Economic Efficiency in Wheat Production, Riyadh Region, Saudi Arabia

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Abstract: This article was set to estimate the economic efficiency and input demand functions for wheat production, utilizing a random sample of 150 observations (farms) in Riyadh Region, Saudi Arabia. Results showed that the unit cost of crop area, irrigation water, and labor used in wheat production was estimated to be 1670 SR/Hectare, SR 290/1000 M^2, and SR 5260/worker, respectively. Whereas the marginal return for these inputs was estimated to be SR 2030/hectare, SR 358/1000 M^3, and SR 6415/worker, for crop area, irrigation water, and labor, respectively. Economic Efficiency (defined as the value of marginal product, VMP, relative to the opportunity cost, OC) for crop area, irrigation water, and labor was estimated to be 1.22 for each input. This means that VMP for these inputs is more than its respected OC; and thus, farmers can increase their wheat profits by increasing these inputs until VMP equals OC for each input. Results also showed that the optimum input use of crop area, irrigation water, and labor in wheat production, was greater than the actual inputs used by 27.2%, 43.6%, and 35.4%, respectively. Price elasticity of demand for crop area, irrigation water, and labor was estimated to be -0.75, - 0.70, and -0.65, respectively. This means that a 10% increase in input cost will decrease these inputs use by 7.5%, 7%, and 6.5%, respectively. The study stresses the need to use the optimal amount of inputs in wheat production, and include the "economic value" of irrigation water in order to conserve it, given the scarcity of water in Saudi Arabia.

[Mohammad H. Al-Qunaibet and A. M. Ghanem. **Economic Efficiency in Wheat Production, Riyadh Region, Saudi Arabia.** *Life Sci J* 2014;11(12):680-683]. (ISSN:1097-8135). http://www.lifesciencesite.com. 128

Keywords: Wheat, input costs, marginal revenue, economic efficiency, demand function.

1. Introduction:

Wheat is the most important cereal crop in Saudi agriculture, which is grown in 215,700 hectares, or 26% of total agricultural area (829,330 hectares, 2008 – 2012). Wheat cultivation is concentrated in six regions: Al-Jouf, Riyadh, Eastern Province, Hail, Qassim and Tabuk (Ministry of Agriculture, 2013). Wheat received considerable government support since 1973, which increased wheat production and productivity over the years.

Research Objectives:

This paper will estimate the economic efficiency and demand functions for inputs used in wheat production in Riyadh Region, Saudi Arabia, by fulfilling the following objectives:

1- Estimating wheat production function.

2- Estimate economic efficiency, cost, marginal return, and the optimal use of inputs in wheat production.

3- Estimate the demand functions and input price elasticity of demand for inputs used in wheat production.

2. Methodology:

Riyadh Region was chosen because it is ranked second, after Al-Jouf, in the relative importance for wheat production in Saudi Arabia during 2008-2012, (Ministry of Agriculture, 2013). A random sample of 150 farms was selected, and person-to-person interviews were conducted with these observations (farms) to complete the questionnaires for this study.

To fulfill the abovementioned objectives, ordinary least squares (OLS) method was used to estimate the production function for wheat, in the following form:

$$\hat{Y}=a + b_1X_1+b_2X_2+b_3X_3+e_i$$

Where:

Y : Wheat production (tons).

X_1: Wheat crop area (hectare).

X_2: Wheat irrigation water quantity (thousand cubic meter M^3).

X_3: Number of workers per farm (worker).

a , b_1, b_2, b_3: model parameters (coefficients).

e_i: Random Error.

It was difficult to get the price for some inputs or input share in wheat production costs, thus the following formulae were used to estimate these variables (Ghanem and Kamara, 2008):

1- Input share in Production (wheat) Value = (production elasticity of the input ÷ sum of Production elasticities) x Total Value of Production.

2- Input cost (price) = Input share of the product value ÷ quantity of input used.

