The HELLENIC OPEN BUSSINES ADMINISTRATION *Journal*

Volume 3 - 2017, No 2

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HELLENIC OPEN UNIVERSITY

ISSN: 2407-9332

Athens2017
Publisher: D. Giannias

Volume 3 - 2017, No 2

ENVIRONMENTALLY OPTIMAL LOCAL WATER MARKETS

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Abstract

A model is presented that incorporates water quantity and quality aspects and a market based system is developed to characterize optimum water allocations between two regions or countries or among users within a region. A methodology is developed to compute the market water quantity and quality price that would prevail in a local market and the methodology is illustrated using the water allocation problem between Greece and Bulgaria concerning Nestos river.

Keywords: optimal allocation, water market, water quality

JEL Classification: Q58, D1, D2

Introduction

The idea of external costs that are imposed directly (not through a market) on economic agents by various production or consumption activities has been used extensively by economists in their theorizing about resources allocation. These ideas served them to illustrate relevant policy implications on market type economies, e.g., see Mishan (1965) and (1971), and in early 1960's they were first applied empirically to the pollution problem. This analytical framework is employed in this paper to investigate empirically and theoretically the efficiency of local markets as a policy for water quantity and quality allocation.

Fresh surface water resources are becoming scarce in our days and the Brundtland Report emphasizes that their use should be compatible with sustainable development. Sustainable water utilization requires the identification of feasible policies that can provide adequate water supplies for everyone, in regional, national and international situations. The identification of such water policies is a complex issue of great importance since river and lake basins are often shared by two or more countries (Oodit and Simonis, 1993). For example, in Africa most fresh water basins are international; in Asia and the Pacific region, 65 percent of the drainage area of rivers, and in Western Asia about 95 percent of the average annual discharge from rivers, also emanate from such basins; in South America, fresh water basins spreading over more than one country account for about 75 percent of the total water flow; in Europe, broadly similar patterns can be observed.

Water quantity and quality constitute the two most important dimensions of all fresh surface water allocation mechanisms, and problems in relation to either dimension or both are encounter in many instances worldwide. For example, India diverts the Ganges waters and this creates dry season conditions for Bangladesh; in the Netherlands the waters of Rhine are used for drinking, while Switzerland, France, and Germany use it as a receiver of wastes; in the Middle East, competition for fresh surface waters has historically led to conflict and even military confrontation (Gleick, 1994).

There are about 200 international river basins that are shared among several countries and only in a the case of the 10% of them the water allocation is based on a cooperation agreement, while for the 30% of them there is not any agreement at all. Oodit and Simonis (1993) report only a handful of bilateral agreements for cooperation. For example, Syria and Jordan in the Middle East have created a joint Commission which is responsible for planning and development of the Yarmuk river basin; in Asia and the Pacific region, a permanent commission regulates the allocation of the Indus waters between India and Pakistan. However, despite the agreements conflicts often arise. For example, Syria has constructed a number of dams on the Yarmuk river which are opposed by Jordan (Gleick, 1994).

The majority of bilateral agreements do not specify precisely the ways of cooperation, and, consequently, are unable to allocate water between regions or countries. Examples of such agreements are reported in Asia between China and N. Korea on the Yalu River; Afghanistan and the former USSR on the Amu river basin; Afghanistan and Iran on the Helmand river basin; Malaysia and Thailand on the Golok river basin; in the Balkans, between Bulgaria and Greece on the Nestos, Ardas, and Strymon rivers .

Water allocation problems are usually not successfully faced in practice because the regions that access the water flow first fear that a forthcoming water shortage may constraint their political and economic options. At the same time regions are operating under incomplete information regarding both the specific alternative water allocation policies and the additional joint benefits associated with them. Unfortunately, the literature on bilateral water sharing is relatively limited.

