships have either turned weakly positive or lost in strength. The relatively high secondary loading for number of pump sets suggest that there is a certain amount of overlap between irrigated and rain based scenarios. As is known fact pumps are widely used in Gujarat not only for drawing underground water but also for tapping water from canals. Significant correlation of agricultural productivity and rainfall to this dimension hence suggests that despite all the development, Gujarat, a predominantly semi-arid zone, is still not insulated from rainfall as a determinant of crop productivity and output. It is likely that this factor would become less important with the spread of Narmada irrigation. As of now we cannot wish away the effect of climate induced anomalies across the State's regions.

4. Ranking of Districts on Factor Scores

By extending the procedure of factor analysis it is possible to assign each district factor score and a rank, along each of the common dimensions identified. The factor score of a district is essentially derived from 1) factor loadings of each variable in chosen factor, 2) correlation matrix and 3) the normalized original values for that district for all variables. This information is given in Appendix 2a and 2b for TE 2000-01 and 2009-10.

At the outset it may be observed that the recent cropping pattern emerging in Gujarat and input needs negates several established norms. It casts a shadow on the results and leads to some ambiguity in disaggregated analysis. Notably, such trends are fuelled by increase in gross irrigated area in regions previously facing water scarcity. Some anomalies that are particularly interesting are - 1) traditionally cotton dominant districts in South and Central Gujarat and now marginalized; 2) Saurashtra and North Gujarat have taken centre stage in cotton economy; 3) significant expansion of wheat area in Saurashtra, Kutch, along with North Gujarat. 4) There is no taluka in canal irrigated areas that is exclusively irrigated by gravity flow from canals (Shah et.al, 2009). The last point thus indicates that conjunctive use of surface and ground water is becoming the norm in the state. Ranking of districts on first factor shows that Middle Gujarat districts display intensive irrigation development with mechanization and use of land augmenting inputs (HYV, fertilizers). Canal irrigation has benefited South Gujarat districts of Surat, Valsad. Input of groundwater and micro irrigation is visible in Kutch and North Gujarat districts (Banaskantha, Sabarkantha, Mehsana). Tribal districts (Dangs, Panchmahals, Bharuch) do not show a particular trend in area expansion under irrigated wheat or Bt cotton and hence also rank low in scores based on irrigation and cropping intensity.

On the second factor high ranking districts are the ones with high proportion of food grains. Bt cotton is gaining prominence in Saurashtra districts, Kutch and Banaskantha. These districts have been traditionally practicing commercial crops such as, oil seeds, spices and other non-food crops. The scores on factor three (in 2010), a dimension accompanying agrarian structure does not confirm to distinct categorization as per regional characteristics. There is no significant territorial agglomeration in the ranking of districts even on fourth factor indicating literacy dimension. Districts with negative scores belong to Saurashtra, Kutch and Panchmahals.

Districts identifiable as a sub-sector of state economy in terms of high agricultural productivity but varying ecological advantages are those that have dominance of commercial farming (Surat, Amreli, Jamnagar, Bhavnagar, Junagadh, Rajkot) cultivating oilseeds, Valsad has horticulture as dominant crop activity. These districts are also benefiting from expansion in Bt cotton area in a big way. Districts belonging to North and Central Gujarat and Kutch noticeably are having lower ranks on this factor. Sabarkantha, Panchmahals, Mehsana, Banaskantha, Kutch are largely rainfed and groundwater irrigated districts. While some of the trends are discernable, it is evident that computation of factor scores raises certain problems. The factor loading matrix adequately summarizes underlying dimensions of the agricultural growth patterns, the district scores are often in conflict with the observed trends. Possibly the discrepancies are owing to the fact that scores are computed on both medium and large factor loadings. The medium loadings on the other hand are disregarded in the interpretation of loading matrix, which concentrates only upon the largest scores (Clark et.al, 1974).

