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Irrigation Water Pricing in Iran: The Gap between Theory and Practice

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Abstract

Pricing policies play an important role in water demand management and its optimal allocation. Determining proper water price leads to optimal allocation of water especially in agricultural consumptions. Applying new subsidy targeting law in Iran which insists on pricing water based on its supply cost, will effects considerably on water resource management in agriculture sector. So, in this study, different Irrigation water pricing methods is investigated and proper irrigation water price is determined using survey data for 2010-2011 farming year in Golestan Province of Iran. At the first step using econometric approach, economic value of irrigation water in different agriculture crops is determined that shows demand side price for water. Then, supply cost of surface and ground water is calculated using accounting approach which shows supply side price for irrigation water. Finally, economic value and supply cost of irrigation water compared and different water pricing methods is evaluated. Results indicated that, weighted average of economic value and supply costs of irrigation water in Golestan province were 1795 and 1399 IRR per cubic meter, respectively. So, improvement of water demand and supply management could be achieved using price policies.

Keywords:
Water, Economic Value, Pricing, Supply cost, Golestan Province

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INTRODUCTION

Iran is one of the countries in the world that suffer from water shortages. Water scarcity is one of the key problems affecting northern Iran. Price of water plays an important role in world's water resource management. One of the main goals of water pricing discipline is incentives creation and responsibilities impose for consumption pattern improvement, increasing water consumption productivity, covering part or financial fund need in water systems investments and operation and maintenance costs, reducing environmental degradation and preserving future generations' rights. Connecting pricing discipline to costs of water service providence is the first step in water pricing system improvement. For determining tariff discipline, three principals include costs covering, economic efficiency and equity are very important.

Table 1 shows the status of groundwater and surface water resources between different uses in Golestan province. As can be seen in table 1, seventy-two percent of surface water and 82 percent of groundwater resources consumed in agricultural uses. Therefore, irrigation water has the largest proportion of water resources and managing water in this kind of consumption is very important.

In this study, irrigation water pricing in Golestan province in Iran has considered. The most important agronomy crops in this province reported in table 2.

Table 2 shows that, wheat, soybean and tomato covered about 63 percent of irrigated acreage in Golestan, and so, managing water demand for these crops can be useful for water sources of this province. In this regard, estimating cost of building dams and water supply facilities costs and economic valuation of irrigation water as an input could be useful criteria for choosing water selling tariffs to water supply costs in future years.

Table 1: Water allocation system up to 2008 (million cubic meters).

Sector		Water	Share
Surface	Agriculture	578.2	0.72
	Industry	30.8	0.04
	Domestic	34.8	0.04
	Fishery	80.7	0.10
	Tourist	0.0	0.00
	Packing	0.1	0.00
	Other	79.8	0.10
	Sum	804	1
Groundwater	Agriculture	790.7	0.82
	Industry	24.9	0.03
	Domestic	144.3	0.15
	Fishery	0.0	0.0
	Tourist	0.0	0.0
	Packing	0.0	0.0
	Other	0.0	0.0
	Sum	960	1

Source: Water Regional Organization of Golestan Province (2010).

National development documents in Iran insist on mentioned goal. Water equity allocation law insist that water tariff in municipal, agriculture, industry and other use should be determined according to quantity and quality of consumption. Also, in the case of adjusted water systems all variable costs include management, maintenance and depreciations should be including in water tariff considering social-economic conditions of each regions. Also, long-run development strategy of Iran's water resource and Fourth Iran's development Plan, economic and social program insist on economic valuation of water and calculating supply costs.

