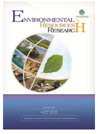

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# Spatial water management under alternative institutional arrangements (A case study of coastal lands of Yengejeh Dam)

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## Abstract

Currently, water demand management and optimal operation of its resources is one of the most important issues in environmental economics and management. Water demand management has been a concern of economic planners as a new approach in environmental economics. This study aims to investigate water demand management in different product markets in downstream of Yengejeh Dam in Neyshabur. This is an exploratory study in nature which was conducted through a questionnaire survey in 2015-2016. The population of this research is composed of all farmers who use water from Yengejeh Dam to irrigate their lands. Using Cochran formula at the level of 6% error, 139 farmers were selected as the sample of this research randomly. 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 monopolar water market, the results suggest that if barley farmers replace cultivation of this crop and orient towards exported products instead, the amount of product is reduced and farmers increase their yield per hectare of land while using more water supply and more area under cultivation.

***Keywords:*** Water demand management, Monopoly water market, Competitive water market system, Export-oriented crops.

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## Introduction

Water demand management requires a greater and typically more efficient exploitation of water. This is perfectly feasible by enacting legislation and regulations, economic levers and planning, monitoring and participation of exploiters, as well as growing those crops which consume less water. As such, the main objective of water demand management is controlling the extent of water demand and its effective exploitation. Accordingly, water demand management is supposed to move towards developing those contemporary perspectives which are in harmony with the objectives of sustainable development of water resources. It also must consider controlling the extent of water exploitation through growing highly efficient products (Chakravorty *et al.,* 2008).

Agriculture is one of the biggest water consuming sectors. Enhancement of water efficiency can considerably decrease water loss (Grafton *et al.,* 2009). Institutes being water end-user with high market production create higher welfare in competitive condition than in exclusive distribution market. In case a policy aims to maximize the size of water supply grid, the exclusive water distribution is preferred (Chakravorty *et al.,* 2003). As water distribution has increasing output compared 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 *et al.,* 2003). According to their findings, public water 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 the competitive water market management, the totally competitive (or decentralized) behavior would work. Farmers buy water from the supplier based on the utility of the marginal cost and choose the optimum amount of water and the farm production. In such cases, 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 based on its marginal cost or develop the water production capacity in the region. The monopoly optimally invests in transferring water to the farm and chooses the product and price maximizing the benefit (Chakravorty *et al.,* 2003).

Located in Sarvelayat, Neyshabur, Yengeje Dam has been placed over Yengejeh Channel. Its basin originates from Amirabad Village, Qochan. Passing from Pirshahvaz and Khaysk Villages, it connects to the dam. The agricultural lands of the downstream are about 5262 hectares in total. In most parts of the lands, barley is cultured. Potato and alfalfa plantation come in second and third places, respectively. The discharged water flow is 7200 $m^3$ per hour. The water is exploited in 13 days. Each day, eight people direct their water share to their farms. The water transferring route to lands occurs through piped channels.

Regarding what mentioned on water market management and the conditions of the studied region (water limitation, the surface under agriculture, production cost, etc.), the question is raised which system (competitive or monopolar) should be replaced to optimally manage water demand? As for the water market condition in the region, if farmers trade and export products with high demand elasticity, they can produce more products using less water and smaller 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 agriculture, 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 cropped 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

### *Data gathering*

Data was gathered through questionnaire and field work to test the research hypotheses in the farming year 2015-2016.

### *Statistical population, sample size and sampling method*

According to the information presented by Agricultural Jihad Organization in Neyshabur, governor of a rural district and the officials of the study region and Water Organization in Neyshabur, the statistical population included 341 farmers watering their farms from this dam. As for the limited number of the research population, the Cochran's formulas was used to calculate the sample size. The research sample includes 139 barley farmers randomly selected for the research.

### *Research method*

The model considered here is a more general form of the one developed by Chakravorty, Hochman and Zilberman (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 firms are located over a continuum on either side of the canal on land of uniform quality. Firms at location x draw water from the canal, where x is distance measured from the source. Let r(=0) be the opportunity rent per unit area of agricultural land. Define α to be the constant width of the project area.