5. Conclusions

Overall impact of the five underlying factors can now be summarized in the context of major growth drivers identified by some of the earlier researches. Shah et.al., (2009), Kumar et.al. (2010) have noted that above normal rainfall after 1999-2000, favourable market environment for cotton, wheat and other crops and availability of reasonably priced Bt cotton seed amongst exogenous drivers leading to the agrarian miracle in the 2000 decade. Findings from our analysis indicate the following:

- Nearly a third of the variation in agricultural productivity is explained by variables representing the effects of water availability. Increase in gross area irrigated through Narmada Canal System (nearly 2.4-3.27 lakh ha till March 2008) aided the dramatic increase in area under wheat and cotton. Canal discharges water into several rivers of Central and North Gujarat replenishing aquifers and raising water tables. Further enhancing water supply to water scarce regions has played a major role in productivity increases in districts of South Gujarat (Bharuch, Baroda, Narmada) and

North Gujarat (Ahmedabad and Gandhinagar). This underscores the salient characteristics of the situation where agricultural economy and cropping pattern respond to availability of water leading to intensive cropping.

- Presently, apart from irrigation, diversion of other land augmenting inputs, such as fertilizers and HYVs (for wheat, rice) and bio-technology (cotton) is causing much of the output increases.
- Regional ecological conditions, notably rainfall explained 12 % of resource structure and about 70 % of variation in land productivity. This underscores that effect of rainfall and other natural parameters on Gujarat's cropping pattern and output. Exploitation of groundwater for expanding irrigation is not possible in water scarce arid and semi-arid regions of Gujarat. After 2000, following a period of drought the state witnessed occurrence of successful monsoons that helped in steady expansion in cropped area and/or yield increases.
- Ecologically advanced districts benefit by greater level of surface and ground irrigation, fertilizer use, and provision of institutional credit. In districts receiving low rainfall, land is sown with non-food crops that are less water intensive. The negative relationship of commercial farming and fertilizer use and rainfall and overall irrigation lends credence to this argument.

Studies have also pointed towards Government's policy initiatives in driving the growth in agriculture. These are in the nature of measures to improve farmers' market access, promote diversification to high value crops and strengthening backward linkages (research, credit, input supply). Our findings while corroborating this additionally make the following factual arguments:

- The dimension representing commercial cropping explained less than a fifth of resource structure, while only 3.3% of the variation in agricultural productivity. High cost of irrigation by ground water offsets the modest yield increases accruing from cultivation of commercial crops; thus income generated from irrigated crops has not risen significantly in drier regions of Gujarat. If this situation continues, agriculture may turn into a net economic losses for large sections of farming community in arid parts of the state.
- The inverse relationship between scale of farming and overall irrigation development increased in Gujarat between 2000-01 and 2009-10. Groundwater usage and average land holding size showed negative relationship. Such trends co-exist with biotechnology revolution specific to cotton and increased HYV use for foodgrains. In Gujarat smaller holdings have been making more intensive use of land and using higher doses of inputs (water, manual labour and mechanization).
- It is of interest to observe that the weight of water, infrastructural and technological dimensions which accounted for 55% of total variance in early 2000s has reduced to 47% by the end of last decade. Presently the structural parameters of human capital and climate have begun to appear as far more important for agricultural growth in the state.

Agricultural development experience of the sixties of Gujarat revealed two technology variants, traditional and modern (Singh, 1980). The other three were institutional variants: agrarian structure, land use pattern and dominance of primary sector. Technology variants commanded a dominant position in explanation of structural variations, more so in agricultural productivity. In the late 60's increase in agricultural productivity was primarily attributed to modern technology adoption- a preserve then of progressive; usually large capitalist farmers. The objective conditions now have changed, more so with liberalization forces ingrained into Gujarat's economy. Absorption of modern technology is now no longer restricted to an elite group of farmers, but far more widespread. However, the long term implications remain unchanged, notably development of agricultural technology suitable to local climate and resource endowment structure. Improvement in conditions would be determined by decisions about location, quantum and composition of crop output as also by investment allocation for embodied and disembodied technology inputs.

