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Decomposition Analysis of Output Change under New Wheat Technology in Arid Region of Rajasthan: An Econometric Study

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Abstract: Wheat is one of the most important food grains known for various uses throughout the world. Introduction of modern technology in this crop has immense advantage. Production response functions for both the modern and traditional technology were estimated to understand the advantage of modern technology over traditional technology. The primary data were collected from 40 farmers each adopting modern and traditional technology in the IVLP villages in Osian Tehsil of Jodhpur District. The field demonstration method was used. The estimated farm level production response functions were significant and the upward shift in the production function due to technological improvement was through a shift in the intercept to the extent of 22%. The total difference in the productivity between modern and traditional wheat technology was estimated to be about 62%. The modern technology of wheat increased the production by 62.30% over the traditional variety. The technical contribution of modern wheat technology is about 46.45 and the remaining 14.22 was of more use of complementary inputs. The major component of this productivity gap was the difference in varietal technology contributing nearly 46%, while remaining 14% was shared by complementary inputs in terms of use levels between the modern and traditional wheat production technology.

Key words: Wheat, production function approach, yield decomposition model, nature of technology change

Wheat stands second in respect of area and production in the country, after rice accounting for 28.04 Mha of the country and 74.89 metric tons of production. It is grown extensively in the states of Maharashtra, Rajasthan, Karnataka, Madhya Pradesh, Andhra Pradesh, Gujarat, Tamil Nadu and Uttar Pradesh. During mid 60's, new agricultural technologies viz., high yielding varieties, fertilizers, irrigation, market, infrastructure, etc., were introduced resulting in self-sufficiency in agriculture. The lab to land and national demonstration of new technologies spread through extension tools played a vital role. During the 1980's the agricultural production was nearly stagnated, but by adoption of new technologies during late 1990's, the agricultural production increased from 180 Mt to 200 Mt. The area under wheat has increased drastically in arid region (from 638080 ha during 1990-91 to 934130 during 2006-2007). Similarly the production in arid region and Jodhpur has increased 63 and 130%, respectively. However, scanty information on impact of new technology is available. Keeping this view an attempt has been made to know the impact of new wheat technology in arid regions of Rajasthan.

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Methodology

The study is based on the primary data collected during 2005-06 through a survey of 40 farmers from a cluster of five IVLP villages spread across Osian Tehsil of Jodhpur District. The highest increase in area under wheat crop was in Jodhpur District (930% from 1990-91 to 2007-08). The maximum area under wheat crop was in Osian Tehsil. Keeping this criteria, Osian Tehsil was selected for the present study. Simple random sampling was adopted for selection of farmers, who were cultivating wheat crop using new as well as traditional technology.

Production function approach

The production function model was used for processing the data. The contributions of technology and resource use differentiates the total productivity difference between modern and traditional technology. The log-linear function (Cobb-Douglas version) of the following specification was considered for both the modern and traditional technologies. Several other workers (Kiresur *et al.*, 1995; Singh *et al.*, 2009) widely used functional form of Cobb-Douglas version and found it appropriate for the input-output

relationship in Indian agriculture due to its ease in interpretation of the results.

$$\text{Ln } Y = \text{Ln } A + a_1 \text{ Ln } X_1 + a_2 \text{ Ln } X_2 + a_3 \text{ Ln } X_3 + a_4 \text{ Ln } X_4 + a_5 \text{Ln } X5 + a_6 \text{Ln } X6 + U_1 \quad \ldots (1)$$

where, Y = Production (q); X_1 = Area under the crop (ha); X_2 = Total expenditure on seed (Rs.); X_3 = Total expenditure on fertilizers and farm yard manure (FYM) (Rs.); X_4 = Total expenditure on irrigation (Rs.); X_5 = Total labor used for work (man-days); X_6 = Other expenditure included the value of machinery used, insecticide/pesticides, depreciation and other charges (Rs.); U = Random disturbance term; 'A' = scale parameter and "a_i' are slope parameters of the regression function.

To examine whether the parameters of the production function of modern technology were different from those of traditional technology, the analysis of covariance test (Chow, 1960) was applied. Since Chow's F-statistics was found significant, an attempt was made to test whether the structural difference in production relationships was due to intercept or slope or both. This was done by introducing in equation (1) dummy variables for intercept slope and for both and then testing the significance levels of the dummy variables so obtained from the equations.

