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Potential Gains from Water Markets Construction: Saveh Region Case Study

Gholam Hossain Kiani*

Department of Environmental and Resource Economics,
Environmental Sciences Research Institute, Shahid Beheshti University, Tehran, Iran.

Abstract

Water is a valuable and scarce production factor in the agricultural sector of Iran. At present, water resources are allocated by the government agencies, based mostly on socio-political criteria instead of economic measurements. Administrative water resource management has resulted in an inappropriate water allocation and water use, as water use efficiency is reported about 36% in the agriculture sector now. Recently, the water market has been introduced as an alternative mechanism to an administrative manner for increasing water use efficiency in several developed and developing countries. Water is transferred from low to highest marginal return use and consequently water use efficiency increases in the water market. This paper estimates potential gains of implementing agricultural water market in Saveh region by using a mathematical programming model. Results show that water trade among 24 villages in this region can increase farmers' profits, particularly during a water scarcity period. Also, a water market can increase labour demand and mitigate negative impacts of water scarcity on employment. Additionally, results show that the transaction costs must be declined to broaden the water markets.

Keywords: water market, efficiency, mathematical programming model.

منافع بالقوه تشکیل بازارهای آب: مطالعه موردی منطقه ساوه

غلامحسین کیانی*

گروه اقتصاد منابع و محیط زیست، پژوهشکده علوم محیطی، دانشگاه شهید بهشتی

چکیده

آب یک نهاده تولیدی با ارزش و کمیاب در بخش کشاورزی ایران می باشد. در حال حاضر منابع آب توسط بنگاه های دولتی و عمدتاً بر اساس معیارهای سیاسی- اجتماعی، به جای معیارهای اقتصادی، تخصیص می یابند. شیوه مدیریت دولتی منابع آب موجب تخصیص و استفاده ناکارآمد از آب شده است به گونه ای که کارایی مصرف آب در بخش کشاورزی حدود ۳۶ درصد گزارش شده است. اخیراً در برخی از کشورهای توسعه یافته و در حال توسعه به منظور افزایش کارایی مصرف آب، بازار آب به عنوان یک جایگزین برای روش اداری مطرح شده است. در بازار آب، آب از مصارف با بازده نهایی کم به سمت مصارف با بالاترین بازده نهایی منتقل شده و در نتیجه کارایی مصرف آن افزایش می یابد. در این مقاله با استفاده از الگوی برنامه ریزی ریاضی منافع بالقوه تشکیل بازار آب در منطقه ساوه برآورد می گردد. نتایج نشان می دهند که مبادله آب بین ۲۴ روستای این منطقه باعث افزایش سود زارعین، خصوصاً در دوره کمبود آب می گردد. همچنین بازار آب می تواند باعث افزایش تقاضای نیروی کار و تسکین تبعات منفی کاهش منابع آب بر روی اشتغال گردد. به علاوه نتایج نشان می دهند که جهت گسترش دامنه بازارهای آب می بایست هزینه های مبادله کاهش یابند.

کلیدواژه ها: بازار آب، کارایی، الگوی برنامه ریزی ریاضی.

* Corresponding author. E-mail Address: G_kiani@sbu.ac.ir.

Introduction

Water scarcity is a serious problem in Iran. The average rainfall is 250 mm/year with high annual variation, whereas droughts occur periodically. Therefore, it is necessary that scarce water resources be used efficiently. While the agriculture sector uses more than 90% of all the nation's available water resources, water use efficiency is about 36% in this sector (Ministry of Energy, 2000). In Iran, historically, most water has been managed by the government agencies based mostly on the socio-political criteria. The absence of price signals in centralized allocation system has decreased irrigators' incentive to use water more efficiently (Sadr, 2003). In recent years, water market has been recommended as a viable alternative to the administrative allocation of water in several developed and developing countries. Water markets can increase water use efficiency through the transfer of water to potentially more efficient uses. Because of the increased opportunity cost of water, even farmers who do not participate directly in water market have sufficient incentive to use water more efficiently (Zekri and Easter, 2005).