Let $z_0$ denote the amount of water supplied from the source. The cost of supplying $z_0$ units of water is $g(z_0)$, assumed to be an increasing, twice differentiable, convex function, $g'(z_0)>0$, $g''(z_0)>0$. The quantity of water delivered (per unit land area) to a firm at location x is q(x), with $q(x)\geq 0$. The fraction of water lost in conveyance per unit length of canal is given by the function a(x), with $a(x)\geq 0$. Let z(x) be the residual quantity of water flowing in the canal through location x, $z(x)\geq 0$. Then:

$$z'(x) = -q(x)\alpha - a(x)z(x) \quad (1)$$

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

$$z_0 = \int_0^x [q(x)\alpha + a(x)z(x)]dx \quad (2)$$

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 $a_0$,

where $a_0 \in [0,1]$. If k(x)>0 (e.g., concrete-lined canals), then $a(x)<a_0$. Let the reduction in the conveyance loss rate obtained by investing k(x) be given by m(k(x)). Then:

$$a(x) = a_0 - m(k(x)) \quad (3)$$

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 $a(x)=a_0$ 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) = v(z)k where v(•) 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, we assume that the perimeter is an increasing, concave function of z, i.e., $v'(z)>0$, $v''(z)<0$. This formulation generates a distinction between investment in canal quality given by the function k(x) and the cost of carrying a given volume of flow is 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 is 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 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:

$$Y = \int_0^x f(e)\ \alpha\ dx \qquad (4)$$

The total cost of producing a given output level Y as C(Y) can be expressed as:

$$C(Y) = g(z_0) + \int_0^x [kv(z) + (l(x) + r)\alpha]dx \qquad (5)$$

In (5) the cost of output Y is the sum of the cost of water generation, conveyance, irrigation investment and the rent of land. The utility chooses control functions q(x), I(x), k(x) and values for X and $z_0$ that maximize aggregate net benefits from the project as follows:

$$\text{minimize } g(z_0) + \int_0^x [kv(z) + (l(x) + r)\alpha]dx \qquad 6(a)$$

$q, l, k, X, z_0$

subject to:

$$z'(x) = -q(x)\alpha - a(x)z(x) \qquad 6(b)$$

$$Y'(x) = f(e)\alpha \qquad 6(c)$$

$$q(x) \geq 0,\ l(x) \geq 0,\ k(x) \geq 0,\ z(x) \geq 0, \qquad 6(d)$$

$$z_0 \text{ free},\ z(X) = 0,\ X \geq 0,\ X \text{ free}. \qquad 6(e)$$

Then, the Hamiltonian and corresponding Lagrangian formulae are:

$$H = kv(z) + (l + r)\alpha + \lambda_1(q\alpha + az) - \lambda_2 f(e)\alpha \qquad 7(a)$$

$$L = H(\bullet) - \lambda_3 z, \qquad 7(b)$$

where $\lambda_1(x)$, $\lambda_2(x)$ and $\lambda_3(x)$ are functions associated with 6(b,c) and the state constraint $z(x) \geq 0$ respectively. The necessary conditions for a solution to problem (6a)-(6e) are:

$$(\lambda_1 - \lambda_2 f'h(l))\alpha \leq 0 \ ( = 0 \text{ if } q > 0) \qquad (8)$$

$$(1 - \lambda_2 f'qh'(l))\alpha \leq 0 \ ( = 0 \text{ if } l > 0) \qquad (9)$$

$$v(z) - \lambda_1 zm'(k) \leq 0 \ ( = 0 \text{ if } k > 0) \qquad (10)$$

$$\lambda_1'(x) = v'(z)k + \lambda_1 a - \lambda_3 \qquad (11)$$

$$\lambda_2'(x) = 0 \qquad (12)$$

$$\lambda_2 = C'(Y) \qquad (13)$$

$$\lambda_3(x) \geq 0 (=0 \text{ if } z(x)>0) \qquad (14)$$

$$\lambda_1(0) = g'(z_0), \qquad (15)$$

$$\lambda_1(X^-) - \lambda_1(X) = \beta, \qquad (16)$$

and

$$L(X) = 0 \qquad (17)$$

where β is a constant. From (1), if z(x)=0 at any x ∈ [0,X), it could not increase from that value. Then the state constraint is never tight except possibly at x=X. From the maximum principle, $\lambda_1(x)$ is continuous on [0,X), $\lambda_3(x)=0$ on [0,X) and q(x), I(x) and k(x) are continuous except at x=X.