Most of the water allocation studies concentrate on the interregional dimensions of water allocation (e.g. Howe and Easter, 1971; Gisser and Johnson, 1983; Rosen, 1990), while those few focusing on the intercountry level are multilateral (e.g. Dinar and Wolf, 1994). This paper focuses on allocation of water between two regions or countries or among users within a region through local market structures and takes as a case study the waters of Nestos river, which are shared between Greece and Bulgaria. By their nature the existing systems for the allocation of the water of Nestos river are characterised by "free" access to them in both quantitative and quantitative terms, with the regions located near the springs being in a relatively privileged position. The allocation mechanism identified in this paper is characterised as environmentally optimal because it accounts for the water quality aspects of the problem.

To discuss the public policy implications of our theoretical and empirical analysis, we start with a characterisation of the water quantity and quality allocation problem and an overview of the main findings of empirical research.

The economics and the political economy of environmentally optimal water allocation

For a variety of reasons water bodies, air mantle, and various other ecological systems are not in private ownership but rather in some not well defined sense collectively hold. The problem of water quantity and quality allocation is part of the class of problems associated with the efficient use of common-property natural resources. In general, up to the second half of our century clean air and water were abundant and the majority of the users would not be willing to pay anything to augment them. As a result of it there were no need for any coherent conservation or management. Water for irrigated agriculture was probably an exception but even for it the dimension of quality was not taken into consideration, Bain et al (1966). However, in the postwar era the deterioration of natural assets is massive and affects the population a lot and in many different ways. This is today widely recognised by the application of the common-property resources and the conservation of mass concepts.

The residuals receiving capacity of land, air, and water environments was large relative to the demand for a long time but the natural reservoirs of assimilative capacity are now filling up rapidly, and waste disposal is associated with important external costs. Private property and our institutional structure cannot support an efficient allocation of our resources in many instances and as a result economists are faced with a large-scale and rather unfamiliar problem of collective action and management.

Although there may be a disagreement about the importance of some externalities, there is always little dispute over the desirability of correcting them. The question is how. The conventional approach to water quality management was based primarily on the imposition of more or less uniform treatment requirements at all existing outfalls even though economic theory suggested that economic incentives could achieve enormous efficiency gains over the conventional approach, e.g., see Kneese (1968). The usual economist's proposal is to correct for externalities by levying charges upon the producer to pay for abatement of pollution or by modifying production processes. But environmentalists are generally less concerned about resource allocation than economists, being mainly interestd in preventing deterioration of the environment and inclined to favor direct action, such as mandating air and water quality standards and waste disposal practices.

Economists usually advocate working through the market by taxing effluent to decrease pollution, by creating a market for pollution "rights", or by subsidies;

most of them, however, are less likely to endorse subsidies because once granted they may grow and survive beyond their need.

A tax on the externality-causing activity reflecting the external costs has long been advocated by economists, while greeted with much skepticism by policy makers at the same time. Economic empirical research supported the practical value and effectiveness of an effluent charges or taxes approach. For example, a water quality standard in the Delaware Estuary area could be met at about half the real cost if a uniform effluent charge were levied on all waste discharges rather than if they were all required to achieve uniform levels of treatment, Kneese (1972).

Individual industries can also be benefited in terms of efficiency by economic incentive techniques targeting their residuals generation and disposal activities. This is possible if they are given real incentives to reduce drastically the generation of industrial waste waters, e.g., by redisigning production processes, changing quality of inputs, etc. Economic incentives are expected to reduce residuals much more cheaply by controlling their generation than by building a treatment facility to attempt to reduce them after they are generated. However, in most cases current policy approaches ignore all possibilities for industrial waste reduction except treatment after the residuals are generated.

In addition to government action (policies), protection of the environment may be initiated by private individuals and organisations. The private bargaining approach suggested by the pioneer work of Marshall and Pigou is feasible so long as the number of injured parties is small and the firm or individual responsible for injury is easily identified.