The impacts of water markets have been investigated in many studies. Hearn and Easter (1997) have assessed the impacts of two real water markets in Chili. They showed that the market transfer of water-use rights produces substantial economic gains from trade in Elqui and Limari Valleys in north-central Chile. Dinar and Lettey (1991) and Weinberg *et al.* (1993), both in the Californian valley of San Joaquin and Garrido (2000) in Spain showed that the implementation of the water market can increase allocation efficiency of this resource. Zekri and Easter (2005) concluded that water transfer among farmers and an urban water company can increase farmers' profitability by up to 7.9% in Tunisia. Also Gomez-Limon and Martinez (2006) showed that the simulated water market would increase economic efficiency and agricultural labor demand, particularly during drought in Spain. Kiani (2009) showed that Mojen water

market has increased the buyers and sellers income 9.5% and 75%, respectively.

This paper investigates the potential impacts of implementing water markets in Iran. For this purpose two agricultural water markets will be simulated in Saveh region and their impacts on farmers' profitability (as a measurement of economic efficiency) and labour demand will be estimated. The impacts of transaction costs and water availability on water trade will also be analyzed in different scenarios.

Materials and Methods

In this study two mathematical programming models are proposed to investigate farmers' economic behavior with respect to water use and the water market. The first model is a farm model where water exchanges are not possible (lack of water market) and farmers allocate their water allowance to agricultural crops. This model is used to determine the optimum profit, which is later used as an input into second model.

In Saveh region a representative farmer receives his water allocation in two periods (winter and summer) and he can produce winter and summer crops. The farmers' problem of decision making would be outlined as follow:

Max:

$$\Pi_0 = \sum_i GM_i^W X_i^W + \sum_j GM_j^S X_j^S \quad (1)$$

Subject to:

$$\sum_i X_i^W + \sum_j X_j^S \leq L \quad (2)$$

$$\sum_i d_i^W X_i^W \leq \alpha TW \quad (3)$$

$$\sum_j d_j^S X_j^S \leq \alpha TS \quad (4)$$

$$X_i^W \geq 0, X_j^S \geq 0 \quad \forall i, j \quad (5)$$

Where Π_0 is total gross margin from cropping, GM_i^w , GM_j^s and are average gross margins for winter crop i and summer crop j , respectively, X_i^w and X_j^s are the areas allocated to winter crop i and summer crop j , respectively (in ha), L is the total available area for cropping activities (in ha), d_i^w and d_j^s are per hectare water requirements of the winter crop i and summer crop j , respectively, TW and TS are the total endowment of water available in winter and summer, respectively (in m^3), and α is the scarcity coefficient.

The first equation is the objective function that maximizes farmers' profit. Equation (2) represents the land constraint in cropping activities. Equations (3) and (4) are winter and summer crops' requirements restricted by water availability. Different scenarios are considered for water availability (αTW and αTS). For instance, when α takes the value 1, the amount of available water is equivalent to the experimental allotment in the base year, whereas if coefficient α takes value 0.8 only 0.8 of this volume is available.

Now it is assumed that a market is established and farmers can exchange water in winter and summer through the water market. In this situation, farmers decide to exchange water in the market, depend on marginal value of water in their farms. The second model is designed to investigate the potential impacts of water markets on the regional economy. The optimization problem at the regional setting can be stated as follows:

Max:

$$\begin{aligned} \sum_k \Pi_k = & \sum_k \sum_i GM_{ik}^w (X_{ik}^w) + \sum_k \sum_j GM_{jk}^s (X_{jk}^s) + \\ & \sum_k \left[(WP^w - \frac{tc}{2}) WS_k^w \right] - \sum_k \left[(WP^w + \frac{tc}{2}) WB_k^w \right] \\ & + \sum_k \left[(WP^s - \frac{tc}{2}) WS_k^s \right] - \sum_k \left[(WP^s + \frac{tc}{2}) WB_k^s \right] \end{aligned} \quad (6)$$