In the above, $\lambda_1(x)$ is interpreted as the shadow price of delivered water at location x. Condition (11) suggests that $\lambda_1'(x) = v'(z)k + \lambda_1 a\ \forall x \in [0,X)$. Because $\lambda_1(0)>0$ by (15), this suggests that $\lambda_1'(x)>0$ for x ∈ [0,X). Intuitively, the shadow price of delivered water increases away from the source because of the cost of conveyance. In order to simplify the analysis, consider the limiting case of a "flat" canal cross-section in which the elasticity of conveyance, given by $\eta_v(= v'(z)z/v(z))$, equals zero. That is, the ratio of the canal perimeter to cross-sectional area, v(z) is constant. Then (11) yields $\lambda_1'(x) = \lambda a$, or that the shadow price of delivered water increases with distance at the conveyance loss rate.

Substituting the limiting values of f'(0) and m'(0) in (8)-(10) suggests that q(x)>0, I(x)>0, k(x)>0 and the corresponding necessary conditions hold with equality. Their spatial distribution as well as the spatial allocation of effective water and output is characterized as follows:

**Proposition 1: (a) q'(x)<0 (b) I'(x)>0 (c) k'(x)<0 (d) e'(x)<0 and (e) y'(x)<0.**

Proof: see CHZ.
At the project boundary X, (17) gives :

$$L(X)=k(X)v(z(X))+[I(X)-r]\alpha+\lambda_1(X)[q(X)\alpha+az(X)]-\lambda_2 f(e(X))\alpha-\lambda_3(X)z(X)=0 \quad (18)$$

Substituting z(X)=0 and v(0)=0 and rearranging, yields

$$\lambda_2 f(e(X)) - I(X) - \lambda_1 q(X) = r \quad (19)$$

which implies that net benefits from expanding the land area by one unit must equal the opportunity rent of land, r. Thus the equilibrium value of X is inversely related to r. If r=0 (land is in infinite supply), that would imply a greater project area. If r increased with x because say, the downstream locations were closer to an urban center, then X would be smaller. On the other hand if an urban area were closer to the upstream section, then the function r(x) would be negatively sloping and various cases may arise depending on the relative magnitude of the land rent function and r(x). For instance, in regions where r(x) is larger than quasi-rents to land, land is better allocated for residential or commercial use than in farming.

***Alternative institutions for water management***

In this section we compare the optimal allocation derived above with water allocation and conveyance investments under three different market structures, each of which are explained as follows:

***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 (see 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 monopoly 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.

***Institutional comparisons***

The next step is to develop the apparatus for comparisons across the above institutional settings. Let the consumers' utility function for aggregate output Y from the project be defined by U(Y) where U(0)=0, U'(Y)>0, U''(Y)<0. We can now derive equilibrium price and output when the water project is operated as a monopoly in the output market. Within the project for any given level of output Y, both the central planner and the monopolist must solve program 6(a)-6(e). Their total cost of producing a given Y would be identical assuming that the program 6(a)-6(e) has a unique solution, since both a social planner and a monopolist would allocate water efficiently over space. However, aggregate output, water use and output prices will in general not be the same. Denote this common cost function by C*(Y), where * denotes optimality.

Let the consumers' utility function for aggregate output Y from the project be defined by U(Y) where it is assumed that U(0)=0, U'(Y)>0, U''(Y)<0. We can now derive equilibrium price and output when the irrigation project is operated as a monopoly in the output market. The monopolist either buys water at marginal cost from the water development authority or develops 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 minimization program is identical to (9), so the relevant cost function faced by the monopolist is C*(Y). Monopoly output $Y_m$ is chosen to maximize profits $\Pi^m$ as follows:

$$\text{Maximize } \Pi^m = pY - C^*(Y) \qquad (20)$$

and $Y_m$ solves

$$MR(Y) - C^{*\prime}(Y) = 0 \qquad (21)$$

and

$$MR'(Y) - C^{*\prime\prime}(Y) < 0 \qquad (22)$$

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:

$$\underset{q,I,k}{\text{Maximize}}\ \pi^w = [pf(qh(I)) - \lambda_0 q - I]\alpha - k \qquad (23)$$

where $\pi^w$ represents competitive profits at 'x'. It is clear from (23) 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 $p_w$ in competition are then obtained as follows:

$$Y_w \in \text{argmax } U(Y) - C_w(Y) \qquad (24)$$

and solves

$$U'(Y) - C_w'(Y) = 0 \qquad (25)$$

and

$$U''(Y) - C_w''(Y) < 0 \qquad (26)$$

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

**Proposition 2: (a) $C^*(Y)<C_w(Y)$ (b) $C^{*\prime}(Y)>0$ (c) $C^{*\prime\prime}(Y)>0$ (d) $C_w'(Y)>C^{*\prime}(Y)$ and (e) $C_w''(Y)>C^{*\prime\prime}(Y)$.**