Previous studies of optimum water pricing in agriculture such as Guohau (1986), Hussain and Young (1985), He and Tyner (2004), Renzeti and Dupont (1999) and Seagraves and Easter (1983) focused on supply cost or operating and maintenance cost as bases for determining optimum price of ir-

Table 2: Acreage and production of important crops in Golestan (farming year 2009-2010)

Crop	Acreage (hectare)			Production (tone)		
	Irrigated	Dry land	Sum	Irrigated	Dry land	Sum
Wheat	164170	221217	385387	501522	564213	1065735
Soybean	52010	5722	57732	111748	8295	120043
Tomato	6703	609	7312	221392	10505	231897
Sum	355616	339461	695077	2155614	1001744	3157358
Share %	63	67	65	39	58	45

Source: Ministry of Jihad-e-Agriculture of Iran.

rigation water in, while price of water in demand side also is important and optimum price of water must show ability of farmers to payment. Singh (2007) reported that there is a big gap between supply cost as water price and economic value of water. Also, Huang *et al.* (2006) showed that farmers were quite responsive if the correct price signal was used and policy makers must increase water price to the level of VMP of water. Also, Guerrero *et al*. (2010), Hussain *et al*. (2009) and Sadeghi *et al*. (2010) have measured economic value of irrigation water in Texas, Iran and Pakistan respectively. So, in this study, different Irrigation water pricing methods is investigated and proper irrigation water price is determined.

MATERIALS AND METHODS

Economic value of irrigation water represent the price of demand side and show the maximum willing to pay of consumers for each unit of irrigation water. In general, methods of estimating economic value of irrigation water as an input, classified in parametric and nonparametric methods. Linear programming method in nonparametric approach and production function method in parametric approach named as the most famous methods in each classification (Deacaluwe *et al.,* 2004 and Young, 2005). Present study use production function method for determining economic value of irrigation water in investigated region. A production function like Y shows the technical relationship among inputs (x_1, x_2… x_{n-1}, water) and output. If water considered as an input in the production of an agricultural product, then the value of marginal product of irrigation water could be interpreted as its economic value (Debertin, 1997).

$$Y = f(x_1, x_2, \ldots, x_{n-1}, water)$$

$$VMP_{water} = p_y \times MP_{water} = p_y \times (\partial Y/\partial_{water}) \quad (1)$$

Where, Y is output quantity, water is irrigation water input quantity, p_Y is output price, MP_{water} is the marginal product of irrigation water and VMP_{water} is the value of marginal product of irrigation water or its economic value. For showing neoclassic conditions a production function should follows some characteristics like homogeneity, continuity, concavity and twice differentiating (Chambers, 1988). All functional forms which follow the mentioned characteristics could be used for estimating production function and the determination of regression coefficients. Functional forms divided into two groups include flexible and inflexible. Quadratic, Translog and Leontief are examples of flexible functional forms. These functional forms preferred to inflexible ones because of their proper characteristics (Chambers, 1988). Flexible functional forms have the same characteristics in many aspects and acceptable in theoretical point of view. So, for determining superior functional form, all estimated functional forms should be compared using econometrics criteria like parsimony, simple interpretation, calculation simplicity, goodness of fit, power of modeling and forecasting (Green, 1993 and Thompson, 1988). Accuracy in functional form selection could express production relationship more actually and avoids misspecification in inputs and output relationships showing (Hossienzad and Salami, 2002).

Present study estimated three functional forms include Quadratic, Translog and Leontief for determination of irrigation water economic value. Variables in the mentioned functional forms include production quantity *(Y)*, irrigation water consumption in cubic meter *(wat)*, seed consumption in Kg *(sed)*, labor in day work *(lab)*, pesticides consumption in liter *(pes)* and fertilizers consumption in Kg *(fer)*. Quadratic functional form could be specified as below:

$$\begin{aligned} y &= \alpha_0 + \alpha_{wat} wat + \alpha_{sed} sed \\ &+ \alpha_{lab} lab + \alpha_{pes} pes + \alpha_{fer} fer \\ &+ 0.5\beta_{wat}(wat)^2 + 0.5\beta_{sed}(sed)^2 \\ &+ 0.5\beta_{lab}(lab)^2 + 0.5\beta_{pes}(pes)^2 \\ &+ 0.5\beta_{fer}(fer)^2 + \beta_{watsed} watsed \\ &+ \beta_{watlab} watlab + \beta_{watpes} watpes \\ &+ \beta_{watfer} watfer + \beta_{sedlab} sedlab \\ &+ \beta_{sedpes} sedpes + \beta_{sedfer} sedfer \\ &+ \beta_{labpes} labpes + \beta_{labfer} labfer + \beta_{pesfer} pesfer \end{aligned} \quad (2)$$