Individual may also sue for damages under the common law, an action that can be viewed as a special kind of coersive private bargaining. The remedy of common law for externalities is quite flexible. However, private damage suits are not the ideal antidote for externalities because 1) the plaintiff may face the difficult task of convincing the court that an injury or monetary loss has been sustained (which is sometimes costly and time-consuming), and 2) if the disputed condition has been recognised and unopposed for years before the suit, the court will usually regard this as evidence that the externality is not seriously disabling.

Historically, the majority of the water allocation policies are in reality quite different from, if not totally contrary to, the solutions which traditional economic analysis would suggest is appropriate. The reason that economic incentive type of policies have not been widely used as an effective mean of water management make us examine another non-traditional policy, namely, the establishment of local water markets for efficient water allocation.

To maintain some degree of focus and simplicity,in our analysis water quality is isolated from its broader context, which includes interrelationships with the quality of other common-property assets[1]. Finally, our analysis incorporates the important interrelationships between water quantity and quality; to be more specific, economic activities that reduce the amount of water available downstream affect adversely the quality of the water supply.

A Theoretical Framework

Our framework assumes that there is no uncertainty, that property rights are exogenous and non-attenuated, and that there is no price for water. The water resource system under consideration is a river shared by two regions, j=1, 2. The river rises in region 1 and flows through region 2 and into the sea. Its water is used by various activities, industrial, agricultural, recreational, tourism, etc along the watercourse in both regions.

The ith production technology in region j is given by,

$$Y_{ij} = Y_{ij}(X_{ij}; W_{ij}, Q_{ij}) \qquad (1)$$

where, i assumes two sets of values, i = 1, 2, ..., m for region 1, and i = 1, 2, 3, ..., n for region 2,

Y_{ij} = the level of activity i in region j,

X_{ij} = set of production inputs other than water used by activity i in region j,

W_{ij} = the flow of water in activity i in region j, and

Q_{ij} = the quality of water in activity i in region j.

The ith activity in region 1 generates and disposes into the river h_{i1} units of waste, where $h_{i1} = h_{i1}(Y_{i1})$. Let $h_1 = (h_{i1}, ..., h_{m1})$ be the vector of all wastes disposed into the river in region 1. This vector together with $Q_1 = (Q_{11}, ..., Q_{m1})$ determine Q_2, the water quality going to region 2. Therefore, Q_2 is a function of the following general form:

$$Q_2 = Q_2(Q_1, Y_1) \qquad (2)$$

Following a similar argument, the general functional form of water quality at the point of the river discharge into the sea is given by

$$Q_3 = Q_3(Q_2, Y_2) \qquad (3)$$

The decrease in water quality caused by economic activities in regions 1 and 2 is equal to Q_1 - Q_2 and Q_2 - Q_3, respectively.

W_1 and Q_1 are exogenous[2]. One of the interesting components of the model would be to determine the optimal allocation of water among activities when the total water volume is exogenous. However, our primary interest is in the inter-regional water allocation. Therefore, the allocation of water within region j is assumed to be exogenous and given by the following function[3]:

$W_{ij} = W_{ij}(W_j)$ (4)

where $Ó_i W_{i1} = W_1$ (5)

Water consumption by the ith activity in region 1 is $W_{i1} - w_{i1} = g(W_{i1}, Y_{i1})$, where w_{i1} is the part of the amount of water diverted to activity i but not consumed by it. Consequently, W_1, the flow of water in region 1, and the amount of consumption by economic activities in region 1 determine the flow of water, W_2, which is available to region 2, that is,

$W_2 = W_2(W_1, Y_1)$ (6)

where $W_2 = Ó_i w_{i1} = Ó_i W_{i2}$.

Following a similar argument, the flow of water at the point of the river discharge into the sea is given by the function,

$W_3 = W_3(W_2, Y_2)$

The amounts of water consumed by regions 1 and 2 are given by (W_1-W_2) and (W_2 -W_3) respectively. This implies that there is no quota allocation to region 2.

The water quality that is eventually allocated to activity i in region 2 is specified by the following equation:

$$Q_{i2} = Q_{i2}(Q_2, D_1, D_2) \qquad (7)$$

where, D_1 is the distance of the activity from the point x, D_2 is the distance of point x from the springs of the river, and x is the closest to the economic activity i point of the river.