Appendix 1a: Correlation Matrix, TE 2000-01

No.	Variables	landprod	nfgarea	cropint	avlsize	rainfall	gia_gca	gwi_nsa	pumpset	mliter	magrwor	fertilizer	HYV	drills	tractors	credit	roads	markets
1	landprod	1.00																
2	nfgarea	0.07	1.00															
3	cropint	0.02	-0.17	1.00														
4	avlsize	-0.44**	0.04	-0.52	1.00													
5	rainfall	-0.06	-0.61*	-0.11	0.21	1.00												
6	gia_gca	0.32	-0.01	0.80*	-0.71*	-0.22	1.00											
7	gwi_nsa	-0.10	0.19	0.75*	-0.52*	-0.26	0.83*	1.00										
8	pumpset	-0.36	-0.28	-0.37	0.53*	0.77*	-0.62*	-0.44**	1.00									
9	mliter	0.36	0.24	0.13	-0.56*	-0.14	0.57*	0.50*	-0.36	1.00								
10	magrwor	-0.05	-0.16	0.64*	-0.53*	0.06	0.66*	0.73*	-0.17	0.32	1.00							
11	fertilizer	-0.05	-0.57*	-0.12	0.09	0.71*	-0.15	-0.21	0.58*	0.09	-0.10	1.00						
12	HYV	-0.01	0.60*	-0.08	-0.07	-0.77*	0.10	0.16	-0.54*	0.29	-0.20	-0.41**	1.00					
13	drills	-0.18	0.06	-0.23	0.43**	-0.22	-0.11	-0.08	-0.11	-0.32	-0.14	-0.24	0.31	1.00				
14	tractors	0.08	0.29	0.67*	-0.47*	-0.26	0.77*	0.87*	-0.39**	0.57*	0.78*	-0.25	0.14	-0.17	1.00			
15	credit	0.04	0.32	0.42**	-0.60*	-0.35	0.57*	0.71*	-0.38	0.62*	0.70*	-0.30	0.30	-0.32	0.74*	1.00		
16	roads	-0.04	-0.61*	0.12	-0.07	0.77*	0.09	0.08	0.51*	-0.01	0.54*	0.53*	-0.70*	-0.01	0.15	-0.02	1.00	
17	markets	-0.32	0.10	-0.42**	0.66*	-0.08	-0.38	-0.28	0.19	-0.45*	-0.32	-0.09	0.25	0.93*	-0.34	-0.46*	-0.02	1.00

Note: *Significant at 5%
** Significant at 10%

Appendix 1b: Correlation Matrix, TE 2009-10

No	Variables	landprod	nfgarea	cropint	avlsize	rainfall	gia_gca	gwi_nsa	pumpset	mliter	magrwor	fertilizer	HYV	drills	tractors	credit	roads	markets
1	landprod	1.00																
2	nfgarea	0.33	1.00															
3	cropint	-0.03	-0.10	1.00														
4	avlsize	-0.33	0.09	-0.47*	1.00													
5	rainfall	0.31	-0.37	-0.30	0.08	1.00												
6	gia_gca	0.41**	0.09	0.49*	-0.75*	-0.13	1.00											
7	gwi_nsa	0.03	0.20	0.72*	-0.55*	-0.41**	0.76*	1.00										
8	pumpset	0.03	-0.12	-0.05	0.37	0.47*	-0.62*	-0.42**	1.00									
9	mliter	0.20	-0.12	0.12	-0.46*	0.13	0.63*	0.33	-0.38	1.00								
10	magrwor	0.12	-0.80*	0.24	-0.52*	0.32	0.35	0.04	-0.16	0.19	1.00							
11	fertilizer	0.72*	0.03	0.19	-0.70*	0.15	0.80*	0.31	-0.48*	0.52*	0.48**	1.00						
12	HYV	0.42**	0.61*	0.22	-0.51*	-0.37	0.62*	0.50*	-0.56*	0.05	-0.08	0.51*	1.00					
13	drills	-0.05	-0.21	0.28	-0.27	-0.24	-0.23	-0.07	0.33	-0.44**	0.29	-0.09	0.01	1.00				
14	tractors	0.34	-0.03	0.47*	-0.61*	-0.06	0.89*	0.67*	-0.52*	0.45**	0.43**	0.69*	0.59*	-0.18	1.00			
15	credit	-0.12	-0.02	0.29	-0.34	-0.13	0.48*	0.38	-0.46*	0.64*	0.00	0.32	0.20	-0.21	0.38	1.00		
16	roads	-0.09	-0.73*	-0.33	0.07	0.63*	-0.08	-0.28	0.21	0.22	0.54*	0.00	-0.56*	-0.17	0.06	-0.12	1.00	
17	markets	-0.22	0.16	-0.37	0.70*	-0.11	-0.37	-0.29	0.08	-0.42*	-0.33	-0.40**	-0.13	-0.21	-0.32	-0.33	0.09	1.00