Yield decomposition model

The separate crop production functions were estimated for modern and traditional technologies. The production function approach has been widely used to decompose total change in output (Bisaliah, 1977; Thakur and Kumar, 1984; Hussain and young, 1985; Kiresur *et al.*, 1995). The specification of production functions used in decomposition analysis is as follows:

$$\text{Ln } Y_t = \text{Ln } A_t + a_1 \text{ Ln } X_{1t} + a_2 \text{ Ln } X_{2t} + a_3 \text{ Ln } X_{3t} + a_4 \text{ Ln } X_{4t} + a_5 \text{Ln } X_{5t} + U_1 \quad \ldots (2)$$

$$\text{Ln } Y_m = \text{Ln } A_m + b_1 \text{ Ln } X_{1m} + b_2 \text{ Ln } X_{2m} + b_3 \text{ Ln } X_{3m} + b_4 \text{ Ln } X_{4m} + b_5 \text{ Ln } X_{5m} + U_2 \quad \ldots (3)$$

where, Y = Crop yield (q ha^{-1}); X_1 = Quantity of seed applied (kg ha^{-1}); X_2 = Exp. on fertilisers and FYM (Rs. ha^{-1}); X_3 = Total expenditure on irrigation (Rs. ha^{-1}); X_4 = Total human labor (man-days ha^{-1}); X_5 = Other expenses include value of seeds, depreciation on machine and bullock etc. (Rs. ha^{-1})

Note: Subscript t and m indicate traditional and modern technology systems, respectively.

In addition to fitting crop production functions for traditional and modern technologies, a pooled function was also fitted using dummy variable for variety. Taking the difference between the equation (2) and (3) and performing a slight algebraic manipulations and rearrangement of some terms, the following decomposition model was arrived at:

$$\text{Ln } Y_m - \text{Ln } Y_t = (\text{Ln } A_m - \text{Ln } A_t) + [(b_1 - a_1) \text{ Ln } X_{1t} + (b_2 - a_2) \text{ Ln } X_{2t} + (b_3 - a_3) \text{ Ln } X_{3t} + (b_4 - a_4) \text{ Ln } X_{4t}) + (b_5 - a_5) \text{ Ln } X_{5t}] + [(b_1 (\text{Ln } X_{1m} - \text{Ln } X_{1t}) + b_2 (\text{Ln } X_{2m} - \text{Ln } X_{2t}) + b_3 (\text{Ln } X_{3m} - \text{Ln } {}_{3t}) + b_4 (\text{Ln } X_{4m} - \text{Ln} X_{4t}) + b_5 (\text{Ln } X_{5m} - \text{Ln } X_{5t}) + (U_2 - U_1) \quad \ldots (4)$$

The decomposition equation (4) approximately measures the percentage change in output with the introduction of HYV's (modern technology) of wheat. The first bracketed expression on right hand side is a measure of percentage change in output due to shift in scale parameter (A) of the production function the second bracketed expression measures. The effect of change in slope parameters, and these two terms sum up to the total effect of modern technology. The third bracketed term measures the contribution of change in input use. The difference between the resources required to produce the per hectare modern technology level of output (Ym) by traditional technology and the resources actually used to produce the output with modern technology indicates the value of input saved due to higher production efficiency. The value of inputs saved (Is) under modern technology over traditional technologies is treated as benefit of modern technology.

Results and Discussion

All the estimated production functions for wheat crop were significant as evident by the significance of F-values at 1% level (Table 1). The adjusted coefficient of multiple determination (R^2) was high and varied from 87.56% in case of traditional technology to 90.13% in case of modern technology. This indicated that variation in yield was adequately explained by the explanatory variables included in the model namely, farm size (X_1), expenditure on seed (X_2), expenditure on fertilizer and FYM (X_3), expenditure on irrigation (X_4), total labor used (X_6) and other expenditure on machinery used, pesticides, interest on working capital and depreciation (X_5). Similar observations were recorded by Kiresur *et al.* (1995) in sorghum.

