Water demand management in different structures of agriculture product market (A case study of Coastal Lands of Yengejeh Dam)

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ABSTRACT
This research aims to study the management of water demand in different product markets in downstream lands of Yengejeh Dam in Neyshabur. This is an exploration research survey and library study conducted in 2015-2016. The required information to test the research hypotheses was gathered by questionnaire. The statistical population includes 150 wheat farmers randomly selected. A scenario of increasing the elasticity of product demand in resource allocation in the competitive and monopolar water market was developed by assimilation algorithm in the studied region. According to the market situation of water in the region which is almost similar to monopoly water market, the results suggest that wheat farming can be superseded by farming some other trade and export-oriented crops. This brings about an increasing amount of product and yield per hectare of land with using less water supply and less area under cultivation.

Key words: Agriculture products market, Competitive system, Monopolar system, Product demand elasticity, Water demand management.

INTRODUCTION
Agriculture is one of the biggest water consuming sectors. Any development of water efficiency can considerably prevent from loss of water (Grafton et al. 2009). Institutes being water end-user with high market production create higher welfare in competitive condition than in exclusively distribution. In case a policy aims to maximize the size of water supply grid, the exclusive water distribution is preferred (Chakravorty et al. 2008). As water distribution has increasing output comparing with the scale, the distribution is carried out by the government. On the other hand, if the government interference is costly, the monopoly is the best alternative for a competitive project and when products are cultured with high demand elasticity (Chakravorty and Umetsu, 2003). According to findings, the water public ownership results in an inefficient water management including weak motivation among farmers to decrease costs, price based on the marginal cost, or maintaining irrigation systems (Cowan and Cowan, 1998). In competitive water market management, the totally competitive (or decentralized) behavior would work. Farmers buy water from the supplier by the utility of the marginal cost and choose the optimum amount of water and the farm production. In such case, farmers do not invest in transferring water to the farm, because the maximization problem is independent of ‘x’. However, in case of monopolar water management, the water monopoly buy water from the water development section by its marginal cost or develop the water production capacity in the region. The monopoly optimally invests in transferring water to the farm and choose the product and price maximizing the benefit (Chakravorty and Umetsu, 2003). There are two alternative institution for water management: Decentralized Water Market Model: In this model we assume that the water utility is weak and fails to provide optimal conveyance in the project. Thus water losses in the canal are higher and farmers trade in water rights and pay spot shadow prices at each location. The output from the project is sold as a competitive industry. This stylized model is meant to represent typical water projects in developing and developed countries where there is a general failure in operation and maintenance leading to a system of laissez faire (Wade (1987), Repetto (1986)). A possibly more relevant model may be one with sub-optimal pricing and uniform pricing (e.g., an output tax or land tax) that is unrelated to water use. This would then lead to sub-optimal water use and concentration of production activity closer to the source. However, the selection of institutional arrangements in this paper is driven by normative criteria relating to the performance of alternative institutions that can help upgrade water management and not those that are already in place. Output Monopoly: Here we investigate the effect of monopolistic behavior in the output market on
social welfare as well as aggregate water use and spatial allocation of input use. This behavior could be the outcome, for example, of a water-users’ association that maintains the canal structures and supervises the allocation process. The allocation of water within the project is done either through some form of water trading or rationing scheme but what is important is that the project output is marketed as a monopoly. The monopolist buys the aggregate amount of water required from the water district at the marginal cost of water generation.

Locating in Sarvelayat, Neyshabur, Yengeje Dam has been placed over Yengejeh Channel. Its basin originating from Amirabad Village, Ghoochan. Passing from Pirshahvaz and Khoysk Villages, it connects to the dam. The agricultural lands of the downstream is 5262 Hectare in total. In most parts of the lands, wheat is cultured. Potato and alfalfa are second and third places respectively. The discharged water flow is 7200 m³ per hour. The water is exploited in 13 days. Each day, eight people directed their water share to their farms. The water transferring route to lands is piped channels.