The value of marginal product of irrigation water could be specified according to the quadratic functional form as below:

$$\begin{aligned} VMP_{wat} &= P_y.MP_{wat} \\ MP_{wat} &= \alpha_{wat} + \beta_{wat}.wat + \beta_{watsed} sed \\ &+ \beta_{watlab} lab + \beta_{watpes} pes + \beta_{watfer} fer \end{aligned} \quad (3)$$

Considering mentioned inputs, the Translog functional form could be specified as below:

$$\ln y = \alpha_0 + \alpha_{wat} \ln wat + \alpha_{sed} \ln sed + \alpha_{lab} \ln lab + \alpha_{pes} \ln pes + \alpha_{fer} \ln fer + 0.5\beta_{wat}(\ln wat)^2 + 0.5\beta_{sed}(\ln sed)^2 + 0.5\beta_{lab}(\ln lab)^2 + 0.5\beta_{pes}(\ln pes)^2 + 0.5\beta_{fer}(\ln fer)^2 + \beta_{watsed} \ln wat \ln sed + \beta_{watlab} \ln wat \ln lab + \beta_{watpes} \ln wat \ln pes + \beta_{watfer} \ln wat \ln fer + \beta_{sedlab} \ln sed \ln lab + \beta_{sedpes} \ln sed \ln pes + \beta_{sedfer} \ln sed \ln fer + \beta_{labpes} \ln lab \ln pes + \beta_{labfer} \ln lab \ln fer + \beta_{pesfer} \ln pes \ln fer \quad (4)$$

From which VMPwat could be determined.

$$VMP_{wat} = P_y . MP_{wat}$$

$$MP_{wat} = \frac{\partial \ln y}{\partial \ln wat} . \frac{y}{wat} = (\alpha_{wat} + \beta_{wat} . \ln wat + \beta_{watsed} \ln sed + \beta_{watlab} \ln lab + \beta_{watpes} \ln pes + \beta_{watfer} \ln fer).(\frac{y}{wat}) \quad (5)$$

The third functional form which is estimated in present study is Leontief.

$$y = \alpha_0 + \beta_{wat} wat^{0.5} + \beta_{sed} sed^{0.5} + \beta_{lab} lab^{0.5} + \beta_{pes} pes^{0.5} + \beta_{fer} fer^{0.5} + 0.5\beta_{watwat} wat + 0.5\beta_{sedsed} sed + 0.5\beta_{lablab} lab + 0.5\beta_{pespes} pes + 0.5\beta_{ferfer} fer + \beta_{watsed} wat^{0.5} sed^{0.5} + \beta_{watlab} wat^{0.5} lab^{0.5} + \beta_{watpes} wat^{0.5} pes^{0.5} + \beta_{watfer} wat^{0.5} fer^{0.5} + \beta_{sedlab} sed^{0.5} lab^{0.5} + \beta_{sedpes} sed^{0.5} pes^{0.5} + \beta_{sedfer} sed^{0.5} fer^{0.5} + \beta_{labpes} lab^{0.5} pes^{0.5} + \beta_{labfer} lab^{0.5} fer^{0.5} + \beta_{pesfer} pes^{0.5} fer^{0.5} \quad (6)$$

Irrigation water economic value based on this functional form could be determined as below:

$$VMP_{wat} = P_y . MP_{wat}$$

$$MP_{wat} = 0.5\beta_{wat} wat^{-0.5} + 0.5\beta_{watwat} + 0.5\beta_{watsed} wat^{-0.5} sed^{0.5} + 0.5\beta_{watlab} wat^{-0.5} lab^{0.5} + 0.5\beta_{watpes} wat^{-0.5} pes^{0.5} + 0.5\beta_{watfer} wat^{-0.5} fer^{0.5} \quad (7)$$