Economic efficiency for inputs used in wheat production was estimated by the ratio of the value of marginal product (VMP) of this input to its opportunity cost (input unit cost). Input price elasticity of demand was calculated by dividing percent change in input by percent change in input price.

Literature Review:

Several studies addressed productivity and economic efficiency for agricultural inputs. Al-Mallah and Gazzaz (1989) addressed the introduction of irrigation water as an economic input in agricultural production in Qassim Region. Among cereal crops grown in Qassim, wheat was shown to be the most efficient in water use, and with greater returns on water unit than winter crops.

Hasian (2004) investigated irrigation water pricing and its effect on water demand management in Syria. He found that adopting irrigation water pricing policy will conserve water, support the government's budget, and increase the efficiency in water management.

Ghanem and Kamara (2008) estimated the unit cost of irrigation water in Egypt's agriculture to be 0.11 Pound/M^3.

Al- Ruwais (2008) estimated the cost of agricultural inputs using input production elasticity derived from the production function of the agricultural sector. He found that the average annual cost of water in agriculture to be 0.12 Riyals/ M^3 (1980-2005).

Finally, Al-Qunaibet *et al.* (2014) stressed the need to restructure the Crop Pattern in Saudi Agriculture with respect to the annual available irrigation water according to every region's crop productivity.

It is clear that previous research used time-series data to estimate the optimum input use and pricing of scarce inputs such as irrigation water. This study uses cross section data to estimate the cost, marginal return, economic efficiency, input demand functions, and price elasticities for wheat inputs in Riyadh Region, Saudi Arabia.

3. Results

Econometric Estimation of Wheat Production Function in Riyadh Region

Ordinary Least Squares regression (OLS) method was used to select the best of two models: Linear and double-log. Regression results showed that the double-log model outperformed the linear model in explaining the changes in wheat production with respect to the explanatory variables as follows:

$$\text{Ln } \hat{Y} = 1.698 + 0.18 \text{ Ln } X_1 + 0.42 \text{ Ln } X_2 + 0.34 \text{ Ln } X_3$$

$(12.23)^{**}$ $(4.22)^{**}$ $(17.15)^{**}$ $(2.15)^{*}$

$R^{-2} = 0.95$ $F = 620.08$

(**significant at 1% level, *significant at 5% level**)**

The estimated double-log model has a good fit represented by high value of adjusted coefficient of determination (R^{-2}) 0.95, with no Heteroskedasticity problem as shown by a non-significant F-value (1.02) at 5%, according to The White Test (William, 2003).

The regression results show that the production elasticity of crop area (X_1), irrigation water (X_2), labor (X_3) to be 0.18, 0.42, 0.34, respectively. This means that a change of 10% in crop area, irrigation water, and labor will lead to change in the same direction for wheat production by 1.8%, 4.2%, and 3.4%, respectively.

Estimating Input Costs in Wheat Production in Riyadh Region:

Wheat inputs' cost were estimated using the amount of input used in relation to its share in total product value. Table (1) shows that average share of crop area (X_1) in the total value of wheat is SR 36,170 or SR 1670/ hectare. On the other hand, share of irrigation water (X_2) in the total value of wheat production was estimated to be SR 84,400 or SR 290 per one unit of irrigation water (1000 M^2). Finally, the share of labor in the total value of wheat production was estimated to be SR 68,330 or SR 5,260/worker.

Table (1): Estimation of Unit Cost of Wheat Inputs, Riyadh Region

Item	Input		
	Crop Area	Irrigation Water	Labor
Amount of the Input used	21.7 (hectare)	288 (1000 M^3)	13 (Workers)
Input share of the value of wheat production (Riyals)	36,170	84,400	68,330
The unit cost of Input (= Input price)	1,670 (Riyals/ hectare)	290 (Riyals/ 1000 M^3)	5,260 (Riyals/worker)

Source: Calculated from the production function estimated for wheat.