Regarding what mentioned on water market management and the conditions of studied region (water limitation, the surface under culture, production cost, etc.), this question is raised that which system (competitive or monopolar) should be replaced to optimally managing water demand? As to the water market condition in the region, if farmers culture trade and export products with high demand elasticity, they can produce more products using less water and smaller cultivating lands. Does it reduce land rent and the whole rent price? To answer these questions, the following hypotheses are developed:

1. Regarding the regional conditions (water limitation, land under culture, production cost, etc.), the competitive system is the best alternative for optimally managing water demand in the downstream of the Yengejeh Dam.
2. High demand elasticity increases production and decreases product price in the competitive system.
3. High demand elasticity decreases cultured lands and the water used in the competitive system.
4. High demand elasticity decreases land rent in the competitive system.
5. High demand elasticity decreases the total rent in the competitive system.
6. High demand elasticity decreases shadow price in the competitive system.

**MATERIALS AND METHODS**

**Method of gathering information:** The information was gathered by questionnaire and field method to test the research hypotheses in farming year 2015-2016.

**Statistical population, sample size, and sampling method:** According to information presented by Agricultural Jihad Organization in Neyshabur, governor of a rural district, and the sheriffs of the study region and Water Organization in Neyshabur, the statistical population included 341 farmers feeding their farms from this dam. As to the limited number of the research population, the Cochran’s formulas was used to calculate the sample size. The research sample includes 150 wheat farmers randomly selected for the research.

**Research method**

The model consider here is a more general form of the one developed by Chakravorty et al., (1995), henceforth referred to as CHZ. It is a simple one-period (i.e., one cropping season), model of a water project with no uncertainty. Water is supplied by the utility from a point source (e.g., a dam or a diversion) into a canal. Identical farms are located over a continuum on either side of the canal on land of uniform quality. Farms at location x draw water from the canal, where x is distance measured from the source. Let r(0)=0 be the opportunity rent per unit area of agricultural land. Let z0 denote the amount of water supplied from the source. The cost of supplying z units of water is g(z), assumed to be an increasing, twice differentiable, convex function, g'(z)>0, g''(z)>0. The quantity of water delivered (per unit land area) to a farm at location x is q(x), with q(x)≥0. The fraction of water lost in conveyance per unit length of canal is given by the function a(x), with a(x)≥0. Let z(x) be the residual quantity of water flowing in the canal through location x, z(x)≥0. Then:

\[ z(x) = -q(x) + a(x)z(x) \]  

(1)  

where the right-hand side terms indicate, respectively, water delivered and water lost in conveyance at location x. It suggests that \( z'(x) < 0 \), i.e., the residual flow of water in the canal decreases away from the source. Let X be the length of the canal. Then:

\[ z_0 = \int_0^X [q(x)\alpha + a(x)z(x)]dx \]  

(2)

From (1) and (2), z(X)=0, i.e., the flow of water in the canal reduces to zero at the project boundary. The loss function \( a(x) \) depends on \( k(x) \), defined as the maintenance expenditures per unit surface area of the canal, which can vary with location. If \( k(x)=0 \) (e.g., unlined canals), then the fraction of water lost \( a(x) \) equals the base loss rate \( a0 \), where \( a0 \in [0,1] \). If \( k(x)>0 \) (e.g., concrete-lined canals), then \( a(x)<a0 \). Let the reduction in the conveyance loss rate obtained by investing \( k(x) \) be given by \( m(k(x)) \). Then:

\[ a(x) = a0 - m(k(x)) \]  

(3)

Assume \( m(*) \) to be an increasing, twice differentiable function with decreasing returns to scale in \( k \), the last limit suggests that marginal returns to conveyance investments approach infinity with decrease in \( k \). Let \( a(x)=a0 \) when \( k=0 \), i.e., investing zero dollars reduces conveyance losses to zero (e.g., metal piping). Annualized investments in conveyance at each location x are assumed to be given by \( u(z,k) = \nu(z,k) \) where \( \nu(*) \) denotes the canal perimeter which increases with the amount of water \( z \) flowing in the canal. Since \( z \) can be taken to represent the...
cross-sectional area. This formulation generates a distinct on between investment in canal quality given by the function
k(x) and the cost of carrying a given volume of flow denoted
by the multiplicative component v(z). This specification also
implies increasing returns to scale in conveyance investments. Firms invest in technology (e.g., drip or
sprinkler irrigation) that conserves water on their land and thereby increases the efficiency of the water delivered, q(x).
Let I(x) denote firm-specific investment in water conservation. Then h(I) gives the proportion of water
delivered that actually reaches the plant, assumed to be increasing, twice differentiable and concave, i.e., the price
of I unity. Also let e(x)=qh(I) where e(x) is “effective water,” i.e., the amount of water actually applied to the crop.
Similar distinctions between ‘delivered’ and ‘applied’ input use have been made elsewhere (e.g., for energy-conserving
appliances, see Repetto (1986)). Then the production technology for each firm is given by f(e) which is assumed
to exhibit constant returns to scale with respect to land and other production inputs.