Proof: (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 (see 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) (see Silberberg (1991)). 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 envelop 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. Figure 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 $P_w$ and quantity $Y_w$ are given by intersecting demand with $C_w'(Y)$. 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:

**Proposition 3: If $P_m \geq P_w$ then (i) $Y_m \leq Y_w$ (ii) $z_{0m}<z_{0w}$ and (iii) $X_m<X_w$.**

Proof: The proof is obvious from Figure 1. A higher monopoly price implies a lower aggregate output. 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.

**Proposition 3: If Pm ≥ Pw then (i) $Y_m \leq Y_w$ (ii) z0m<z0w and (iii) $X_m<X_w$.**

Comparing the monopoly and socially optimal models, we obtain:

**Proposition 4: (i) $P_m$>P** (ii) $Y_m$<Y** (iii) $z_{0m}<z_0$** (iv) $X_m$<X**,**

where '**' denotes the parameters of the socially optimal model.
Proof: Same as above.

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 yield:

**Proposition 5: (i) $P_w$>P** (ii) $Y_w$<Y**.**

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:

**Proposition 6: (i) $dP_m/d|\varepsilon| <0$ (ii) $dY_m/d|\varepsilon| >0$ (iii) $dz_{0m}/d|\varepsilon| >0$ (iv) $dX_m/d|\varepsilon| >0$ (v) $dP_w/d|\varepsilon| <0$ (vi) $dY_w/d|\varepsilon| <0$ (vii) $dz_{0w}/d|\varepsilon| <0$ (viii) $dX_w/d|\varepsilon| <0$.**

Proof: The proofs of (iii), (iv), (vi), (vii) and (viii) are omitted because they are similar to the following:

(i) The pricing rule for a monopolist is given by:

$P_m(1 + 1/\varepsilon)=C^{*\prime}$ which gives $P_m=C^{*\prime}\varepsilon/(1+\varepsilon)$. Differentiating with respect to ε by using the quotient rule, we obtain:

$dP_m/d\varepsilon = C^{*\prime}/(1+\varepsilon)^2 >0$. Since ε<0, we get the desired result.

(ii) The monopolist sets the output price off 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 $dY_m/d|\varepsilon| >0$.

(v) The competitive price is set by the condition $P_w=U'(Y_w)$, or $P_w=U''(Y_w)Y_w/\varepsilon$. Differentiating with respect to ε, we get $dP_w/d\varepsilon= -U''(Y_w)Y/\varepsilon >0$, 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.

A computer algorithm was written that starts by assuming an initial value of output price P and $z_0$ and computes $\lambda_0$ from (15). At x=0, (10) gives m'(k). By iterating on k, we compute k(x) that satisfies (33) and (32) gives a(x). Knowing $\lambda_1(0)$, (8) and (9) used simultaneously yield I(x), q(x) and thus e(x), y(x) and $R_L(x)$ respectively. Next, when x=1, using a(0) and $\lambda_1(0)$ in the solution to (11) gives $\lambda_1(1)$ and z(1) is obtained from (1) by subtracting the water already used up previously. Again, $\lambda_1(1)$ and z(1) give k(1) from (10) and the cycle is repeated to give q(1), I(1), etc. The process is continued with increasing values of x until exhaustion of $z_0$ terminates the cycle and a new value of $z_0$ is assumed. Aggregate land rents are calculated for each $z_0$ by summing over $R_L(x)$ and aggregate rents to water are computed similarly. The algorithm selects the value of $z_0$ that minimizes total cost (given by (6(a)). For each price P, the corresponding Y is computed to generate the supply function. The equilibrium is computed by solving the supply and demand equations (see below) jointly. The algorithm was modified suitably for the competitive, monopoly and monopsony solutions.