Supply cost of irrigation water calculated base on two general approaches includes accounting and engineering economics. In accounting approach, industrial accounting techniques have been used. Annual depreciation calculated as annual investment costs which summed with operational and maintenance costs and outcome divided by output quantity (water). In engineering economics approach, total costs of investment, substitution, operation and maintenance calculated for project life cycle and by constructing costs liquidity operation table, supply cost of irrigation water was determined. The main source of difference in two mentioned approach is considering money time value which is considered only in engineering economics approach. One of the methods of supply costs determination in engineering economics approach is average cost method which is used in present study. Average cost method calculated average cost for each volume unit of irrigation water. One of the advantages of applying this method is that average cost of a water unit (supply costs) per fixed costs (investment) and variable costs (operation and maintenance) could be calculated.

Requested data sets for estimating economic value of irrigation water has been acquired through surveys and filling questionnaires in Golestan province of Iran during 2010-2011. Investigated crops include irrigated wheat, soybean and tomato that the number of questionnaire of these crops was 154, 104 and 96 farms, respectively. Also, for calculating supply costs of irrigation water, regional water company data and Iran's water resource management company database were used.

RESULTS AND DISCUSSION

For each of investigated crops, results of different functional forms estimation were presented, separately. Determination of superior functional form done base on two criteria include normality of residuals and the number of significant coefficients. After determining superior functional form for each crop production function, economic value of irrigation water was calculated. Estimating three functional forms for irrigated wheat production using cross section data of 154 farms showed below summarized results in Table 3.

P-value amounts for calculated JB statistics in quadratic and Leontief functional forms showed that null hypothesis of residuals normal distribution have been rejected. Hence, these two functional forms could not be used for determining economic value of irrigated water in

Table 3: Comparing different estimated functional forms for irrigated wheat.

Functional form	Coefficients*	Significant coefficients*	Jurque-Bera Statistics**	p-value
Quadratic	21	11	93.46	0.000
Translog	21	8	4.59	0.1
Leontief	21	7	32.82	0.000

* Number ** Residuals Normality test

Table 4: Results of Translog functional form estimation for irrigated wheat production.

Variable	Coefficients	Standard Error	t-statistic	p-value
α_0	2.57	7.981	0.32	0.748
α_{wat}	-1.53	4.492	-0.34	0.734
α_{sed}	1.14	3.505	0.33	0.746
α_{lab}	-1.23	0.499	-2.47	0.015
α_{pes}	0.37	0.171	2.17	0.032
α_{fer}	2.14	1.53	1.4	0.164
β_{wat}	0.72	1.312	0.55	0.585
β_{sed}	-1.44	0.935	-1.54	0.126
β_{lab}	0.01	0.026	0.49	0.622
β_{pes}	-0.01	0.007	-1.34	0.182
β_{fer}	-0.21	0.192	-1.11	0.267
β_{watsed}	0.11	1.007	0.11	0.914
β_{watlab}	0.3	0.152	1.96	0.052
β_{watpes}	-0.2	0.068	-2.97	0.004
β_{watfer}	-0.85	0.515	-1.65	0.101
β_{sedlab}	-0.2	0.134	-1.51	0.133
β_{sedpes}	0.3	0.095	3.12	0.002
β_{sedfer}	1.14	0.459	2.49	0.014
β_{labpes}	-0.04	0.015	-2.69	0.008
β_{labfer}	-0.04	0.053	-0.69	0.493
β_{pesfer}	-0.04	0.025	-1.52	0.131

Adjusted $R^2 = 0.98$ D-W statistic = 2.02

wheat production and Translog functional form chosen as the superior one. Table 4 contains results of Translog functional form estimation.

Using Translog functional form economic value of irrigation water in wheat production equals 1624 IRR per cubic meter.

Estimating three functional forms for irrigated soybean production using cross section data of 104 farms revealed below summarized results in Table 5.

According to the JB statistics and its p-value, quadratic functional form residuals did not follow normal distribution. So from two functional forms of Translog and Leontief, the last one chosen based on the number of significant coefficients. Results of Leontief functional form estimation reported in table 6.

Economic value of irrigation water in soybean production calculated based on above estimation results. Mentioned value equals 2084 IRR per cubic meter.