In the economy described above there is an externality and individual profit maximisation will not support an optimum allocation in equilibrium. Several policies including input controls, output controls, social prices, taxes and subsidies, bilateral water trade, a water market for all water users, and a fixed allocation rule may support a pareto optimum allocation.

Local markets for efficient water quantity and quality allocations

An optimal water quantity and quality allocation is possible if the authorities of both regions agree to establish a market for water in which all users in region 1 receive the prices $P_W(W_2, Q_2)$ and $P_Q(W_2, Q_2)$ for the part of their water diverted to region 2, that is, if water quantity and quality are identified as just another production output of the economy of region 1, so that each one of them faces the following profit maximization problem:

$$\max P_{i1} Y_{i1} - r_{i1} X_{i1} + w_{2i} P_W(W_2, Q_2) + Q_{2i} P_Q(W_2, Q_2)$$

with respect to X_{i1},

subject to (1), (2), (3), (4), (5), (6), (7)

where,

$$P_W\,(W_2\,,\,Q_2) = \sum_{i=1}^{n} P_i 2\,\frac{\partial Y_i 2}{\partial W_i 2} \qquad (8)$$

and

$$P_Q\,(W_2\,,\,Q_2) = \sum_{i=1}^{n} P_i 2\,\frac{\partial Y_i 2}{\partial Q_i 2} \qquad (9)$$

Taking the first order condition of this last optimization problem and substituting (8) and (9) in it, it is seen that the optimality conditions in (9) are satisfied[4]. The allocation specified by the above solution is characterized as environmentally optimal because all relevant environmental aspects can be incorporated in water quality which is explicitly introduced in the model and the analysis.

We saw above that profit incentives lead to the creation of a new market and to the elimination of the water externality. The economic activities (upstream) that can sell reduced water pollution will take into account the true social cost of its polluting actions. Once external costs are perceived as potential foregone revenues, the economic activity internalises them as private opportunity costs. Then, through the market mechanism, the water resource will be allocated efficiently among alternative uses.

Enforceable and well-defined property rights are very important for the success of this policy. If the economic activities of region 1 were not able (and not having the right) to affect several aspects of the water that is diverted to region 2, they would have no incentive to reduce water pollution. Equally important, all economic activities of region 1 that affect any aspect of the water going to region 2 and all economic activities of region 2 that are affected by the aspects of the water must participate in the local market. The latter is equivalent to the existence of exclusivity rights in both regions[5] 1 and 2.

Estimating the structure of a local water market in the Balkans

The Nestos river originates from the Rila mountain of Bulgaria and flows into the Mediterranean through Thrace of Greece. The waters of Nestos are of low quality and suitable mostly for irrigation. Based on the theoretical premisses of the model, it is possible to support an optimum water allocation if we can apply the policy specified above.

Corn and vegetables are irrigated crops and the majority of the communities in the area of Nestos river grow corn and vegetables in their irrigated land. To evaluate[6] $P_W(X_2, Q_2)$ and $P_Q(X_2, Q_2)$ given in equations (8) and (9), we concentrate on the corn and vegetable production in Northern Greece, assume that they exhibit constant returns to scales, and that the demand for land devoted to corn and vegetable production is a Cobb Douglas function of capital, labor, and water, and estimate them using OLS on cross-section data. For the estimation of the demand for land devoted to corn production a sample of 122 communities in the area is used, while for the estimation of the demand for land devoted to vegetable production a sample of 88 communities is used. The results are given in Tables 1 and 2. These estimation results, a \$ 120 per ton price of corn, a \$ 200 price of vegetables, a 1,200 Kgr/stremma yield of corn, and a 2,000 Kgr/stremma yield of vegetables imply that

$P_W(W_2,Q_2) = Ó_i MVPW_i = 0.00031$ USD per m^3, and

$P_Q(W_2,Q_2) = Ó_i MVPW_i = 0.00021$ USD.