Subject to:

$$\sum_i X_{ik}^w + \sum_j X_{jk}^s \leq L_k \quad \forall k \quad (7)$$

$$\sum_i \sum_k d_{ik}^w X_{ik}^w \leq \alpha \sum_k TW_k \quad (8)$$

$$\sum_j \sum_k d_{jk}^s X_{jk}^s \leq \alpha \sum_k TS_k \quad (9)$$

$$\sum_i d_{ik}^w X_{ik}^w + WS_k^w - WB_k^w \leq \alpha TW_k \quad \forall k \quad (10)$$

$$\sum_j d_{jk}^s X_{jk}^s + WS_k^s - WB_k^s \leq \alpha TS_k \quad \forall k \quad (11)$$

$$\Pi_k \geq \Pi_0 \quad (12)$$

$$\begin{aligned} X_{ik}^w \geq 0, X_{jk}^s \geq 0, WP^w \geq 0, WP^s \geq 0, \\ WB_k^w \geq 0, WS_k^w \geq 0, WB_k^s \geq 0, WS_k^s \geq 0 \\ \forall i, j, k \end{aligned} \quad (13)$$

Where Π_k is farmers' profit after participating in the water market, index k denotes a representative farmer, WP^w and WP^s are the market price of water in winter and summer respectively, tc is the transaction cost, WS_k^w and WB_k^w are the amount of water sold and purchased by farmer k in the winter water market, WS_k^s and WB_k^s are the amount of it sold and purchased by farmer k in summer water market.

With respect to Equation (6), farmers maximize their profits through cropping and the exchange of water. The transaction cost contains operating and

management costs and it is assumed that is fixed exogenously and buyers and sellers pay them equally.

Some authors have considered price in the simulated water market as a parameter. Garrido (2000) assumed that market equilibrium price is equal to the buyers' shadow price for water. Zekri and Easter (2005) argued that the water market price is fixed exogenously and sellers receive the lowest opportunity cost of water whereas buyers pay price received by sellers, plus the operating and management costs and the transaction cost. In this study, according to Gomez-Limon and Martinez (2006), in the above model water market prices (WP^w and WP^s) are variable and endogenously would be determined, while water supply equals water demand.

The set of constraints (8) and (9) guarantee that the volume of water used at region level is less than or equal to the total water available in winter and summer. Equations (10) and (11) ensure that in both water markets volume of water used plus net volume of water traded by each farmer is less or equal to his allotment. Equation (12) guarantees that the profit reached by each farmer in the market should be superior or at least equal to his profit in the first case, when exchanges are not permitted.

Since this model is a non-linear model, 'global optima' could not be obtained. To credit 'local optima', attention was paid to the fact that water market prices lay in an acceptable domain. According to the literature, price in the water market must be lower or equal to the highest opportunity cost of water (in without market scenario) and higher or equal to the lowest of them.

It is important to know the limitations of this approach. The linear programming models consider the fixed production coefficient at various levels of water use, whereas differences between the value of marginal products of water promote water transactions among market participants. Furthermore, due to information limitations, input and output price risks are ignored in these models while Caltrava and Garrido (2002) and Kiani *et al.* (2008) showed that

risk and uncertainty affect participants' behavior in the water market. Also, as Gomez-Limon and Martinez (2006) commented, it should be noted that because of the set of constraints in Equation (12), the market equilibria obtained via this model should be considered as 'second best' optimal. On the other hand, in this model voluntary transfers are based on individual profit gains whereas implementation of a compensating mechanism, which transfers benefits from gainers to losers, can increase total profit more in market equilibria.