Finally, estimating three functional forms for irrigated tomato production using cross section data of 96 farms revealed below summarized

Table 5: Comparing different estimated functional forms for irrigated soybean.

Functional form	Coefficients*	Significant coefficients*	Jurque-Bera Statistics**	p-value
Quadratic	21	13	23.09	0
Translog	21	4	3.93	0.13
Leontief	21	11	8.1	0.12

* Number ** Residuals Normality test

Table 6: Results of Leontief functional form estimation for irrigated soybean production.

Variable	Coefficients	Standard Error	t-statistic	p-value
α_0	-3002	908.8	-3.3	0.001
β_{wat}	-189	86.6	-2.18	0.032
β_{sed}	1756	771.3	2.28	0.025
β_{lab}	1355	296.2	4.57	0.000
β_{pes}	-1035	415.1	-2.49	0.015
β_{fert}	-25	83.2	-0.3	0.765
β_{watwat}	-12	7.4	-1.68	0.097
$\beta_{sedsedt}$	-259	462.7	-0.56	0.577
$\beta_{lablabt}$	-142	97.1	-1.46	0.147
$\beta_{pespest}$	369	320.5	1.15	0.253
β_{ferfer}	38	5.9	6.43	0.000
β_{watsed}	88	54.3	1.62	0.109
β_{watlab}	-20	27.9	-0.7	0.485
β_{watpes}	70	52.1	1.35	0.181
β_{watfer}	27	7.5	3.58	0.001
β_{sedlab}	-32	249.8	-0.13	0.899
β_{sedpes}	-699	435.7	-1.61	0.112
β_{sedfer}	-310	62.3	-4.97	0.000
β_{labpes}	383	120.1	3.19	0.002
β_{labfer}	56	29.6	1.88	0.063
β_{pesfer}	-94	79.1	-1.19	0.239

Adjusted R^2 = 0.98 D-W statistic = 1.85

results in Table 7.

Considering the rejection of null hypothesis in JB normality test for two quadratic and Translog functional forms, only, Leontief functional form could be used for determining economic value of irrigated water in tomato production that estimation results of this form reported in table 8.

Using above functional form, the economic value of cubic meter irrigation water in tomato production equals 3250 IRR. Considering acreages of these three products in Golestan province, weighted average economic value of irrigation water in mentioned region calculated which equals to 1795 IRR per cubic meter.

Supply costs of irrigation water in surface water resource for each of Golestan province dams calculated using data of initial investments costs, operation and maintenance costs and annual adjustable water volume of dams. Usually, operation and maintenance costs calculated base on 0.6 percentages of initial investments costs for a dam and 1.3 percentages for irrigation network. Initial investments costs updated using civil index. Also, annual investments costs of dams calculated using discount factor of 7 percentages and 50 years time horizon. After calculating equivalent of annual investments costs for all dams, this amount summed with operation and maintenance costs. Dividing this outcome by annual adjustable water volume, price of irrigation water per cubic meter gained. Table (9) contains supply costs of irrigation water per Golestan's province dams.

Annual adjustable water volume (A.A.V.) calculated by considering 90% transfer and distribution efficiency.

For calculating A.A.V. in irrigation and drainage network 81% of dam's A.A.V. applied.

For calculating supply cost of groundwater,

Table 7: Comparing different estimated functional forms for irrigated tomato.

Functional form	Coefficients*	Significant coefficients*	Jurque-Bera Statistics**	p-value
Quadratic	21	8	14.75	0.000
Translog	21	7	16.06	0.000
Leontief	21	15	1.61	0.44

* Number ** Residuals Normality test

Table 8: Results of Leontief functional form estimation for irrigated tomato production.