An optimal allocation could be obtained if the two sides agree to establish a local market around the borders where the Bulgarian producers would consider water quantity and quality as an output sold by them to greek corn and vegetable producers at the above prices. The optimality of the local market requires that a Bulgarian producer who participates in this local market should faces a water contract which gives him (0.00031 W + 0.00021 Q) USD for W units of Q quality water that he lets go to Greece.

The market is a versatile tool and the above specified solution indicates that the establishment of a water market will support an efficient water quantity and quality allocation. The outcome of this policy will result to rewarding the economic activities in region 1 for providing more and better quality water to region 2 (oe equivalently for not polluting). If the economic activities of region 1 had also the initial assignment of property rights this would be equivalent to paying to pollute.

To many the idea of allowing an industry to pollute for a price (or foregone revenue) is shocking. But this is not indiscriminate pollution, it is pollution reduction by bringing it under market control.

If producers and others are charged a price or loose some revenue to pollute, it will no longer be possible to contaminate the water without "charge". Since water markets do not exist they should be established by a public authority, if we consider water allocation among economic activities of a region, or by an agreement of all regional authorities involved in the water allocation problem. This would provide an effective way to protect the environment, while at the same time ensuring that the economy operates efficiently.

The feasibility of a market solution

The above analysis suggests that the environmental problems traceable to water externalities can be corrected within the framework of a private market system in which transactions take the form of water contracts depending on both water quantity and quality. The profit and loss incentives of economic production activities tend to restore efficiency of water allocation through the establishment of a new market wherever the opportunity of gains to all or some of the participants are present (given that noone is worse off). This process of market extension tends to provide a comprehensive accounting for all economic consequences of interest. The idedntified market solution requires the existence of enforceable property rights to environmental resources and the possibility of contractual agreements between the parties affected by the externality and those responsible for it. These will warantee that the new market will internalise the costs and benefits of the water externality and incduce economic agents to include the consequences of their polluting activities in their rational economic calculations. Moreover, the solution specified by our analysis requires the ability to monitor the water quantity and quality diverted to region 2 from each economic activity of region 1. This should be undertaken by an institutional framework authorised and supervised by all interested parties including the authorities of region 2, since this mechanism will specify the payments to region 1; where the precise payment to each economic activity of region 1 is given by the water contract which requires that (P_X X + P_Q Q) is paied for the (X,Q) water quantity and quality combination. The need for the establishment of such a system in order for the water market to operate, together with the need for exclusivity rights make us believe that in practice this policy is enforceable and feasible only at a local level; a case in which the number of economic activities involved is relatively small.

In addition to the above the total payment to region 1 is equal to the marginal value of water quantity and quality to all economic activities of region 2. This implies that, if the authorities of region 2 decide to have economic activities in their juristiction pay their marginal value of water quantity and quality, a mechanism should be established to monitor the water quantity and quality diverted to each economic activity in region 2, too. This second monitoring mechanism should be authorised and supervised by all interested parties of region 2.

This market solution has great appeal, because it appears to involve no basic changes in the organisation of economic activities in the private sector of the economy. The only task of the regional government would be to extend its traditional role in a market economy by assigning and enforcing property rights to water. Are markets for pollution rights or amenity rights feasible under the realistic conditionss of the present-day world? The fact that such markets have not arisen suggests a negative answer. However, despite the difficulties, the USA Environmental Protection Agency has begun to provide the necessary conditions for such markets to develop for some pollutants. These markets are only in their infancy and must confront many serious problems - information and transaction costs, enforcability, credibility, market boundaries etc. Nevertheless, the contribution of such marketlike methods of reducing water and other kinds of pollution has considerable efficiency advantages over alternative measures available for carrying out environmental policy.