Results and Discussion

The Saveh region is situated in the north of the Markazi Province. The average rainfall in this area is 180 mm/year and the average available water is 300 million cubic meters per year. The crops irrigated in this region are winter crops, i.e. wheat and barely, and summer crops, namely cotton, cantaloupe and pomegranate. The irrigated area considered in this study includes 24 villages under the Saveh irrigation network, which covers 12500 ha. The efficiency of water transfers from the main channel to farmers varies among 24 villages, ranged from 35% to 100%. Thus, it is expected that these differences motivate farmers to participate in the water market and water exchanges among villages. All information such as output and input prices, inputs used per crops and crop yields were obtained from the study of Mohamadinejad (2001).

Irrigation water in Saveh region was delivered to farmers during two periods (November to next June and July to September) at two different prices (20 Rials/m³ in the first period and 30 Rials/m³ in the second period during 1999-2000). Hence, two water markets are designed in this case study. Winter and summer water markets are separate but since winter crops and summer crops use the land competitively, both markets are implicitly interdependent. On the other hand, the winter water market influences the winter plantation pattern and consequently the summer plantation pattern and summer water market and vice

versa. At the equilibrium point, total gross margin from production plus gains from both water markets are maximized. Water markets were simulated in alternative scenarios for different amounts of available water (by changing α) and two transaction costs (for $t_c=10, 20$ Rials). The results of these scenarios were compared with those estimated in the first model (where water markets are not implemented) and changes in aggregate gross margin and labor demand were calculated in the whole of the areas studied. For instance, Table 1 presents the results obtained by simulating water markets when transaction cost equal to 20 Rials.

The volume of water exchanged is 85.2 million m^3 in both markets (28% of total water used) and the average improvement in farmers' profitability is 5%. Also total labor demand increased by 6% in the region.

Figure 1 shows the impacts of both markets on aggregate gross margin. When available water decreases (α diminishes), the aggregated gross margin is reduced but this reduction is greater in a "without market" scenario than a "with market" scenario. This improvement in aggregate gross margin (as a measurement of economic efficiency) ranged from 1.6% to 26% for different values of α ($t_c=10$ Rials). It can be observed that transaction cost has a negative impact on this improvement. For example, if the transaction cost increases from 10 to 20 Rials (for $\alpha=1$), then aggregate the gross margin diminishes from 12% to 9% and water market loses its advantage about 3%. Figure 2 shows that implementing water market can mitigate negative impact of water scarcity on labor demand within agriculture sector. As accessible water drops, labor demand decline in both cases but this reduction is

Table 1- Impacts of simulating water markets ($\alpha=1, t_c=20$ Rials).

Villages	Winter water market		Summer water market		Profit without market (billion Rials)	yearly Improvement on profit (%)	Increase labor Use in days number (%)
	Volume of water (million m^3)		Volume of water (million m^3)				
	sold	purchased	sold	purchased			
Yal abad	0.0	0.0	0.0	8.8	6.4	1	0
Ghardin	10.7	0.0	0.0	6.0	5.7	2	10.4
Alusjerd	0.0	0.0	0.0	8.43	5.3	0	0
Herisan	0.0	11.0	13.6	0.0	3.2	15	0
Ojan	6.8	0.0	0.0	3.8	3.6	2	29
Khoram abad	0.0	2.7	4.3	0.0	2.5	1	0
Malkabad	4.6	0.0	0.0	2.5	2.4	2	29
Ostoj	2.6	0.0	0.0	3.1	2.3	1	0
Sorkhade	4	0.0	0.0	1.7	2.2	2	22
Sef abad	3.7	0.0	0.0	2.4	1.9	1	0
Holol	3.5	0.0	0.0	2.4	1.8	1	0
Lalaeen	3.36	0.0	0.0	2.7	1.7	1	0
Abasabad	0.0	0.0	0.0	0.0	1.6	0	0
Mahmod abad	0.0	0.0	0.0	0.0	1.5	0	0
Fansghan	0.0	6.5	4.9	0.0	0.8	0	0
Mehr abad	0.0	5.0	4.6	0.0	0.9	52	0
Asyabak	2.7	0.0	0.0	0.3	1.6	35	6
Tarkhoran	0.0	5.6	4.2	0.0	0.7	1	0
Labar	0.0	3.6	4.0	0.0	0.9	52	0
Jojen	0.7	0.0	0.0	0.0	1.0	22	0
Dalestan	0.0	3.9	3.5	0.0	0.7	0	0
Hasan abad	0.0	0.0	0.0	0.25	1.3	35	6
Chal dagh	0.0	4.5	3.3	0.0	0.6	1	0
Ali abad	0.14	0.0	0.0	0.02	.09	52	6
Total	42.8	42.8	42.4	42.4	50.69	5	6