Let Y be the aggregate output from the project. It is then given by:

\[ Y = f(e) \alpha \, dx \quad (4) \]

Define the total cost of producing a given output level Y as C(Y) which can then be expressed as

\[ C(Y) = g(z_0) + \int_0^X [kv(z) + l(x) + r] \, dx \quad (5) \]

In (5) the cost of output Y is the sum of the cost of water generation, conveyance, irrigation investment and the rent to land. The utility chooses control functions q(x), I(x), k(x), and values for X and z0 that maximize aggregate net benefits from the project. Monopolist buys water at marginal cost from the water development authority or develops the water generation capacity within the project. In either case, the monopolist invests optimally in conveyance and chooses the profit-maximizing output and price. The monopolist's cost maximization program is identical to (6), so the relevant cost function faced by the monopolist is C*(Y). Monopoly output \( Y_m \) is chosen to maximize profits \( \Delta \mu \) as follows:

Maximize \[ \Pi = pY - C(Y) \quad (6) \]

and \( Y_m \) solves \[ MR(Y) - C*(Y) = 0 \] \( (7) \)
and \[ MR'(Y) - C'''(Y) < 0 \] \( (8) \)
where \( p \) is the output price of the agricultural commodity. Let \( p_m \) be the output price under monopoly.
Then \( p_m = U'(Y_m) \).

Let the corresponding cost function under a water market be \( C_w(Y) \). Purely competitive (or decentralized)
behavior will result when individual farmers act competitively. Farmers purchase water from the water utility
at its marginal cost at source, and choose optimal amounts of water and on-farm technology. The optimization problem for a farmer at location ‘x’ is given by

Maximize \[ \pi_w = [pf(qh(I)) - \lambda q - I] \alpha - k \q, l, k \]

where \( \pi_w \) represents competitive profits at ‘x’. It is clear from (11) that in a decentralized, competitive regime, the individual farmer will not invest in conveyance, and since the maximization problem is independent of ‘x’, conveyance expenditures under competition are zero at each ‘x’. Let us denote the cost function for aggregate output under competition as \( C_w(Y) \). Equilibrium aggregate output \( Y_w \) and price \( pw \) in competition are then obtained as follows:

\[ Y_w = \text{argmax} \, U(Y) - C_w(Y) \quad (10) \]
\[ U'(Y) - C_w'(Y) = 0 \quad (11) \]
\[ U''(Y) - C_w''(Y) < 0. \quad (12) \]

Then the following proposition establishes the relationship between \( C*(Y) \) and \( C_w(Y) \):

(a) The cost function \( C*(Y) \) is optimal by definition while the function \( C_w(Y) \) is the total cost of producing output \( Y \) under the additional restriction that \( k(x) \) is identically equal to zero. By the envelop theorem, \( C*(Y) \) must be smaller than \( C_w(Y) \).

(b) Follows directly from complementary slackness, i.e., the shadow price of aggregate output must be non-negative (Repetto, 1986).

c) \( C''(Y) > 0 \) follows from the comparative statics results derived from the sufficient second order conditions for cost minimization for the problem 6(a-e) (Silberberg, 1991). The details are available in a technical appendix from the authors. Intuitively, as output increases, a higher aggregate stock of water is used, which in turn implies a higher marginal cost of water generation \( (g'(z_0)) \) which increases the marginal cost of output.

(d.e) These results too follow directly from the application of the envelope theorem to the two cost functions \( C*(Y) \) and \( C_w(Y) \). The cost function \( C_w(Y) \) is tangential and lies everywhere above the unrestricted cost function \( C*(Y) \). Thus the first and second derivatives of the former are greater in the neighborhood of the minimum point of the restricted cost function than the corresponding derivatives of the unrestricted cost function.