***Research findings***

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

In monopolar water market, an increase in the price of the product, declines the amount of crop production per hectare and this decline will cause the farmer to use fewer water supplies. Thus the cost of supplying water for agriculture is reduced. As a result, the shadow price of water is reduced per cubic meter. Reduction in the use of water supply thereby reduces the amount of product being produced leading to reduction in the amount of water flow in the channel. Reduction in the amount of water flowing in the channel causes agricultural investment in water transmission to the farm to reduce at any channel length. The decline in investments in water transmission to the farm increases the amount of water losses in the transmission path. Thus, the volume of water remaining in the channel length is reduced and as a result, the amount of water delivered to the farm per hectare reduced. Since the amount of product produced per hectare of downstream land of dam falls, thus the rent per hectare of downstream lands also declines (Table 1).

In competitive water market with an increase in the price of the product, the amount of per hectare crop production increases. With the increase in the amount of the products, it should reduce the costs of produce and water supply, but the shadow price of water per cubic meter remains constant, indicating that the cost of developing and supplying water for agriculture does not change. An increase in the amount of the products leads to increase agricultural use of water supply. Therefore, the remaining volume of water flow per meter of the channel length increases. It also increases the amount of water delivered to the farm per hectare. Due to the increase in the value of crop production per hectare of land downstream of dam as a result of an increase in product prices, lands lease near dam continues to increase (Table 2).

**Table 1.** Changes in product price and its effect on resources allocation under monopolar systems in 2015-2016.

| Land rent (toman/hectar) | Water delivered to farm ($m^3$/hectar) | Water remaining in canal ($m^3$/km) | Investment in transferring water (toman/m) | Shadow price of water (toman/$m^3$) | Products (Kg/hectar) | Product price (toman/kg) |
|---|---|---|---|---|---|---|
| 529628.73 | 3654.89 | 4720.95 | 423.08 | 22.53 | 5735.04 | 1000 |
| 483053.80 | 3201.43 | 4165.93 | 383.07 | 22.51 | 4989.65 | 2100 |
| 361053.321 | 2614.2 | 3226.56 | 301.63 | 22.49 | 4441.34 | 5100 |
| 240419.46 | 1891.10 | 2499.45 | 298.73 | 22.48 | 3558.41 | 8000 |

Resource: Research findings

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

| Land rent (toman/hectar) | Water delivered to farm ($m^3$/hectar) | Water remaining in canal ($m^3$/km) | Shadow price of water (toman/$m^3$) | Products (Kg/hectar) | Product price (toman/kg) |
|---|---|---|---|---|---|
| 365217.43 | 2423.5 | 3195.94 | 37.9 | 5735.04 | 1000 |
| 401242.13 | 4711.48 | 5582.98 | 37.9 | 6213.52 | 2100 |
| 620303.34 | 5707.9 | 7753.52 | 37.9 | 7587.06 | 5100 |
| 786749.28 | 6320.9 | 7866.08 | 37.9 | 7867.49 | 8000 |

Resource: Research findings

## Discussion and Conclusion

Based on the main hypothesis on regional conditions (water restrictions, cultivation, production costs and water, the type of crops, etc.), it is necessary for optimal management of water demand in downstream lands of dam, that competitive water market be presented as the best alternative.

The first research sub-hypothesis was confirmed that showed an increase in the elasticity of demand increases the amount of products in terms of a more competitive water market. The second research sub-hypothesis was confirmed that an increase in the elasticity of demand reduced the acreage of land in the competitive water market. The third research sub-hypothesis was not confirmed that an increase in the elasticity of demand decreases the amount of water used in the competitive water market. The fourth research sub-hypothesis was not confirmed that an increase in the elasticity of demand reduced land rental in the competitive water market. The fifth research sub-hypothesis was confirmed that an increase in the elasticity of demand reduces the total rental market in the competitive water market. The sixth research sub-hypothesis was not confirmed that an increase in the elasticity of demand decreases shadow price of water in the competitive water market.

### *Practical suggestions based on research findings*

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

1- The market situation of water in the region is almost "like a monopoly system" and it cannot replace commercial barley farming. To amend this condition, it should become competitive. In other words, water rights should be rented at a price that reflects the cost of operations and local assessments.

2- Public organizations in the region should be formed to manage water distribution in the area. They can monitor water consumption and water quotas. Regulations that are imposed on transactions and their enforcement can be set as the responsibility of these public organizations.

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