Variable	Coefficients	Standard Error	t-statistic	p-value
α_0	16555.2	9653.4	1.71	0.091
β_{wat}	-659.4	290.4	-2.27	0.026
β_{sed}	90070.6	30016	3	0.004
β_{lab}	3566.2	2091.2	1.71	0.093
β_{pes}	-15577.1	10103	-1.54	0.128
β_{fert}	-2669	853.1	-3.13	0.003
β_{watwat}	6.3	9.3	0.68	0.50
$\beta_{sedsedt}$	-20554.4	26177.2	-0.79	0.435
$\beta_{lablabt}$	-1428.1	680.4	-2.1	0.039
$\beta_{pespest}$	4398.5	2224.9	1.98	0.052
β_{ferfer}	505.8	121.9	4.15	0.000
β_{watsed}	471.7	570.5	0.83	0.411
β_{watlab}	207.6	69.4	2.99	0.004
β_{watpes}	-401.7	93.8	-4.28	0.000
β_{watfer}	37.3	23.9	-1.56	0.123
β_{sedlab}	-18293.3	6269.2	-2.92	0.005
β_{sedpes}	22589.7	4194.8	5.39	0.000
β_{sedfer}	544.8	2160.5	0.25	0.802
β_{labpes}	4125.5	1828.6	2.26	0.027
β_{labfer}	-137.1	126.3	-1.09	0.281
β_{pesfer}	-1132.4	535	-2.12	0.038

Adjusted $R^2 = 0.94$ D-W statistic = 1.99

Table 9: Supply costs calculation of irrigation water per dams in Golestan province.

Condition	Dams	Investments costs (Million Rials)		A.A.V (MCM)	Price of irrigation water (Rial/m³)
		Dam	Irrigation network		
Existing dams	Voshmgir	126878	448232	91.31	109
	Kosar	36551	17852	6.73	426
	Golestan 1	477906	158643	116.17	321
	Golestan 2	413652	247673	32.28	1005
	Alagol	109863	7106	83.4	103
Planned dams	Chayli	1006795	444264	204	387
	Normab	1903178	521900	115	1298
	Kivdoval	311138	938060	54.2	450

Annual adjustable water volume (A.A.V.) calculated by considering 90% transfer and distribution efficiency.
For calculating A.A.V. in irrigation and drainage network 81% of dam's A.A.V. applied.

considering wells as the main source of groundwater in Golestan province, for investigating supply costs of groundwater, equivalent of annual investments cost calculated and divided by well's output water volume. In calculating annual investments cost, discount factor equals 8% and 35 years time horizon considered. Using sample data of a well in investigated region, average supply costs of groundwater in Golestan province equals 1695 IRR per cubic meter. 25 percentages of total irrigation water use in Golestan province provides by surface water and 75 percentages supplied by groundwater resources. So, weighted average supply costs of irrigation water in Golestan province equals 1399 IRR per cubic meter.

CONCLUSION

After determining economic value and supply cost of irrigation water in Golestan province, different pricing scenarios investigated in order to provide proper framework for policy makers and planners in water sector.

1) Scenario of existing non-beneficial irrigation water supply company

If water regional companies would work in a non-beneficial framework which means pricing irrigation water equal to its supply cost then this company should price irrigation water 1399 per cubic meter. While, water tariffs in modern and semi-modern irrigation networks, is 20 to120 IRR per cubic meter, now. So, regional water company should increase irrigation water tariff to its supply cost.

2) Scenario of equating water tariff to its economic value

Economic value shows consumers' willingness to pay for water. Each additional cubic meter of irrigation water added 1795 IRR to farmer's income in average. In means farmers will pay 1795 IRR for a cubic meter of irrigation water. If there are circumstances in which water scarcity raised in investigated region, pricing irrigation water equal to its economic value would be a good policy for optimal allocation of irrigation water.

3) Scenario of pricing based on equity of value and cost

Considering irrigation water as an economic commodity, water supplier act efficiently only when for each output unit (water) marginal cost equals marginal revenue or benefit. Results of present study showed that supply cost of cubic meter irrigation water equals 1399 which is less than its economic value (1795 IRR). So, improvement of water demand and supply management could be achieved by using price policies.

Results of present study provide good framework for regional managers in order to improve water resource management considering sustainable development rules in their region. It is necessary to study economic value and supply cost of irrigation water in different provinces of Iran. Mentioned studies provide good policy implications in Iran's water sector.

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