In summary, the above proposition states that the cost of producing a unit of output under the competitive system in which conveyance investments are fixed to be zero must be greater than in the optimal system. Since the marginal cost of output is increasing, the marginal cost of output for the competitive model is higher than the optimal. Fig.1 shows the marginal cost functions in the optimal and competitive case, \( C*(Y) \) and \( C_w(Y) \). Both the socially optimal irrigation project and the monopolist operate with the marginal cost function \( C*(Y) \). The socially optimal price \( P** \) and output \( Y** \) are obtained at the point of intersection of the demand function \( D \) and \( C*(Y) \). The competitive price \( Pw \) and quantity \( Y_w \) are given by intersecting demand
with \( CW(Y) \). The monopolist equates marginal revenue \( MR(Y) \) with \( C^*(Y) \) to give price \( P_m \) and quantity \( Y_m \).

The figure has been drawn such that the monopolist produces a higher quantity and charges a lower price than the competitive case. However, it is easy to see that the converse could happen under alternative parameter values. The following proposition compares monopoly and competitive output and water use:

Since the monopolist is more efficient, it produces a lower (or equal) output relative to competition by using a smaller aggregate water stock at source and distributing it over a smaller project area. However, when \( P_m < P_w \), then \( Y_m > Y_w \), but the relative sizes of the water stock and acreage are unclear. That is, if competitive output were higher than the monopoly output, the relative order of aggregate output and project area are indeterminate. Comparing the monopoly and socially optimal models, we obtain:

The monopoly price (output) is always higher (lower) than optimal. Therefore, an irrigation system under monopoly uses less water and irrigates a smaller area, as compared to a system that maximizes net social benefits.

**Comparison between the optimal and competitive models:** Since the marginal cost function under competition is everywhere higher than optimal, it intersects the demand function at a higher price and smaller aggregate output. However, the relative magnitude of water use and acreage in the two models is indeterminate. The following results examine the impact of the elasticity of demand on monopoly and competitive resource allocation:

(i) \( dP_m/d\epsilon < 0 \) (ii) \( dY_m/d\epsilon > 0 \) (iii) \( dZ_m/d\epsilon > 0 \)

(iv) \( dX_w/d\epsilon > 0 \) (v) \( dP_w/d\epsilon < 0 \) (vi) \( dY_w/d\epsilon < 0 \)

(vii) \( dX_w/d\epsilon < 0 \) (viii) \( dY_w/d\epsilon < 0 \).

The pricing rule for a monopolist is given by \( P_m = C^* + \epsilon \) which gives \( P_m = C^* \epsilon + \epsilon^2 \). Differentiating with respect to \( \epsilon \) by using the quotient rule, we obtain

\[
dP_m/d\epsilon = C^*/(1+\epsilon)^2 > 0. \quad \text{Since } \epsilon < 0, \text{ we get the desired result.}
\]

(ii) The monopolist sets the output price of the consumer’s demand function, or \( U'(Y_m) = P_m \). Differentiating totally, we get \( U''(Y_m) dY_m/dP_m = 1 \) or \( dY_m/dP_m < 0 \). By the chain rule, using Proposition 6(i), we get \( dY_m/d\epsilon > 0 \).

(v) The competitive price is set by the condition \( P_w = U'(Y_w) \), or \( P_w = U''(Y_w) Y_w/\epsilon \). Differentiating with respect to \( \epsilon \), we get \( dP_w/d\epsilon = U''(Y_w)Y_w/\epsilon \), which gives the result.

The above proposition suggests that as the absolute value of demand elasticity increases, output prices under both the monopolistic and the competitive systems decrease. However, the output under monopoly increases while the competitive output decreases. With increase in absolute elasticity, the monopolist produces more output by using more water and expanding irrigated acreage, while the competitive system shrinks in acreage, and uses a smaller water stock. This asymmetry between competitive and monopoly behavior has major implications for second-best water allocation: if demand elasticity is relatively high (low), monopoly (competitive) behavior in water may be the preferred institutional choice.

**RESULTS AND DISCUSSION**

Tables 1 and 2 show changes in product price and its effect on the amount of water reaching to the farm, products, investment in transferring water to farm, and renting wheat farms affected by high price of products under monopolistic and competitive systems in 2015-2016 year.