The perusal of the production function estimate revealed that the coefficients of all the explanatory variables were positive and significant at varying degrees of significance with the only exception of "other expenses variable" (X_6) in case of traditional technologies, which was although positive but non-significant. The values of estimated regression coefficients of modern technology were more than estimated value of regression coefficient of traditional technology indicated that modern technology is more responsive due to judicious use of fertilizer and FYM (X_3), irrigation (X_4) and labor (X_5). It may be recalled that regression coefficients in Cobb-Douglas production function, are equivalent to production elasticities. It could be noticed that the production elasticity of the inputs were invariably less than unity indicating diminishing marginal productivity with respect to each of the inputs. The production elasticities of all the inputs were relatively higher in case of modern technology when compared to traditional technology resulting in higher efficiency levels, owing to the diminishing marginal productivity property of the production function.

Structural break and nature of technological change

The existence of structural break was examined by conducting tests for the equality of regression equations. Chow's F-statistics were computed for the equality of regression coefficients including the intercept term obtained as 4.54 which at 7 and 64 d.f. was significant at 5% level. This indicated that the introduction of the modern technology in wheat crops caused structural break in the production response and shifted the wheat production function in the process of technological change.

The nature of technological change was examined by testing the homogeneity of regression coefficients of various inputs expressed in the form of explanatory variables while the intercept terms (constant) in the two production functions (production function of modern technology and traditional technology) were allowed to differ (Alshi *et al.*, 1983). The computed F-ratio of 1.08 at 6 and 68 d.f. were found to be non-significant implying that shift in the production was due to intercept and not due to slope. It could be seen that intercept for modern technology in wheat was higher by 22.47% as compared to traditional technology in wheat as inferred by the intercept dummy variable value (Table 1). Thus, as a result of introduction of modern technology of wheat, the technological change was neutral type.

The analysis of covariance test indicated that the structural break (shift in production function)

Table 1. Estimated regression parameters of farm production functions of wheat crop

Particular	Wheat technology			
	Modern	Traditional	Pooled	Pooled with dummy variable
Intercept	1.8307	1.5209	1.7059	0.8107 0.2247** (0.0832)
Farm size (ha) (X_1)	0.1994*** (0.0472)	0.1427*** (0.0341)	0.1881*** (0.0433)	0.1175*
Seed (X_2)	0.1213** (0.0582)	0.1083*** (0.0417)	0.1103** (0.0475)	0.1440*
Fertilizer and FYM (X_3)	0.1308*** (0.0327)	0.1179*** (0.051)	0.1257*** (0.0512)	0.0471*
Irrigation (X_4)	0.2557*** (0.1009)	0.2163* (0.1306)	0.2397** (0.1035)	0.2607***
Total labor used (X_5)	0.3215*** (0.0958)	0.2871*** (0.1079)	0.3071*** (0.1253)	0.2967***
Other expenses (X_6)	0.1193 (0.0900)	0.1107 (0.0964)	0.1278 (0.0815)	0.1075*
R^2	0.9013	0.8756	0.9257	0.9402
No. of observations	40	40	80	80
F-value	25.167	18.09	31.58	38.11

***, ** and * significant at 1, 5 and 10% level of significance.

was due to significant change in intercept rather than the slope. However, to know the complete structural relationship in the parameters of the production functions for the two technologies, the log linear production function (Cobb-Douglas production function) was estimated with both intercept and slope dummies. The estimated regression coefficients are presented in Table 2.

The model was significant at 5% level and having high coefficient of determination (R^2). None of the slope dummies turned out to be significant indicating that the complete structural break-through was due to shift in intercept in production function. The positive sign of the dummies for all the explanatory variables used in the production function indicated that production of the crops were due to higher use of inputs in case of modern technology.

Yield decomposition

The productivity difference between modern and traditional technologies was disaggregated into its constituents i.e., sources of technological and input components used with the help of the decomposition model as suggested by Bisalliah (1977). The per hectare log-linear production functions as specified in equation (2) and (3) and the geometric mean levels of inputs used for both technologies, were used for decomposition of yield.