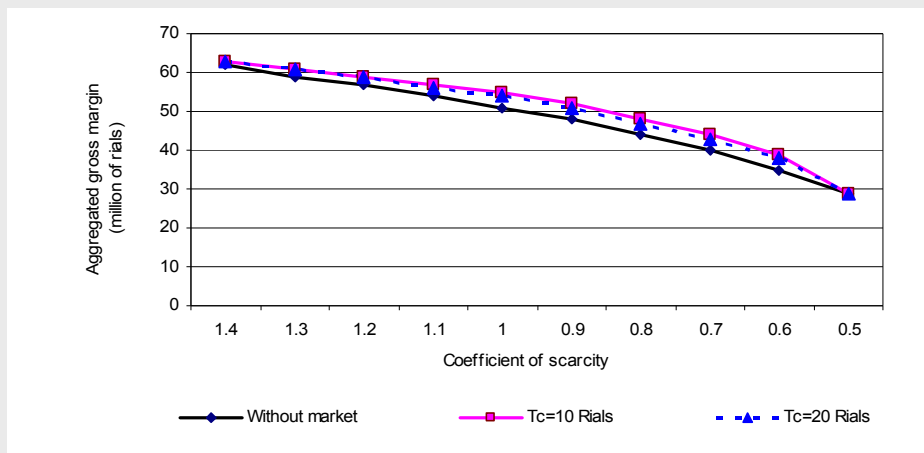


Figure 1. Impact of markets on aggregated gross margin.

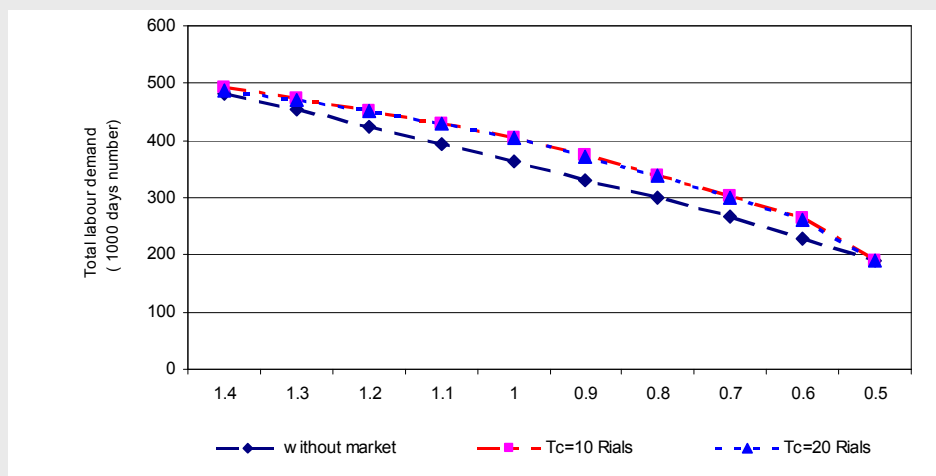


Figure 2. Impact of water market on total labor demand

more moderate in the “with market scenario” than the “without market scenario”. This improvement in total labor demand ranges from 2% to 15.2 %. Also, increasing transaction cost shrinks this positive impact of water market. Although this impact looks to be negligible, it does exist. Figure 3 shows the volume of water exchanges in the winter water market. When

water scarcity increases (α diminishes), the volume of exchanged water raises until the point that the scarcity coefficient equals to 0.9. After this point, the volume of exchanged water decreases, due to decreasing the absolute available water. In the summer water market, this issue occurs in experimented water availability, where the scarcity coefficient is equal to 1(Fig. 4)

