



Factorization of agricultural production in India: A quantile regression approach

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ABSTRACT

A study was undertaken at the ICAR-Indian Agricultural Research Institute, New Delhi (2017) to readdress the economic productivity of agricultural system in India with in-depth scrutiny of productivity differentials. Secondary data for the period 1999–2013 from various published sources were used for analyzing the drivers of agricultural production. It was observed that, overall economic productivity of agriculture is nearly ₹ 83275/ha in case of India which disperse widely over the states with standard deviation of ₹ 36935/ha. This variation is subjected to a broad set of ecological, socio-economic and other institutional factors. A model of nonparametric regression, viz. quantile regression approach was used to discern and measure the role of identified factors in determining agricultural economic productivity. The study provides a deeper insight in addressing spatially distributed productivity gap further. It was observed that market concentration, Wholesale price index of high value crops and land fragmentation are the decisive factors for explaining productivity differentials across the regions.

Key words: Agricultural productivity, Land fragmentation, Market concentration, Productivity gap, Quantile regression

Agriculture is the major sector in Indian economy and it plays a crucial role in the development of an agrarian country like India. In addition to being the major source of employment, it also provides raw materials to the industrial sector (Economic Survey 2016–17). Agriculture is an engine for achieving food and nutritional security, income generation, poverty alleviation, employment augmentation, and sustainable development. So, to meet the Sustainable Development Goals (SDGs) of no poverty and economic growth, developing a robust agriculture sector is vital. Empirical evidence across the globe revealed that agricultural development and enhancing farmers' income is more effective in reducing poverty in under developed and developing nations (Christiaensen *et al.* 2011, BIRTHAL *et al.* 2015). However, non-homogenous production pattern in terms of variation in size group, location distribution and other ecological factors leads to productivity differential across the regions and hinders realization of economic benefit from agriculture. This productivity lag and non-capitalization of economic benefit is most aggravated in subsistence oriented farming approach. It implicates that while the dynamic nature of efficient large commercial

farming system is not being questioned, the notion that the subsistence farming systems are static and non-profitable and requires to be addressed afresh as it cannot be generalized with large commercial agricultural systems. It forms the rationale to analyse the agricultural production system after segregating different production class and disentangling the complex behaviour of socio-economic, institutional and other external factors on agricultural productivity. The present study is an attempt to focus on this problem with new approach of analytics.

MATERIALS AND METHODS

The study was undertaken at the ICAR-Indian Agricultural Research Institute, New Delhi (2017) to analyze the agricultural production in India using secondary pooled data for the period 1999–2013 from various sources. Data for agricultural productivity is measured in ₹/ha and the data is compiled from Ministry of Statistics and Programme Implementation. The independent variables used in the study were classified into two categories namely socio-economic variables and input variables. Socio-economic variables include proportion of small and marginal variables a proxy for land fragmentation and WPI Index of horticultural crops a proxy for price volatility. The input variables were fertilizer usage (kg/ha), proportion of irrigated area (%) and Simpson Index of diversification which was estimated by authors.

Econometric model specification: To examine the factors affecting economic productivity the econometric

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model specified in equation 1 was used. The fact that agricultural production pattern and productivity varies across the states is very evident (Kumar and Mittal 2006). So, using Ordinary Least Square (OLS) regression and its interpretation will not be valid due to evident differences in productivity in the cross section. Hence, quantile regression approach was adopted to explain the econometric model (Hallock 2001, Yu *et al.* 2003 and Koenker 2004). Further, to explicate productivity gap between top and lowest quartile, interquartile regression model was used based on several socio-institutional and infrastructural parameters (Syverson 2004).

$$Y_q = \alpha_q + \sum_{i=1}^n \beta_{q,i} X_i + \varepsilon_{q,i} \quad (1)$$

RESULTS AND DISCUSSION

Variable definition: The exogenous variables were selected after a comprehensive review of literature (Singh *et al.* 2006, Kumar and Gupta 2015, BIRTHAL *et al.* 2015). Gross value of output per hectare at constant prices (GVO) is used as a proxy for economic productivity. The average value of GVO over the study period amounted ₹83275/ha. Simpson index was calculated as an indicator of diversification of agriculture enterprise.

The effect of diversification on GVO is expected to be positive as diversification towards high value products is expected to increase farmers' income and economic productivity. The per capita NSDP was used as proxy for economic well-being and as indicator to account for transmission of progress in other sectors to the agrarian community (Gupta and Mitra 2004). Increase in cropping intensity is expected to increase output via increase in productive seasons. We hypothesize that irrigation will increase the value of agriculture produce through two mechanisms by bringing additional area under cultivation and facilitating the cultivation of water intensive high value crops. Fertilizer consumption is expected to positively influence economic productivity especially in case of food-grains. Whole sale price index of horticultural produce is used as a control for impact of price volatility on value of agricultural output.