It is also important that the computation of the water contract requires only computation of equations (8) and (9), which needs knowledge of the production processes of only region 2. Consequently, the authority of region 2 can undertake this computation and bring this mechanism to the authorities of region 1 for negotiations and approval. The authority of region 1 is expected then to agree for the establishment of the water market since all economic agents in it will be better off. This coupled with the fact that economic agents of region 2 are neither better off nor worse off from their participation in the water market will probably result in a lump-sum transfer (monetary or other) from region 1 to 2. If the other conditions mentioned above are satisfied, the participants in the local water market may be only one organisation from each region that represents the producers of each region; in this case, the two regions need only to establish a monitoring station at the borders of the two regions that will be supervised by them and each of them has to establish within its juristiction another monitoring system that will identify the water quantity and quality of the water that each economic activity uses (in region 2) or that it lets return to the river (in region 1).

Conclusions

A theoretical model is developed to investigate the possibilities of incorporating aspects of water quality in the amalysis and specify simultaneously an optimal allocation through a market based mechanism. The analysis shows the procedure needed to obtain computationaly these policies and verifies their feasibility at a local level where the number of participants in the market is relatively low. Finally, the available data suitably processed through a standard econometric model provide some first estimates of the market prices that will be able to support an environmentally optimal allocation for sharing the waters of Nestos river in the Balkans between Greece and Bulgaria in equilibrium.

TABLE 1

Factors affecting the demand for land devoted to corn production

VARIABLE	COEFFICIENT	STD ERROR	T-STAT
CONSTANT	3101.8285	12493.606	0.2482733
K	0.0181795	0.1187890	0.1530402
L	0.0043885	0.0965092	0.0454726
W	0.8931758	0.1230391	7,2592845
D_1	-0.1241152	0.0522965	-2.3732962
D_2	-0.4943910	0.3146383	-1.5712994

$R^2 = 66.8$

N = 122

TABLE 2

Factors affecting the demand for land devoted to vegetable production

VARIABLE	COEFFICIENT	STD ERROR	T-STAT
CONSTANT	3102.3975	21620.609	0.1434926
K	0.2613068	0.0689332	3.7907247
L	0.9030617	0.1401138	6.4452034
W	0.3651673	0.1154803	3.1621597
D_1	-0.1032739	0.1275100	-0.8099283
D_2	-0.9641628	0.4872928	-1.9786106

$R^2 = 70.6$

N = 88

APPENDIX

To estimate (8) and (9), we assume that the corn and vegetable production is of the following functional form:

$$Y_{pi2} = \min \{á_{pi2}\, LAND_{pi2},\; â_{pi2}\, R_{pi2}(K_{pi2}, L_{pi2}; X_{i2}, Q_{i2})\}$$

where, p = c, p (c indicating corn and v vegetables), i is an economic activity in region 2 (Greece),

Y_{pi2} = production of p (corn or vegetables) in community i of Greece,

$LAND_{pi2}$ = land devoted to the production of p in the i community of Greece,

K_{pi2} = capital employed in the production of p in the i community of Greece; it contains the total number of agricultural machines in each rural community related to p crops,

L_{pi2} = the agricultural population in community i of Greece.

X_{i2} = the amount of water available to community i of Greece irrigation purposes,

Q_{i2} = the quality of the water that is available to all communities of Greece for irrigation purposes in the area of Nestos of Northern Greece,

$R_{pi2}(K_{pi2}, L_{pi2}; X_{i2}, Q_{i2})$ is a composite input which is a function of K_{pi2}, L_{pi2}, X_{i2}, and Q_{i2}, and

$á_{pi2}$, and $â_{pi2}$ are two parameters that are specific to each community.

To be more specific, within the assumed structure the demand for land is given by the following equation:

$$LAND_{pi2} = â_{pi2}\, R_{pi2}(K_{pi2}, L_{pi2}; X_{i2}, Q_{12})/a_{i2}$$

It is assumed that $\hat{a}_{pi2}/\acute{a}_{pi2}$ is a constant across all communities (not necessarily the same for the two crops) and that $R_{pi2}(K_{pi2}, L_{pi2}; X_{i2}, Q_{i2})$ is of the following functional form:

$$R_{pi2}(K_{pi2}, L_{pi2}; X_{i2}, Q_{i2}) = B\, K_{pi2}^{b}\, L_{pi2}^{c}\, X_{i2}^{d}\, Q_{i2}^{h}$$

where B, b, c, d, and h are parameters.