Table 2. Testing of complete structural relationship between production function of modern and traditional technologies of wheat crop

Variables	Regression coefficient with dummy variables
Intercept	0.7183
Intercept dummy	0.0809***
Farm size (ha) (X_1)	0.1086**
Seed (X_2)	0.1587**
Fertilizer and FYM (X_3)	0.1206***
Irrigation (X_4)	0.2378****
Total labour used (X_5)	0.2961****
Other expenses (X_6)	0.0956*
Slope dummy for,	
Farm size (ha) (X_1)	0.1109
Seed (X_2)	0.7711
Fertilizer and FYM (X_3)	0.1044
Irrigation (X_4)	0.1327
Total labor used (X_5)	0.0993
Other expenses (X_6)	0.1104
R^2	0.9603
No. of observations	80

The per hectare Cobb-Douglas production functions for modern, traditional, pooled (both modern and traditional) and pooled with intercept (constant term) dummy were estimated and results are presented in Table 3. The estimated production functions were significant at 5% level as indicated by F-value. The coefficient of determination (R^2) was 81.05% and 94.73% for traditional technology and pooled with intercept dummy, respectively. Estimated regression coefficients were significant at varying degree of freedom except other expense variable (X_5) under traditional technology.

The Chow's F-test was also carried out to find out the existence of any significant difference between two production functions (modern and traditional technologies) in terms of their parameters. The production functions as well as pooled function with intercept dummy were also fitted. The pooled production function showed positive and significant coefficients for all the explanatory variables. The significant Chow's 'F' value indicated a difference in production parameters between modern and traditional technology, while estimated regression coefficients were significant at varying degree of freedom except other expense variable (X_5) under traditional technology.

The constant term of modern technology was higher than that of traditional technology, indicating that the shift in production function was due to technological change. It also indicated that at a given level of inputs, more yield could be generated under modern technology as compared to traditional technology.

Mean geometric levels of inputs used

In addition to estimated parameters of production functions (Table 3), the decomposition analysis required geometric mean values of different explanatory variables (inputs) in model are given in Table 4. Geometric mean values of various inputs used on the modern technology were higher in comparison to those used on traditional technology (Table 4). The total difference in the productivity was decomposed into technical change and its explanatory variables (inputs used) in the model. Decomposition of yield was estimated with the parameters of production functions (Table 3) and geometric mean levels of inputs used (Table 4). The results of the decomposition analysis are presented in Table 5.

The total estimated change due to technological and inputs used was of the order of 60.67%, whereas,

Table 3. Estimated regression coefficient per hectare for wheat production functions

Particulars	Regression coefficients			
	MT	TT	Pooled	Pooled with dummy
Intercept	03915	-0.6017	0.1445	0.0583
Intercept dummy	–	–	–	0.2917***
				(0.0922)
Seed (X_1)	0.0569**	0.0517***	0.0621***	0.0823
	(0.0211)	(0.0199)	(0.0256)	(0.0311)
Fertilizer and FYM (X_2)	0.0213**	0.0179*	0.0189**	0.1059*
	(0.0094)	(0.0089)	(0.0078)	(0.0421)
Irrigation (X_3)	0.1968**	0.1305*	0.1905**	0.1136**
	(0.0851)	(0.0599)	(0.0865)	(0.0471)
Total labor used (X_4)	0.2867	0.2609	0.2909	0.3259
	(0.10022)	(0.0889)	(0.1059)	(0.1153)
Other expenses (X_5)	0.0713**	0.0629	0.0763*	0.0739
	(0.0296)	(0.0381)	(0.0307)	(0.0411)
R^2	0.9057	0.8105	0.9283	0.9473
F-Value	21.7109	24.5133	27.0015	23.2205
No. of observation	40	40	80	80
Chow's F – value	3.0054**			

***, ** and * significant at 1, 5 and 10% level of significant.

the technological component contributed 46.45%. This indicated with the present levels of inputs used by traditional technology users, the production of wheat could be increased by 46.45% by merely adopting or switching over to modern technology. Such increase in the yield was exclusively due to technological improvement through a shift in the scale (intercept) and/or slope parameters of the production function. The yield of wheat can be further increased by 14.22% by increasing the inputs to the levels as that under modern technology. As explained above, there was a large gap in the input levels between modern technologies and traditional technology. It might not be possible for the farmers adopting traditional technology to adopt complete package of modern technology due to their poor resources. But, they may adopt modern technology with existing resource or possibly, higher levels of input, which may help earn better returns.