Factors affecting efficiency in agricultural production: The OLS regression model revealed that NSDP per capita, proportion of small and marginal farmers, fertilizer usage and cropping intensity were key determinants of agricultural productivity. These variables were found to positively influence agricultural productivity. A kernel density plot of the regressand and residual terms of OLS regression were estimated and compared with that of a standard normal distribution (Fig 1). The plots indicate that the residuals and regressand belong to a family of bi-modal distributions. Portmanteaus test rejected the null hypothesis of normality thereby invalidating the results of the OLS model. Ramsey RESET test revealed the absence of omitted variable bias thereby validating the adequacy

of the regression.

Findings from quartile regression estimation: Quantile regression is a widely used non-parametric approach. In our alternative empirical model we regress the first, second and third quartiles of GVO against the regressors used in OLS model. Three different quartiles were regressed as low productive, moderately productive and highly productive regions are incomparable due to inherent differences between them arising out of socio-economic, political, geographical and topological factors.

The estimates of quartile regression are substantially different from the OLS regression model (Table 1). The first quartile regression revealed that fertilizer usage, cropping intensity, per capita NSDP, positively influences economic productivity. Wholesale price index for horticultural crops were found to be non-significant indicating that price volatility did not play any significant role in increasing economic productivity. Contrary to our expectations irrigation was not found to be significant in low productivity states. The predominance of rainfed agriculture in these states could have potentially masked the higher productivity of irrigated pockets in these regions. Diversification did not contribute significantly to economic productivity in the first quartile.

The factors contributing significantly to economic productivity in moderately productive regions were

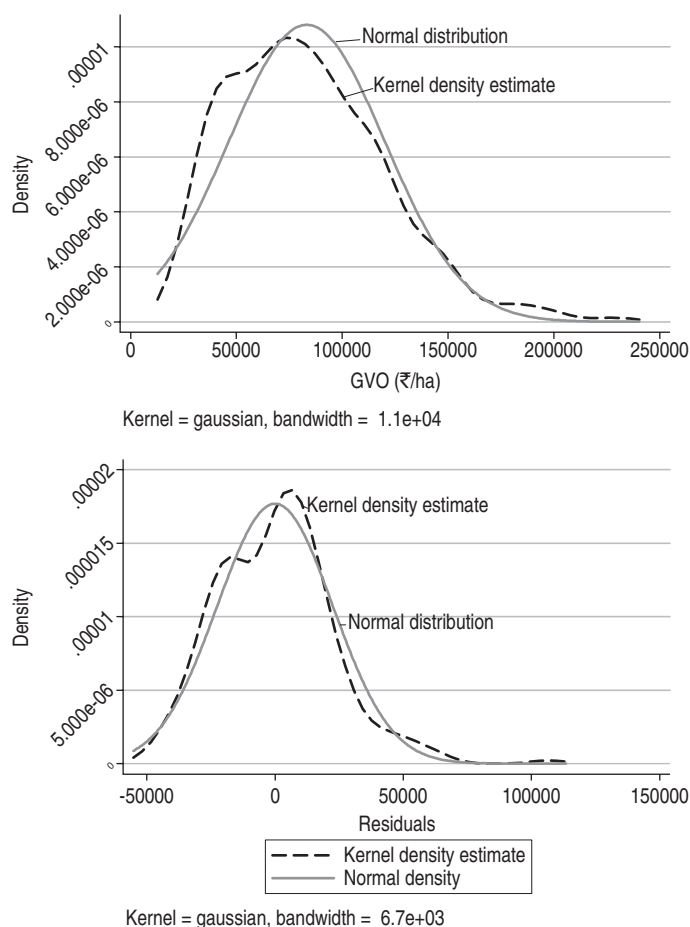


Fig 1 Distribution of residual and GVO.