Assuming that $Q_{i2} = C\, Q_2^{g/h}\, D_1^{e/h}\, D_2^{f/h}$, the latter implies that the demand for land is of the following functional form:

$$LAND_{pi2} = A\, K_{pi2}^{b}\, L_{pi2}^{c}\, X_{i2}^{d}\, D_1^{e}\, D_2^{f}$$

where $A = B\, C\, \hat{a}_{i2}\, Q_2^{g} / \acute{a}_{i2}$, and C, e, f, and g are parameters.

To see if the model makes a significant contribution to explaining the data, the hypothesis that all the coefficients of the demand for land devoted to corn production equation equals zero is tested and rejected at the 1% significance level. A similar test rejects the hypothesis that all the coefficients of demand for land devoted to vegetable production equation equal zero.

The water quality is a latent variable. Without loss of generality we impose the normalisation $Q_2 = 100$ and $g = h = 1$. This and the estimation results let me obtain that the demand for land devoted to corn and vegetable production are respectively given by the following two equations:

$$LAND_{ci2} = 31.02\, K^{0.18}\, L^{0.004}\, W^{0.89}\, Q\, D_1^{-0.12}\, D_2^{-0.49} \qquad (13)$$

$$LAND_{vi2} = 31.02\ K^{0.26}\ L^{0.90}\ W^{0.36}\ Q\ D_1^{-0.10}\ D_2^{-0.96} \quad (14)$$

As seen in Table 1, water quantity and labor are the most important factor affecting corn and vegetables production respectively, something that should be anticipated given the nature of the two crops. Moreover, the output and the demand for land are affected by the distance of the activity from the river and the springs of the river. For the case of corn the distance from the river is more significant while for the case of vegetables the distance from the springs. Our structure and the estimation results imply that the water quality of the water that is eventually allocated to each activity is affected by the river and the springs of the river in the following way:

$Q_{ci2} = Q_2\ D_1^{-0.12}\ D_2^{-0.49}$, and

$Q_{vi2} = Q_2\ D_1^{-0.10}\ D_2^{-0.96}$

The estimation results imply that we cannot reject the hypotheses that the effects of the distance from the river and the springs on the water quality that is eventually delivered to each activity is different for the two kinds of crops[5]. That is we cannot reject any of the null hypothesis that follow: H_0: $e_c = -\ 0.10$, H_0: $f_c = -\ 0.96$, H_0: $e_v = -0.12$, H_0: $f_v = -0.49$.

Since corn and vegetable yields per stremma are constant for each community, we can obtain corn and vegetables production figures by the product of land devoted to each production times the constant yield factor. This implies that the marginal value of water quantity, MVW, and quality, MVQ, of activity i in region 2 are respectively given by the following equations:

$MVW_{ci2} = 27.77\ P_c\ y_c\ \ K^{0.18}\ L^{0.004}\ W^{-0.11}\ Q\ D_1^{-0.12}\ D_2^{-0.49}$

$MVW_{vi2} = 11.17\ P_v\ y_v\ \ K^{0.26}\ L^{0.90}\ W^{-0.64}\ Q\ D_1^{-0.10}\ D_2^{-0.96}$

$MVQ_{ci2} = 31.02\ K^{0.18}\ L^{0.004}\ W^{0.89}\ D_1^{-0.12}\ D_2^{-0.49}$

$MVQ_{vi2} = 31.02\ K^{0.26}\ L^{0.90}\ W^{0.36}\ D_1^{-0.10}\ D_2^{-0.96}$

where, P is the product price, and y the yield.