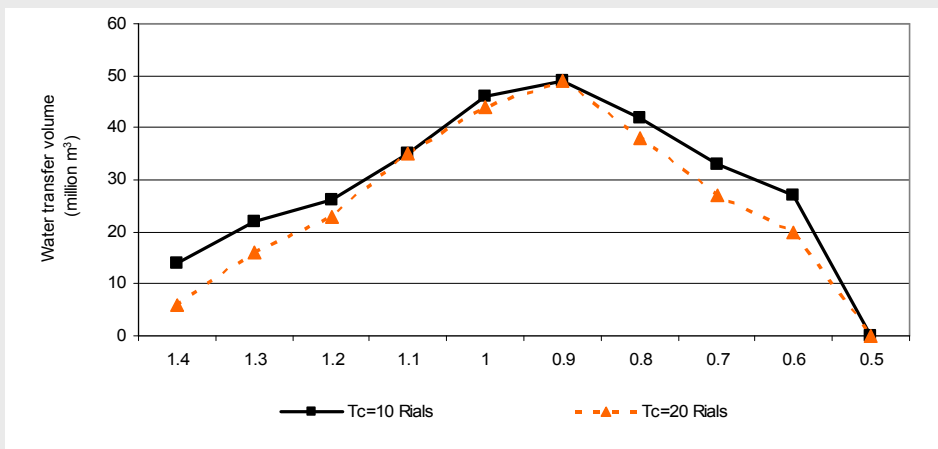


Figure 3. Water transferred in winter water market.

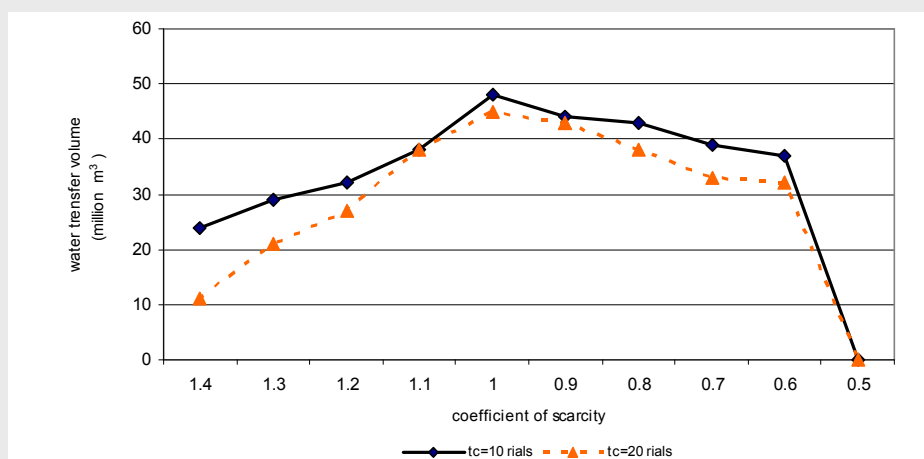


Figure 4. Water transferred in summer water market.

Conclusion

In this study the potential gains of implementing water market estimated in Saveh region. Results show that the water market can increase farmers' profits, particularly during a water scarcity period. Also, a water market can increase labour demand and reduce the negative impacts of water scarcity on employment in the agriculture sector. In addition, these results show that transaction costs reduce water trading among farmers in the water market.

It is worth mentioning that implementing a water market and achieving these gains would require certain institutional arrangements (Kiani, 2009). In this context, well-defined water rights, separate from that of land, an administrative system, a well-maintained water delivery infrastructure, low transaction costs and the elimination of monopolistic behavior and negative externalities are all prerequisites for the formation and efficient functioning of a water market.

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