Note: *Significant at 5%
** Significant at 10%

Appendix 2a: Factor Scores, TE 2000-01

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Gandhinagar	3.637	Dangs	3.311	Kachchh	4.045	Dangs	2.000	Ahmadabad	1.247
Kheda	0.645	Valsad	1.098	Dangs	0.198	Gandhinagar	1.235	Rajkot	0.910
Sabarkantha	0.501	Kheda	0.724	Gandhinagar	0.092	Jamnagar	1.216	Gandhinagar	0.842
Mahesana	0.499	Sabarkantha	0.527	Bhavnagar	0.034	Surendranagar	0.770	Jamnagar	0.769
Banaskantha	0.329	Surat	0.321	Ahmadabad	-0.008	Junagadh	0.695	Junagadh	0.627
Panchmahal	0.249	Panchmahal	0.302	Kheda	-0.015	Amreli	0.593	Valsad	0.581
Vadodara	-0.016	Bharuch	0.134	Valsad	-0.170	Rajkot	0.248	Kheda	0.578
Valsad	-0.096	Gandhinagar	0.073	Surat	-0.214	Bhavnagar	0.212	Bharuch	0.348
Surat	-0.204	Vadodara	0.045	Jamnagar	-0.229	Ahmadabad	0.034	Vadodara	0.319
Kachchh	-0.217	Ahmadabad	-0.316	Sabarkantha	-0.239	Banaskantha	0.002	Bhavnagar	0.136
Junagadh	-0.269	Bhavnagar	-0.404	Surendranagar	-0.258	Panchmahal	-0.004	Surat	0.087
Ahmadabad	-0.353	Mahesana	-0.473	Junagadh	-0.259	Kachchh	-0.162	Amreli	-0.009
Bhavnagar	-0.562	Kachchh	-0.500	Mahesana	-0.317	Mahesana	-0.310	Sabarkantha	-0.076
Rajkot	-0.588	Banaskantha	-0.639	Bharuch	-0.370	Vadodara	-0.482	Dangs	-0.207
Amreli	-0.590	Rajkot	-0.713	Panchmahal	-0.417	Sabarkantha	-0.497	Surendranagar	-0.270
Surendranagar	-0.624	Junagadh	-0.772	Rajkot	-0.436	Bharuch	-0.537	Kachchh	-0.359
Jamnagar	-0.692	Jamnagar	-0.788	Vadodara	-0.443	Valsad	-1.499	Mahesana	-0.560
Bharuch	-0.700	Amreli	-0.895	Banaskantha	-0.454	Kheda	-1.740	Panchmahal	-2.269
Dangs	-0.947	Surendranagar	-1.036	Amreli	-0.537	Surat	-1.776	Banaskantha	-2.694