Marginal Revenue and Optimal Use of Wheat Production Inputs:

Re-writing the above mentioned double-log wheat production function in its exponential form, we get the following equation:

$$Y = 5.463\, X_1^{0.18} X_2^{0.42} X_3^{0.34}$$

Which we can use to derive the marginal revenue (return) for crop area (X_1) of wheat production as follows:

$MP_1 = \frac{dY}{dX_1} = 0.983\, X_1^{-0.82}\, X_2^{0.42}\, X_3^{0.34}$

Given the government's wheat buying price was set at 1000 SR / ton, and using the estimated figures in Table (1) for irrigation water (X_2) and labor (X_3), one can calculate the value of marginal product for crop area in wheat production (VMP_1) as follows:

$VMP_1 = MP1 . P_Y = \frac{dY}{dX_1} . P_Y = 2034$ Riyal / hectare

And with average wheat crop area of 21.7 hectares per farm, the marginal revenue (return) for crop area (MR) will be SR 2,030/hectare.

As we know the optimal use of an input will be realized at the point where marginal revenue equals marginal cost (MR = MC) for that input. Thus, for wheat crop area (X_1), the optimal crop area will be 27.6 hectares, which is more than the average crop area in the sample (21.7 hectares) by 27.2% or 5.9 hectares.

In the same way, the marginal product of irrigation water (MP_2) used for growing wheat and its VMP_2 will be estimated as follows:

$MP_2 = \frac{dY}{dX_2} = 2.294\, X_1^{0.18} X_2^{-0.58} X_3^{0.34}$

$VMP_2 = \frac{dY}{dX_2} . P_Y = 9550\, X_2^{-0.58}$

$= 358\ Riyal/\ 1000\ \mathrm{M}^3$

And the optimal amount of irrigation water used in wheat production can be calculated by equating the marginal revenue for irrigation water in wheat production to its marginal cost ($MR_2 = MC_2$). The resulting optimal amount of irrigation water per farm is 423,600 M^3, which is more than the actual amount used (288,000 M^3) by 125,600 M^3, or by 43.6%.

Finally, the marginal product of labor (MP_3) used in wheat production and its VMP_3 (= $MP_3 . P_Y$) will be estimated as follows:

$MP_3 = \frac{dY}{dX_3} = 1.857\, X_1^{0.18} X_2^{0.42} X_3^{-0.66}$

$VMP_3 = \frac{dY}{dX_3} . P_Y = 34870\, X_3^{-0.66}$

$= 6415\ Riyal/worker.$

And the optimal amount of labor used in wheat production can be calculated by equating the marginal revenue for labor in wheat production to its marginal cost ($MR_3 = MC_3$). The resulting optimal amount of labor per farm is 17.6 workers, which is more than the actual number of workers used (13) by 4.6 workers, or 35.4%.

Economic Efficiency for Inputs in Wheat Production:

The economic efficiency of wheat inputs was measured by the ratio of the value of marginal product (VMP_i) of each input to its opportunity cost (i.e., unit input cost). Table (2) shows the estimated economic efficiency to be 1.22 for crop land, 1.23 for irrigation water, and 1.22 for labor. This means that the value of marginal product (VMP_i) for every one of these three inputs is more than its opportunity cost (i.e., unit input cost). Thus, farmers can increase their profits from wheat by increasing the amount used from each input until its VMP equals its opportunity cost.

Table (2): The Economic Efficiency for Wheat Inputs, Riyadh Region

Input	Average	Value of Marginal Product (VMP_i)	Opportunity Cost	Economic Efficiency
Cultivated Area (hectares)	21.7	2,030 (Riyals/hectare)	1,670 (Riyals/hectare)	1.22
Irrigation Water (1000 m^3)	288	358 (Riyals/1000 $M^{3)}$	290 (Riyals/1000 M^3)	1.23
Number of Workers	13	6,420 (Riyals/worker)	5,260 (Riyals/worker)	1.22

Source: Calculated from data in table (1) and marginal return function for resources used.

