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Optimum Wheat Production in Saudi Arabia

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Abstract. The objective of this paper is to find the optimum wheat production under competitive market and with a government intervention. At support price of SR 2000 per ton, the results provide that wheat production should be 1.004 million tons and the market clearing price is SR 1834.5 per ton.

Thus, the gains to producer and consumer are SR 112.6 million and SR 48 million, while the government and net social costs are SR 166.2 million and 5.6 million respectively. This indicates producers benefited proportionally more relative to consumers. Producers received about 67.7% of the total benefits, while consumers received only about 30% of the total benefits. Net social loss is about 3.3% of the total government costs.

Introduction

Even though with the policy of decreasing price support to 2000 S.R. per ton as a result of achieving self-sufficiency in wheat production in 1984, wheat production is still increasing. Wheat production was more than 3 million tons in 1989 [1] while consumption was about 1.219 million tons in the same year [2, p.12] indicating a large quantity of wheat produciton as a surplus but under very high government cost. However, Saudi exports were about 1.3 million tons in 1990 [3] either in the form of aid to some poor countries or sales in the open market, but Saudi Arabia does not have a comparative advantage of exporting wheat. Total wheat imports have decreased from 294 thousand tons in 1971 to 50 thousand tons in 1986 or about 83% decrease [4].

Most of the studies that have been carried out on wheat market were in terms of welfare analysis. Where the question is how much of wheat should be produced or in a simple way what is the optimum of wheat production. A logical answer is tried in this paper.

Objectives

The aims of this paper are the following:

1. To determine the equilibrium of wheat quantity and price under competitive market, and

2. To determine the optimum of wheat production and market clearing price under the Saudi government intervention (market equilibrium with government purchasing all domestic production at price support of SR 2000 per ton and subsidized resale to consumers).

Materials and Methods

A time series data over the period 1971-1986 is used in ths paper. Quantity supplied and demanded are obtained from the Ministry of Agriculture and Water [5], USDA [4], and FAO publications [6]. Tweeten [7, p.118] assumed free market clearing price to be the c.i.f. price plus marketing margin in the absence of a support price. Al-Kahtani [8] has estimated the free market clearing price as follows:

1. The free market supply price is calculated as the c.i.f. price [3] plus the expected marketing margin. The marketing margin is calculated by viewing the difference beween the c.i.f. price and the producer price [4] during the period 1971-1979 when commodity market was generally considered a free market. Expected marketing margin is calculated by regressing the marketing margin on the c.i.f. price [8].
2. Information on government pricing of wheat flour is not available. Therefore, Al-Abrahem [9] research is used to compute the marketing margin and free market demand price over the period 1971-1986. Hence, the free market demand price for wheat and wheat equivalent would be the c.i.f. price plus market margin [8].

Two theoretical methods are developed to derive the equilibrium solution of wheat commodity market. First is a mathematical approach and second is a linear programming approach. The two methods are carrying out Hazell and Norton, and Tweeten approaches of deriving an objective function that will produce an equilibrium solution [10, pp. 164-168, 11].

1. A mathematical approach

This method produces an exact solution. It can be simply done by using Lagrangian multiplier that maximizes producer plus consumer surplus subject to the constraint that the quantity supplied equal the quantity demanded for competitive market, and second constraint that requires free market supply prices equal to price support for government intervention.

Driving price flexibility equations are the cornerstone of calculating the producer and consumer surplus. Utilizing the assumption of linearity supply and demand, the inverse supply and demand functions can be written as:

$$P_s = C(Q_s) = a_0 + a_1 Q_s \qquad (1)$$

$$P_d = R(Q_d) = b_0 - b_1 Q_d \qquad (2)$$

where

P_s = free market supply price,

P_d = free market demand price,

Q_s = quantity supplied, and

Q_d = quantity demanded.