Appendix 2b: Factor Scores, TE 2009-10

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Surat	1.560	Dangs	1.874	Panchmahal	1.626	Ahmadabad	2.412	Surat	2.091
Gandhinagar	1.335	Panchmahal	1.540	Junagadh	1.340	Gandhinagar	0.988	Valsad	1.541
Kheda	1.274	Valsad	1.458	Kheda	0.956	Dangs	0.577	Junagadh	0.944
Valsad	0.757	Kheda	0.972	Banaskantha	0.626	Rajkot	0.571	Rajkot	0.761
Kachchh	0.618	Surat	0.780	Rajkot	0.519	Mahesana	0.566	Amreli	0.706
Banaskantha	0.576	Sabarkantha	0.456	Sabarkantha	0.458	Sabarkantha	0.477	Jamnagar	0.535
Sabarkantha	0.106	Gandhinagar	0.445	Mahesana	0.386	Kheda	0.444	Bhavnagar	0.487
Vadodara	0.069	Vadodara	0.153	Jamnagar	0.265	Valsad	0.439	Dangs	0.302
Bhavnagar	0.065	Bharuch	0.120	Vadodara	0.161	Bharuch	0.188	Bharuch	0.209
Mahesana	0.006	Kachchh	-0.069	Ahmadabad	0.146	Vadodara	0.072	Surendranagar	-0.010
Amreli	-0.191	Ahmadabad	-0.326	Bhavnagar	0.104	Surat	-0.180	Vadodara	-0.071
Bharuch	-0.215	Banaskantha	-0.358	Gandhinagar	-0.006	Bhavnagar	-0.271	Sabarkantha	-0.254
Surendranagar	-0.246	Mahesana	-0.417	Amreli	-0.274	Banaskantha	-0.289	Gandhinagar	-0.475
Rajkot	-0.380	Junagadh	-0.738	Surat	-0.371	Junagadh	-0.378	Kheda	-0.573
Junagadh	-0.470	Bhavnagar	-0.928	Bharuch	-0.544	Surendranagar	-0.467	Panchmahal	-0.970
Panchmahal	-0.487	Jamnagar	-1.120	Valsad	-0.574	Jamnagar	-0.544	Mahesana	-1.085
Ahmadabad	-0.506	Amreli	-1.262	Dangs	-0.907	Amreli	-0.839	Ahmadabad	-1.178
Jamnagar	-0.851	Rajkot	-1.288	Surendranagar	-0.943	Kachchh	-1.218	Kachchh	-1.387
Dangs	-3.020	Surendranagar	-1.294	Kachchh	-2.967	Panchmahal	-2.548	Banaskantha	-1.575

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Endnotes

1 Mehta (2011), Kumar et.al (2010), Narayanamoorthy & Hanjira, (2006) provide a detailed treatment.

2 The Kaiser-Guttman rule states that factors should be interpreted that have 'eigenvalues' greater than 1. An eigenvalue measures the amount of variance in the variables explained by a factor.

3 If the factors are uncorrelated or orthogonal, the aij coefficients will also be Pearson correlations between the factors and measured variables.

4 Communality feature of factor analysis is akin to R2 in the regression analysis. Communality is the total unit variance explained by all the factors. A row of the table thus amounts to a regression equation in which each indicator is treated as a dependent variable explained by the general factors identified.

5 Factor analysis solution attempts to eliminate unique and error variance from factors, unlike Principal component analysis (PCA).

6 Mehta (2006, 2011). Value of output/hectare was regressed on fertilizer consumption, male agricultural workers, irrigation, pump sets, cropping intensity and tractors.

7 The high negative association that this factor has with overall irrigation (GIA % to GCA) and irrigation by ground water underscores the difficulties that smaller peasantry face in access to ground water. It also presents the regional variations prevailing in Gujarat in mode of irrigation and resultant cropping activities (Shaheen & Shiyani, 2005).

8 The variable representing occurrence of small and marginal holdings was dropped from the analysis due to collinearity problem. These objective conditions were highlighted for Gujarat in earlier studies (Singh, 1980) for 60s and 70s.

9 However, no explanation of inverse relationship was found in terms of technical efficiency for villages in Haryana. Small farms in Haryana use far more inputs/ha than large farms and their rate of adaptation to technical change is lower (Carter, 2000; Bhalla, 1974).

10 It may be noted that the inverse correlation coefficient between farm size and land productivity in Gujarat has weakened from -0.44 to -0.33 between TE 2000 and 2010.

11 Interestingly in earlier periods i.e.1960s and 1970s, analysis reported that unequal land distribution coupled with unequal control over limited ground water resources had no role to play vis-à-vis overall agricultural productivity (Singh, 1980). Obviously the objective conditions have changed significantly in a liberalized and open economy.

12 Experience of East Asian countries reveals that concentration of small holders has remained very high, with average farm size in Japan, Korea and China remaining below 1.2 ha. The agricultural productivity growth in these countries is significantly higher than in India.

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