There was a slight difference in estimation of productivity change i.e. observed change was 62.30% where as estimated change was 60.67%. This discrepancy was attributed to random error in the model possibly due to some omitted variable. Such discrepancy of varying degree in decomposition model was also reported by other workers (Bisaliah, 1977; Singh and Gajja, 2004). However, in the present study, discrepancy was of a very low order, satisfying the decomposition analysis. A perusal of these results revealed that there was a slight discrepancy between the observed (49.47) and the estimated (51.99%) differences in the productivities of modern and traditional technologies. This discrepancy was attributed to random error term that, among others, accounts for variables that could not be included in the model. Such discrepancies of varying degree in decomposition model analysis were also encountered in many studies (Bisaliah, 1977; Joshi and Jha, 1992; Singh *et al.*, 2004). However, in the present study, the discrepancy in question was of a very low order. As explained above, there is a large gap in the input levels between modern and traditional technologies. Due to poor resources it is not possible for the farmers adopting traditional

Table 4. Geometric mean levels of inputs used per hectare for wheat crop

Crop/Input Level	Technology	
	Modern	Traditional
Seed (X_1) (Rs. ha^{-1})	689.41	644.31
Fertilizer and FYM (X_2) (Rs. ha^{-1})	1249.03	965.81
Irrigation (X_3) (Rs. ha^{-1})	1121.09	895.09
Total labor used (X_4) (man-day ha^{-1})	32.72	24.82
Other expenses (X_5)	1355.61	1176.29

Table 5. Decomposition of yield of wheat crop between modern and traditional technologies

Source of change	Per cent attribute
Total observed change	62.30
Due to difference in technology	46.45
Due to technology	18.98
Seed (X_1) (Rs. ha^{-1})	3.36
Fertilizer and FYM (X_2) (Rs. ha^{-1})	2.34
Irrigation (X_3) (Rs. ha^{-1})	7.54
Total labour used (X_4) (man-day ha^{-1})	8.29
Other expenses (X_5)	5.94
Due to change in complementary inputs	14.22
Seed (X_1) (Rs. ha^{-1})	0.30
Fertilizer and FYM (X_2) (Rs. ha^{-1})	0.55
Irrigation (X_3) (Rs. ha^{-1})	4.44
Total labor used (X_4) (man-day ha^{-1})	7.92
Other expenses (X_5)	1.01
Total estimated change due to difference in technology	60.67

technology growers to completely adopt package of modern technology. But, with the adoption of modern technology they could earn better results from their inputs.

References

Alshi, M.R., Kumar, P. and Mathur, V.C. 1983. Technological change and factor shares in cotton production: A case study of Akola cotton farms. *Indian Journal of Agricultural Economics* 38 (3): 407-415.

Bisaliah, S. 1977. Decomposition analysis of output change under new production technology in wheat farming: Some implications to returns on research investment. *Indian Journal of Agricultural Economics* 32(3): 193-201.

Chow, G. 1960. Tests of equality between sets of coefficient in two linear regressions. *Econometrica* 28(3): 591-605.

Hussain, R.Z and Young R.A. 1985. Salinity damage of irrigated crops: Economic measurements from a farm survey in Pakistan, Working Paper 85-4, Department of Agriculture and Natural Resource Economics, Colorado State University, Fort Collins, Colorado, U.S.A.

Joshi, P.K. and Jha, D. 1992. An economic enquiry into impact of soil salinity and water lodging. *Indian Journal of Agricultural Economics* 47: 195-204.

Kiresur, V., Pandey, R.K. and Mruthyunjaya 1995. Technological change in sorghum production: An econometric study of Dharwad farms in Karnataka. *Indian Journal of Agricultural Economics* 50(2): 185-192.

Singh, B., Gajja, B.L., Khem Chand and Beniwal, R.K. 2004. Impact of modern technology of legumes in arid zone of Rajasthan. *Annals of Arid Zone* 43(1): 91-95.

Singh, S.P., Gangawar, B. and Singh, M.P. 2009. Economics of farming systems in Uttar Pradesh. *Agricultural Economics Research Review* 22 (1): 129-138.

Thakur, J. and Kumar, P. 1984. A comparative study of economic efficiency of different irrigation systems in western U.P. *Indian Journal of Agricultural Economics* 39(3): 521-527.