Wheat Input Demand Functions and Changes in Inputs' Costs

Wheat inputs demand functions are estimated by equating the value of marginal product of each input with its marginal cost (i.e., unit cost, P_i). That is:

$VMP_i = P_i$

$MP_i . P_Y = P_i$

Thus, the demand function for crop land (X_1) will be:

$$VMP_1 = \frac{dY}{dX_1} . P_Y = 25370\, X_1^{-0.82} = P_{X_1}$$

$$X_1 = \frac{P_{X_1}}{25370}^{\frac{1}{-0.82}}$$

Therefore, keeping the government's wheat purchasing price fixed at SR 1000/Ton, doubling the crop land rent (cost) will decrease the average farm crop land by 57%, from 27.6 to 11.9 hectares- Table (3).

The demand price elasticity of wheat irrigation water was estimated to be - 0.57, which means that increasing crop land rent by 10% will decrease the crop land by 5.7%.

Similarly, the demand function for wheat irrigation water (X_2) will be:

$$VMP_2 = \frac{dY}{dX_2} . P_Y = 9550\, X_2^{-0.58} = P_{X_2}$$

$$X_2 = \frac{P_{X_2}}{9550}^{\frac{1}{-0.58}}$$

Thus, doubling irrigation water unit cost will result in a decrease of wheat's irrigation water by 69.7%, from 413,600 M^3 to 125,200 M^3 - Table (3). The price demand elasticity for irrigation water was estimated to be - 0.70, which means an increase in irrigation water cost by 10% will reduce irrigation water by 7%.

Finally, the farm labor demand function (X_3) has been expressed by the following equation:

$$VMP_3 = \frac{dY}{dX_3} . P_Y = 34870\, X_3^{-0.66} = P_{X_3}$$

$$X_3 = \frac{P_{X_3}}{34870}^{\frac{1}{-0.66}}$$

This means that doubling labor cost in wheat production in Riyadh Region will decrease the average number of workers by 65.1% from 17.6 to 6.1 workers per farm - Table (3). The price elasticity of demand for farm workers was estimated to be - 0.65, which means that a 10% increase in the cost of workers will decrease the number of workers by 6.5%.

Table (3) Effects of Changes in Inputs' Cost on its Use in Wheat Production, Riyadh Region.

Changes in Costs (%)	Crop Land			Irrigation Water (1000 M^3)			Labor (worker)		
	Rent Value (Riyals)	Area (hectares)	Decreasing Rate (%)	Cost of Irrigation Water (Riyals)	Amount of Irrigation Water (M^2)	Decreasing Rate (%)	Worker's Wage (Riyals)	Workers Number	Decreasing Rate (%)
-	1670	27.6	-	290	413.6	-	5260	17.6	-
10	1837	24.6	11.0	319	350.9	15.2	5786	15.2	13.6
20	2004	22.1	19.9	348	302.0	27.0	6312	13.3	24.3
30	2171	20.0	27.4	377	263.1	36.4	6838	11.8	32.9
40	2338	18.3	33.6	406	231.5	44.0	7364	10.5	40.1
50	2505	16.8	39.0	435	205.6	50.3	7890	9.5	46.0
60	2672	15.6	43.6	464	183.9	55.5	8416	8.6	51.0
70	2839	14.5	47.6	493	165.7	59.9	8942	7.9	55.3
80	3006	13.5	51.2	522	150.1	63.7	9468	7.2	59.0
90	3173	12.6	54.3	551	136.8	66.9	9994	6.6	62.3
100	3340	11.9	57.1	580	125.2	69.7	10520	6.1	65.1

Source: Study's estimates.

Recommendations:

Due to a serious water scarcity in Saudi Arabia, coupled with sharp increase in water depletion from non-renewable ground water aquifers during the last thirty years, the Saudi sustainable agricultural development requires conserving the non-renewable aquifers through a very well managed agricultural water policy. This requires the Ministry of Water and Electricity to include the cost of water in agricultural production when devising a ***Crop Pattern*** for the many regions of Saudi Arabia, which will strengthen an overdue ***Water Conservation Policy***.

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11/23/2014