Given the above we can compute the water quantity and quality prices specified in (8) and (9) and obtain the iptimum water contract that will prevail in the local water market in equilibrium.

References

J.S. Bain, R.E. Caves, J. Margolis, Northern California's Water Industry, Baltimore: The John Hopkins Press, 1966.

Clifford S. Russel, Walter O. Spofford, Jr., "A quantitative framework for residuals management decisions", in A. Kneese and B.T. Bower, eds. Environmental Quality Analysis: Research Studies in the Social Sciences, Baltimore, The John Hopkins Press, 1971.

Dinar, A. and A. Wolf (1994). "International Markets for Water and the Potential for Regional Cooperation: Economic and Political Perspectives in the Western Middle East," *Economic Development and Cultural Change*, **43(1)**: pp. 43-66.

Downs, Kneese, Ogden, Perloff, The Political Economy of Environmental Contro, Institute of Business and Economic Research, University of California, Berkeley, 1972.

Gibbons, R. (1992), *Game Theory for Applied Economists*, New Jersey: Princeton University Press.

Gisser, M. and R.N. Johnson (1983)."Institutional Restrictions on the Tranfer of Water and the Survival of an Agency," in T. L. Anderson and J. Hirshliefer (eds.), *Water Rights: Scarce Resource Allocation, Bureaucracy, and the Environment*, San Francisco: Pacific Research Institute for Public Policy, pp. 137-165.

Gleick, P. (1994), "Water, War, and Peace in the Middle East," *Environment*, **36(3)**: pp. 6-15 & 35-42.

Howe, C. W. and K. W. Easter (1971), *Interbasin Transfers of Water - Economic Issues and Impacts*, Baltimore: The Johns Hopkins University Press.

A. Kneese, B.T. Bower, Managing Water Quality: Economics, Technology, Institutions, Baltimore: The Johns Hopkins Press, 1968.

A. Kneese , R. Ayres, R. d' Arge, Economics and the Environment: A Materials Balance Approach, Washington, D.C.: Resources for the Future, Inc. 1970

E.J. Mishan (1965), "Reflection on recent developments in the concept of external effects", Canadian Journal of Economics and Political Science, February 1965.

E.J. Mishan (1971), "The postwar literature on externalities: an an interpretive essay", Journal of Economic Literature, March 1971.

Oodit, D. and U. E. Simonis (1993), "Water Development: Water Scarcity and Water Pollution and the Resulting Economic, Social, and Technological Interactions," paper FS II 93-405, WZB, Science Center, Reichpietschufer 50, D-100, Berlin.

Rosen, M. D. (1990). " Property Rights and Public Choice in Water Districts: An Application to Water Markets," Ph.D. Dissertation, Department of Agricultural Economics, University of California, Davis.

ENDNOTES

1. For example, see Russel et al (1971) and Kneese et al (1970).

2. These are the water quantiry and quality at the springs, respectively.

3. If the exogeneity assumption is relaxed, our model would run into the danger of producing a second best solution, whereas it will certainly generate a first best solution if the optimal allocation rule is given by equation (4).

4. These are 1) the first order condition of the profit maximisation problem of a firm in region 2, and 2) the following equation:

$$P_i1 \frac{\partial Y_i1}{\partial X_i1} + \sum_{k=1}^{n} [\, P_k2 \frac{\partial Y_k2}{\partial W_k2} \frac{\partial W_k2}{\partial W_2} \frac{\partial W_2}{\partial Y_i1} \frac{\partial Y_i1}{\partial X_i1} + P_k2 \frac{\partial Y_k2}{\partial Q_k2} \frac{\partial Q_k2}{\partial Q_2} \frac{\partial Q_2}{\partial Y_i1} \frac{\partial Y_i1}{\partial X_i1} \,] = r_i1$$

5. In case we consider the problem of allocating water among users within a region, the analysis is still valid but we will have to consider group of economic activities 1 and 2 instead of regions 1 and 2.

6. See Appendix.

7. A relationship which is determined by the characteristics of the location of each activity, too.