Table 1 Estimates of state-wise pooled regression (1999–00 to 2013–14)

Dependent variable: GVO	OLS	Median		
		1 st quartile	(2 nd quartile)	3 rd quartile
SID	-25996 (0.48)	-43193 (0.12)	31627 (0.34)	60997** (0.00)
Per capita NSDP*	0.79** (0.00)	0.28** (0.00)	0.79** (0.00)	1.23** (0.00)
Small and marginal farmer*	1177** (0.00)	483** (0.00)	951** (0.00)	1293** (0.00)
Cropping intensity*	269.6** (0.00)	193.9** (0.00)	334.6** (0.00)	306.7** (0.00)
Irrigated land	140.7 (0.39)	11.5 (0.92)	225.1 (0.14)	607.2** (0.00)
Fertilizer use	133.0* (0.02)	269.2** (0.00)	133.3** (0.01)	-24.7 (0.50)
WPI (horticultural items)	-31.5 (0.65)	36.82 (0.46)	-51.4 (0.41)	-142.2** (0.00)
Constant	-88907 (0.01)	-15556.8 (0.55)	-129685 (0.00)	-179929 (0.00)
<i>Model validation test</i>				
R square	0.63	-	-	-
adj. R square	0.62	-	-	-
pseudo R square	-	0.45	0.42	0.49
Ramsay RESET				
H_0 : model has no omitted variable				
F (3,274)	0.86	-	-	-
Prob.>F	0.46	-	-	-

*, **, *** indicates significant at 10%, 5% and 1% level respectively

cropping intensity, fertilizer usage, per capita NSDP and proportion of small and marginal farmers. A unit increase in per capita NSDP resulted in an increase in economic productivity by 0.79 units indicating that the linkages with other sectors of the economy were significant and substantial. Productivity gains from the increase in cropping intensity was comparatively higher in moderately productive regions, while fertilizer usage contributed more to economic productivity in low productive areas. These findings are in line with our previous studies (Singh *et al.* 2015). The results of quartile regression of highly productive states were substantially different from the others. Reinstating existing literature, the study found that diversification and share of irrigated agriculture were found to contribute to economic productivity significantly while increase in price volatility measured through WPI of horticultural produce have negatively affected agricultural productivity (Birthal *et al.* 2015, Sen *et al.* 2017). Fertilizer usage does not contribute substantially to economic productivity in these regions. The results indicate that diversification is a key determinant of

economic productivity only in highly productive regions. Several studies have indicated that diversification towards high value crops are disproportionately, higher in regions with an innovative farming community, superior technical knowhow, efficient institutions and ample natural resource base. Regions with high levels of productivity are thereby likely to diversify towards high value crops in comparison to regions with low levels of productivity which are hampered by institutional, socio-economic and resource constraints. Highly productive regions have larger proportion of area under irrigation. Availability of irrigation can reduce risk in farming enterprise and facilitates the cultivation of high value commodities thereby aiding economic productivity. Irrigation also contributes to higher production through area expansion and increase in yields. The usage of fertilizers in highly productive regions is substantially higher in comparison to low and moderately productive regions. The marginal contribution of fertilizers in these regions is negligible in comparison to other regions, possibly explaining the discrepancy concerning fertilizers in these regions.

Deciphering the factors causing productivity gap:

Given the productivity differentials among different regions, identifying factors responsible for these differentials is vital in framing policies to reduce these inequalities. The first step in this direction would be identifying an indicator of the productivity gap. The inter-quartile range can be used as simple and powerful tool for measuring productivity gap (Syverson 2004). Descriptive statistics revealed substantial differences between regions in proportion of irrigated area, distribution of markets and fertilizer usage. Level of diversification and wholesale price index (horticultural produce) were found to have differential impacts across different regions on farm productivity. Hence these variables were initially selected as regressors. The scatter plot matrix of the relevant variables was obtained and is depicted in Fig 2.

The scatter plots indicate a high degree of correlation between proportion of irrigated area and fertilizer usage possibly due to complementary relationship between these factors. Due to apprehensions concerning multi-collinearity

Table 2 Factors affecting productivity gap.

Dependent var.: GVO	Coefficient	Bootstrap Std.		
		error	t	P> t
<i>Interquartile regression</i>				
WPI (horticultural items)	358.78	114.20	3.14	0.01
Small and marginal farmer	855.90	62.70	13.65	0.01
Fertilizer use	12.11	56.51	0.21	0.83
Market concentration	-1.96	0.49	-3.98	0.01
Constant	-56869.55	4793.80	-11.86	0.02
0.75 Pseudo R square	0.22			
0.25 Pseudo R square	0.37			