In monopolistic systems, the water shadow price decreases with increase in product prices. As a result, farmers show more inclination to invest in water transfer. Therefore, the remaining water in the channel increases. Therefore, the amount of water delivered to the farm is to be increased (Table 1). In competitive market, on the other hand, as there is no cost for the maintenance of water flow route, the remaining

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**Table 1:** changes in product price and its effect on resources allocation under monopolistic systems in 2015-2016

<table>
<thead>
<tr>
<th>product price (Toman/Kg)</th>
<th>Products (Kg)</th>
<th>Shadow price of water (Toman/m³)</th>
<th>investment in transferring water (Toman/m)</th>
<th>water remaining in canal (m³/m)</th>
<th>water delivered to farm (m³/H)</th>
<th>land rent (Toman/H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100</td>
<td>4012.76</td>
<td>48.53</td>
<td>180.43</td>
<td>4998.27</td>
<td>2706.47</td>
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<tr>
<td>2100</td>
<td>5742.63</td>
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<td>196.76</td>
<td>5002.61</td>
<td>2706.34</td>
<td>1150676.44</td>
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<tr>
<td>5100</td>
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<td>52.23</td>
<td>216.50</td>
<td>5107.6</td>
<td>2906.34</td>
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<tr>
<td>8000</td>
<td>6649.04</td>
<td>54.20</td>
<td>226.76</td>
<td>5239.04</td>
<td>3045.29</td>
<td>1778445.43</td>
</tr>
</tbody>
</table>

Resource: Research Findings

**Table 2:** changes in product price and its effect on resources allocation under competitive systems in 2015-2016

<table>
<thead>
<tr>
<th>product price (Toman/Kg)</th>
<th>Products (Kg)</th>
<th>shadow price of water (Toman/m³)</th>
<th>water remaining in canal (m³/m)</th>
<th>water delivered to farm (m³/H)</th>
<th>land rent (Toman/H)</th>
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<td>1284.85</td>
<td>129441.08</td>
</tr>
</tbody>
</table>

Resource: Research Findings
water in the channel decreases. Therefore, the amount of water delivered to the farm to be decreased (Table 2). In such case, the forth hypothesis, i.e. increasing demand elasticity reduces water used by competitive system, is confirmed.

In monopolar system, as the water reaching farm and absorbed by plant increases, more products are, thus, produced (Table 1). However, in competitive market, due to a reduction in the water remaining in canal, the water reaching farm and used by plants also decreases (Table 2). Therefore, the second hypothesis, i.e. increasing demand elasticity raises production under competitive system, is not confirmed.

In monopolar system, the land rent increases with product price (Table 1). In competitive market, though, land rent decreases (Table 2). The fifth hypothesis states that growing demand elasticity reduces land rent under the competitive system.

In monopolar system, increasing land rent makes farmers produce more in smaller surfaces under culture (Table 1). But in competitive market, increased land under culture forces farmers to increase their production (Table 2). Accordingly, the third hypothesis, i.e. higher demand elasticity reduces the land under culture in the competitive system, is not confirmed.

Higher rent for each hectare, in monopolar system, increases the total rent rate (Table 1). However, in the competitive system, the total rate decrease with the land rent (Table 2). The sixth hypothesis, i.e. higher demand elasticity decreases the total rent in the competitive system, is rejected.

In competitive system, increasing product price makes farmers increases the surfaces under culture. As there is no maintenance cost and less water reaches products (Table 2). The first hypothesis is not confirmed.

As the water market in the region is monopolar, the following findings are presented for farmers:

1. Results showed that higher product demand elasticity lead farmers invest in water transfer. This prevents from water loss in the distribution rout and transferring to the farm. Regarding results, the loss ratio in transferring route decreases and the amount of water reaching farm and absorbed by plants increases. Wheat farmers can be suggested export and trade products with high demand elasticity instead of wheat.

2. In monopolar system, higher product demand elasticity increases water reaching farm and consumed by plants. Products increases in this system. Wheat farmers can be suggested export and trade products with high demand elasticity instead of wheat. This increases production capacity and gross profits.

3. In monopolar system, if farmers culture trade and export products, they should consider the chance of renting each hectare. They try to increase their capacity and production power by decreasing land in order to increase gross profits. This results in the reduction of total rent, especially for farmers whose farmlands are mostly rented.

4. As results show, the amount of water reaching farmlands and used by plants increases with product price. Farmers try to reduce lands because of higher rent per hectare. Therefore, regarding the limited lands and higher cost of water supply and irrigation, farmers are suggested to culture trade and export products with high prices.

REFERENCES