The integral over equation (1) represents total cost while the integral over equation (2) is the consumer surplus plus gross margin. The difference between the integral over equations (1) and (2) is the objective function which represents producer plus consumer surplus. Thus, the objective function is:

$$z = \int_0^{Q_d} R(Q_d)dQ_d - \int_0^{Q_s} C(Q_s)dQ_s \qquad (3)$$

and the Lagrangian function under competitive market is:

$$\max L = \int_0^{Q_d} R(Q_d)dQ_d - \int_0^{Q_s} C(Q_s)dQ_s + \pi (Q_s - Q_d) \qquad (4)$$

Taking the first-order conditions for an optimal solution, the necessary Kuhn-Tucker conditions are:

$$\phi L/\phi Q_d = R'(Q_d) - \pi \leq 0 \qquad (5)$$

$$\phi L/\phi Q_s = C'(Q_s) - \pi \leq 0 \qquad (6)$$

$$\phi L/\phi \pi = Q_d - Q_s \leq 0 \qquad (7)$$

The symbol ϕ denotes the partial derivatives. For the case in which demand and supply are nonzero, the equations (5) and (6) imply that:

$$b_0 - b_1 Q_d = \pi \qquad (8)$$

$$a_0 + a_1 Q_s = \pi \qquad (9)$$

where (π) Langrangian multiplier is the equilibrium price.

The definition of equation (8) is that, at the optimal solution, the model's shadow prices on the commodity balance are equal to the corresponding commodity prices. The definition of equation (9) is that, at the optimum, each commodity price is equal to the corresponding marginal cost of production. The marginal costs include both explicit costs of purchases inputs at the margin [$C'(Q_s)$] and the opportunity costs of fixed resources at margin. Equation (4) is suitable with competitive market but with government intervention an adjustment of free market supply price (P_s) equal to support price (P_s^*) is needed in the objective function. Thus the adjusted Lagrangian function is:

$$\max L = \int_0^{Q_d} R(Q_d)dQ_d - \int_0^{Q_s} C(Q_s)dQ_s + \pi_1(Q_s - Q_d) + \pi_2[C(Q_s) - P_s^*] \quad (10)$$

where

π_1 = market clearing price, and

π_2 = subsidy

2. A linear programming approach (LP)

The optimal solution can be found by incorporating the producer plus consumer surplus to a linear programming model. The LP model for competitive market is the following:

Model (1):

$$\max z = \int_0^{Q_d} R(Q_d)dQ_d - \int_0^{Q_s} C(Q_s)dQ_s \quad (11)$$

subject to

$$Q_d - Q_s \leq 0 \quad (12)$$

$$Q_d, Q_s \geq 0$$

The objective function (11) is a nonlinear function (quadratic) subject to a linear constraint function (12); therefore; an approximation method of a non-linear objective function is used. An approximation method can be done by segmenting the inverse supply and demand functions to n segments. The more the segments are the more accurate the result will be (10, pp. 169-178]. Thus, equations (1) and (2) can be written as:

$$P_{sj} = a_{0j} + a_{1j} Q_{sj} \quad (13)$$

$$P_{dj} = b_{0j} - b_{1j}Q_{dj} \quad (14)$$

$$j=1,2,\ldots\ldots n$$

$$n=30$$

The outcome of incorporating equations (13) and (14) in the producer and consumer surplus are a set of linear objective functions. Thus, model (1) can be written as follows:

Model (2):

$$\max z= \sum_{j=1}^{n} \int_{0}^{Q_{dj}} R(Q_{dj})dQ_{dj}\, D_j - \sum_{j=1}^{n} \int_{0}^{Q_{sj}} C(Q_{sj})dQ_{sj}\, S_j \quad (15)$$

s.t

$$-\sum_{j=1}^{n} \Phi_j S_j + \sum_{j=1}^{n} \Theta_j D_j \leq 0 \quad \text{for all } j \quad (16)$$

$$\sum_{j=1}^{n} D_j \leq 1 \quad \text{for all } j \quad (17)$$

$$\sum_{j=1}^{n} S_j \leq 1 \quad \text{for all } j \quad (18)$$

$$D_j, J_j \geq 0$$

The symbols Φ_j and $\ominus_j$ denote the associated quantity supplied and demanded respectively. The variables D_j and S_j are the choice variables regarding position on the demand and supply functions and may not exceed unity in value. The convex combination constraints (17) and (18) force the model's solution to be located on or below the demand and supply functions. At the optimal solution the choice variables will lie on the demand and supply functions. For government intervention analysis, another value of $[\pi_2\, a_1]$ should be added into the objective function in model (2). Thus, the LP solution under government intervention is given by the following model:

Model (3):

$$\max z= \sum_{j=1}^{n} \int_{0}^{Q_{dj}} R(Q_{dj})\, dQ_{dj}\, D_j - \sum_{j=1}^{n} \int_{0}^{Q_{sj}} C(Q_{sj})\, dQ_{sj}\, S_j + \pi_2\, a_1 \quad (19)$$

s.t

$$-\sum_{j=1}^{n} \Phi_j S_j + \sum_{j=1}^{n} \Theta_j D_j \leq 0 \qquad \text{for all j} \qquad (20)$$

$$\sum_{j=1}^{n} D_j \leq 1 \qquad \text{for all j} \qquad (21)$$

$$\sum_{j=1}^{n} S_j \leq 1 \qquad \text{for all j} \qquad (22)$$

$$D_j \quad S_j \geq 0$$

Results and Discussion

The estimated inverse supply and demand functions are:

$$P_s = 267.1 + 1.73\, Q_s \qquad (23)$$
$$t(.73) \quad t(2.51) \qquad R^2 = .33 \text{ F-test} = 6.3$$

$$P_d = 2575.13 - .74\, Q_d \qquad (24)$$
$$t(11.4) \quad t(3.8) \qquad R^2 = .54 \text{ F-test} = 16.7$$

The above results are consistent with demand and supply theories. Equations (23) and (24) satisfy standard tests. The t-test of estimated coefficients are statistically significant at 1% level except the constant term in equation (23). Regression F-tests are significant at 1% level for equation (24) and at 5% level for equation (23). Thus, it is reasonable to be utilized for driving the optimal solution of wheat production.

The optimal solutions of the mathematical and the LP approaches for competitive market are presented in Table 1. The results of the mathematical solution provide that the quantity supplied and demanded are .937 million tons associated with

Table 1. An optimal solution of competitive market

Item		Mathematical solution	LP solution
1) Equilibrium price	(S.R/ton)	1,884.0	1,876.0
2) Quantity supplied	(1000 ton)	936.8844	900.0
3) Quantity demanded	(1000 ton)	936.8844	900.0
4) Consumer surplus	(1000 S.R.)	322.837.2	331,017.0
5) Producer surplus	(1000 S.R.)	757,408.51	749,353.0
6) Objective function	(1000 S.R.)	1,080,245.71	1,080,370.0

market clearing price of SR 1884 per ton. In the LP solution, the optimal quantity produced and consumed is .9 million tons associated with SR 1876 per ton as an equilibrium price. The results indicate that both approaches produce almost an identical solution.

The analysis of support price at SR 2000 per ton and resell all purchases on the domestic market to consumers at subsidized price is presented in Table 2. The mathematical solution shows that the domestic quantity supplied and demanded is 1.004 million tons associated with market clearing price of SR 1834.5 per ton. While in the LP solution, the optimal quantity produced and consumed should be 1 million tons with market clearing price of SR 1803 per ton. At the exact optimal solution, the subsidy is SR 165.5 per ton, so that; the gain to producer is SR 112.6 million, the gain to consumer is SR 48 million. the government cost is SR 166.2 million, and the net social cost is SR 5.6 million. Producers benefited proportionally more relative to consumers. Producers received about 67.7% of the total benefits, while consumers received only about 30% of the total benefits. Net social loss is about 3.3% of the total government costs.

Table 2. An optimal solution with government intervention

Item		Mathematical solution	LP solution
1) Market clearing price	(S.R/ton)	1,834.0	1,803.0
2) Quantity supplied	(1000 ton)	1,004.125	1,000.0
3) Quantity demanded	(1000 ton)	1,004.125	1,000.0
4) Producer surplus	(1000 S.R)	870,029.89	838,273.0
5) Consumer surplus	(1000 S.R)	370,840.88	404,577.0
6) Objective function	(1000 S.R)	1,240,870.775	1,242,850.0
7) Support price	(S.R/ton)	2,000.0	1,968.257
8) Subsidy	(S.R/ton)	165.508	165.507
9) Gain to producers	(1000 S.R)	112,621.38	88,920.0
10) Gain to consumers	(1000 S.R)	48,003.684	73,560.0
11) Government cost	(1000 S.R.)	166,190.7205	165,507.0
12) Net social cost	(1000 S.R)	5,564.428612	3,027.0

Market equilibrium with government price support at SR 2000 per ton and subsidized resale to consumers at SR 1834.5 per ton is illustrated graphically in Fig. 1. The gain to producers is represented by the areas 1 plus 2. The gain to consumers is the areas 4 plus 5. The net social cost is the area 3. The government cost is the sum of the gain to producers, consumers, and net social cost.