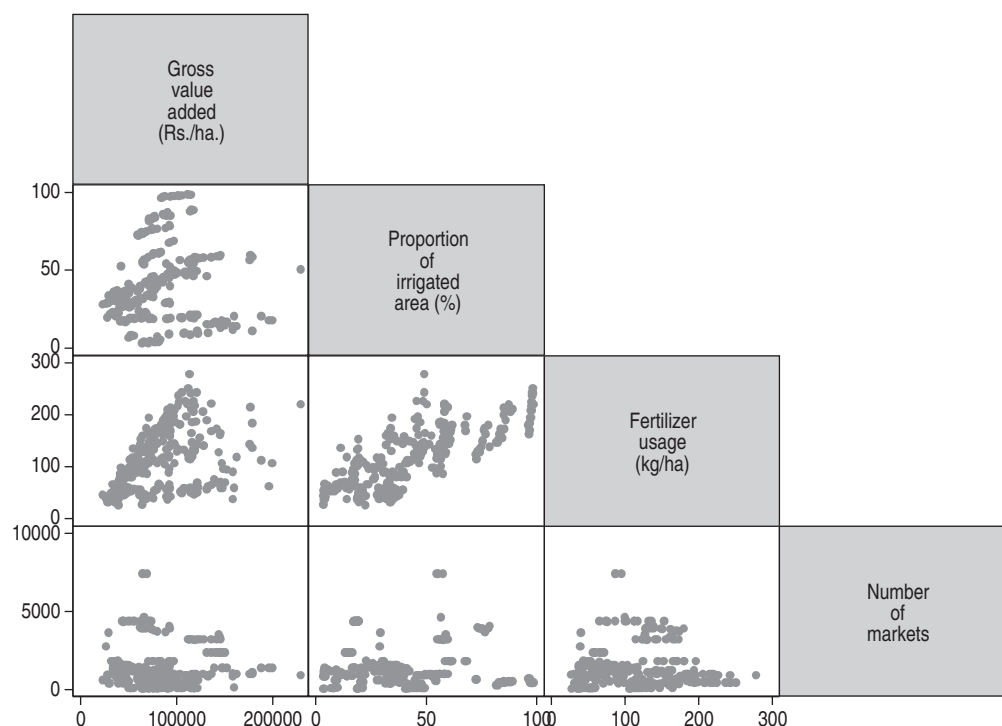


Fig 2 Scatter plot matrix of selected study variables.

and the substantial role played by fertilizer usage in enhancing productivity in moderately and low productive regions we have decided to retain only fertilizer usage in our model. Simpson index was subsequently dropped due to minimal variability across regions. The proportion of small and marginal farmers in total population was added as a proxy for land fragmentation to identify potential impact on productivity gap. An inter-quartile regression model was used to identify the factors affecting productivity gap with WPI (horticulture), fertilizer usage, market concentration and proportion of small and marginal farmers as the dependent variables. Increase in WPI (horticultural produce) was found to increase productivity gap, thereby indicating that price volatility increased productivity differentials (Table 2).

An increase in market concentration decreased productivity gaps indicating that assured markets and infrastructural facilities are vital in reducing productivity gap. Land fragmentation was found to augment productivity differentials across regions. Small and marginal holdings fail to reap economies of scale in production process and the results indicate that consolidation of land holding and institutional amendments like legalising tenancy and land lease arrangements would be beneficial in reducing productivity differentials (Rahman and Rahman 2009). Fertilizer usage was found to have no significant influence on productivity gap.

The study revealed that increase in per capita NSDP contributed substantially to productivity of the agriculture sector across regions indicating that benefits of economic growth are trickling down to the agriculture sector. The effects of this trickle down were found to be higher in regions with higher productivity. Diversification was found to

contribute to productivity only in regions which were highly productive even as the level of diversification did not vary substantially across regions indicating that diversification served as a risk minimizing mechanism in low productivity regions. Similarly irrigation aided to increase in value of output only in highly productive regions while fertilizer usage was influential only in low and moderately productive regions. These findings indicate that better nutrient management strategies in regions with low productivity are vital in increasing economic productivity in these

regions. The inefficient management of irrigation systems have been a cause of concern in low productive regions and better management of irrigation systems is vital in translating increase in irrigated area into economic productivity. The factors, viz. that access to markets are vital in reducing productivity differentials across regions. Increasing market access especially in low productivity regions characterized by low market density is essential in trimming down the productivity gap. The increase in WPI (of horticultural produce) was found to increase differentials in economic productivity indicating that integration of markets and effective price transmission are vital in reducing productivity gaps. The newly launched e-NAM could possibly help in reducing regional disparities in agricultural productivity. Land fragmentation indicated by relative share of small and marginal farmers was found to increase productivity gap. Consolidation of holdings and legalising tenancy and land lease arrangements could enable farmers to attain economies of scale and bridge productivity gaps.

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