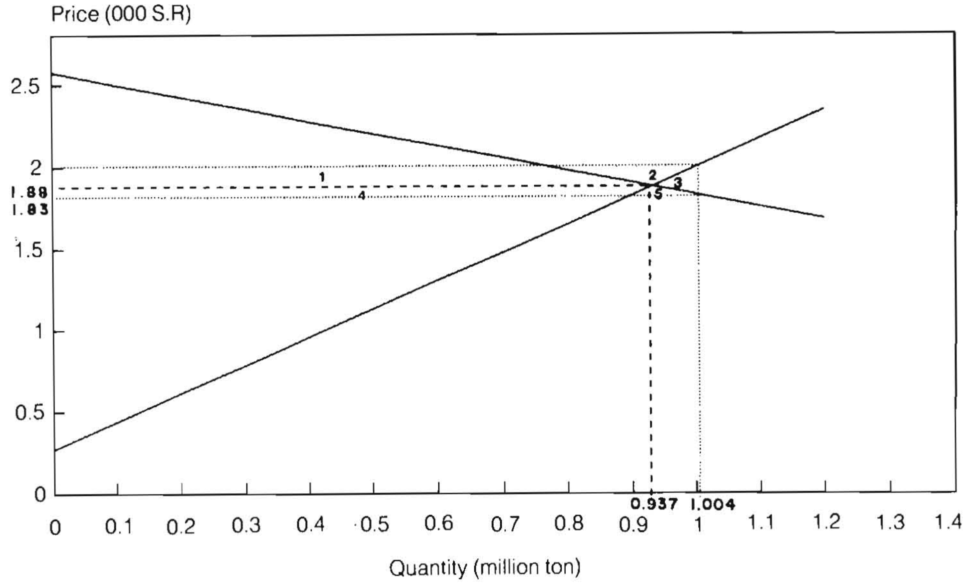

Fig. 1. Market equilibrium with government price support and subsidized resale to consumers.

In conclusion, since Saudi Arabia does not have a comparative advantage for exporting wheat, it should not produce more than its needs. Thus, this study shows the optimal quantity of domestic wheat that should be produced. While the extra wheat production should be transferred into other important cereal crops, particularly barley and sorghum, which are in high demand for livestock feed.

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الإنتاج الأمثل للقمح في المملكة العربية السعودية

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ملخص البحث. على الرغم من سياسة تخفيض الدعم الحكومي لأسعار القمح إلى ٢٠٠٠ ريال لكل طن وذلك بعد تحقيق الاكتفاء الذاتي في إنتاج القمح في عام ١٩٨٤م، إلا أن إنتاج محصول القمح لا يزال في ازدياد مطرد حيث بلغ أكثر من ثلاثة ملايين طن في عام ١٩٨٩م. وحيث إن هذه الكمية المنتجة من محصول القمح تفوق حاجة الطلب عليه حيث إن الاستهلاك المحلي كان حوالي ١,٢١٣ مليون للعام نفسه، فإن هذا البحث يهدف إلى تحديد الكمية المثلى لإنتاج القمح في ظل سياسة السوق الحر وكذلك في ظل سياسة الدعم الحكومي لإنتاج القمح. وقد بينت النتائج أنه في ظل سياسة الدعم الحكومي لأسعار القمح (٢٠٠٠ ريال لكل طن) أن الإنتاج الأمثل للقمح يجب أن يكون ١,٠٠٤ مليون طن.

وبالتالي فإن فوائد المنتج والمستهلك تبلغ ١١٢,٦ و٤٨ مليون ريال على الترتيب، بينما التكاليف الحكومية والاجتماعية فهي تبلغ ١٦٦,٢ و ٥,٦ مليون ريال ريال على التوالي، لذلك يتضح أن الفوائد النسبية للمنتج أعلى منها للمستهلك. حيث يحصل المنتج على ٦٧,٧٪ والمستهلك على ٣٠٪ من الفوائد الكلية. وكذلك فإن صافي خسارة المنتج تمثل ٣,٣٪ من التكاليف الحكومية الكلية.