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AN OVERVIEW OF THE OPTIONS FOR EFFICIENT WATER ALLOCATION WITHIN AN INTEGRATED EUROPE: THE CASE OF NESTOS RIVER

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ABSTRACT: A model is presented that incorporates both water quantity and quality aspects and a market based system is developed to characterize optimum water allocations between two regions or countries. A methodology is developed to compute the optimum tax or subsidy that could support an optimum water quantity and quality allocation in case that the relevant authorities agreed to impose in the marketplace.

KEYWORDS: Water allocation, Efficient allocations, Nestos river

JEL Classification: D04, D41, D61, D62

Introduction

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 interested 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 scepticism by policy makers at the same time. Economic empirical research supported the practical value and effectiveness of an effluent charge or tax 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 redesigning 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.

An effective water management plan requires accounting for the entire river basin, Abbas (1983). This is very important since worldwide many river basins are under the jurisdiction of several nations; 214 river or lake basins, populated by 40% of the world’s human population and covering more than 50% of the Earth’s land area, are shared by two or more countries, Priscolli (1990) and Biswas (1983). By 1971, 286 international treaties concerning water resources had been negotiated. More than 65% of them concerned river basins in Europe and North America, and most sought coordinated surveys and planning or regulation of navigation, Petersen (1984).

One of the few examples of international efforts to reduce pollutants in an international river basin is a series of treaties concerning the Rhine River, eight countries and a basin covering 225,000 km^2. These international efforts, combined with domestic pollution controls, have produced measurable benefits: since the early 1970s, concentrations of heavy metals have fallen and biological treatment of organic waste has reduced oxygen depletion and fish kills, Kiss (1985) and Holman (1991).

Cooperation among regional and national authorities is necessary to effectively manage watershed pollution, but those located upstream have little incentive to curbe their pollution since they can simply pass the damage on to their downstream neighbours. The situation becomes even more difficult if the upstream polluters can see no benefit from the expense of curbing their pollution.

Even within a nation, where a central planner or authority can provide economic incentives and/or impose regulations to protect downstream economic agents, there are few examples of effective watershed management. Most industrialized nations have applied discharge regulations to industrial polluters and have helped finance municipal sewage systems. Controls on runoff pollution are just emerging, however, and very little has been done to hold upstream polluters, such as farming and logging , which are responsible for downstream loss of water quality, fisheries, and habitat. A watershed «polluter pays» management scheme might involve policy tools such as regulations, penalties, compensation, or tax incentives to discourage upstream pollution.

There are several policies that can be identified to support an optimum allocation, e.g., price policies, tax schemes, quantity policies, establishment of new markets, etc. However, the implementation and enforcement of these policies is an issue (often complicated) that is usually not faced in most studies. Giannias and Lekakis (1997) undertake a characterisation of the available freshwater management efficient policies for the purpose of evaluating policies which are identical in terms of efficiency.

This type of policies are becoming very important today for effectively facing the transboundary freshwater pollution concerning Central and East European Countries (CEECs) and European Union (EU) member States. This is possible today because the lines of communication and cooperation are open and working towards the integration of the whole European economic space. The allocation of the water of the Nestos River between Greece and Bulgaria is a case that can be benefited from the application of this type of policies.

The freshwater supplies of Greece are limited and its year-round supply is unstable due to rainfall distribution patterns, the overwhelmingly rocky structure of its land, uneven regional development, and the international common property identity of some of its surface water bodies.

In the Northern part of Greece there are four large watersheds around the rivers of Nestos (Mesta), Axios, Strymon (Struma), Evros (Maritza), and Aoos. These are shared by Greece, Bulgaria, Yugoslavia, Turkey, and Albania -- countries which are currently undergoing swift socioeconomic changes. Thus, approximately one fourth of Greece's surface waters, which irrigate the cultivated plains of Macedonia and Thrace, originate from international common property water resource systems (OECD 1983). By their very nature these systems are characterized by "free" access to them in both quantitative and qualitative terms, with the countries located near the springs being in a relatively privileged position. Water benefits accrue to the countries in the watersheds and although serious conflicts over the river waters have not occurred as of yet, it is rather inescapable that international co-operation is necessary to resolve conflicts before they even arise.

The Nestos river originates from the Rila mountain within the Bulgarian territory and flows into the Mediterranean through Thrace which is in the 12th water resource region of Greece. In this region 68.6% of the surface water is coming from Turkey and Bulgaria, KEPE (1989, I).

Environmental pollution problems in the region are summarized by Efthimoglou (1988) who states for the Thissavros site crossed by Nestos: "The sole, at the moment, but serious nevertheless, pollution which was found in the area has its sources in Bulgaria. It concerns the state of the water of Nestos, the changes caused by this state on the flora and animals and on the economic activities related to the river, such as fishing in internal and sea water as well as the irrigated areas of cultivation".

In Bulgaria, Behar (1992), there are more than 240 factories and agricultural cooperative units along Nestos, Strymon, and Evros. Only the 20% of them use some kind of waste water treatment technology. Water pollution problems are of main concern for both countries. However, there are no special centers to monitor the water quality of the river and as a result several environmental damages cannot be avoided, since there is no mechanism to identify them and inform both sides properly and in time. For example, in April 1992, a Bulgarian coal factory discharged into Evros 565,000 m^3 of heavily polluted water that poisoned a lot of the fish in the river, since the incident was not monitored in time; Behar (1992).

Thrace is one of the less developed areas in Greece. All indices of regional development for Thrace are relatively low, see KEPE (1989, II). However, it is rich in natural resources and physical attractions, with a good potential for further development which is conditional on the availability of the waters of Nestos river. For example, on August 22, 1995 the Ministry of Agriculture of Greece announced the forthcoming construction of a major irrigation project in the area that will provide 170,000,000 m^3 of water from Nestos river to 400,000 stremmas of agricultural land, even though an agreement for the allocation of the waters of the waters of Nestos has not been reached yet.

To avoid conflicts in the future, the allocation of the Nestos waters, as well as the allocation of the waters of other rivers shared by the two countries, is an issue of main concern for Greece and Bulgaria. However, this issue remains unsolved for the last 20 years, Naftemporiki (1991). In March 1991, the Greek deputy-Minister of Agriculture announced that a agreement should be reached with the Bulgarian side by the end of May 1991, Express (1991, I). The announcement was followed by meetings in Sofia and Athens, Naftemporiki (1991). At the meetings held in Athens, Express (1991,II), the Bulgarian side proposed a 25% of the water for Greece for 20 years, and a renegotiation between the two countries after the 20 years. The Greek side insisted on a 33% for 35 years. No final agreement was reached during that meeting and as far as we know the problem remains unsolved until today. In the following 5 years until recently the two sides agreed that Greece will receive the 29% of the average water flow for the following 35 years. This, however, does not imply that the problem is solved since no practical steps have been announced about how the agreement will be enforced, Express (1996).

The issue of allocating the water between the two countries is very important and it can be seen not only from the recent negotiations between the officials of the two countries but also from Behar (1992), who states that for the 1956-1966 period Greece protested by sending more than 30 diplomatic notes to Bulgaria to complain for the insufficient volume of the water of Nestos and Strymon.

As it concerns the waters of Strymon the Greek and the Bulgarian government agreed recently to cooperate, Express (1995), for protecting the destruction of the ecosystems around the lake Kerkine by the waters of river Strymon that erodes the Bulgarian soil, which is subsequently transfered to Greece in large quantities. The signs of destruction are severe and if the current trends continue it is expected that the Kerkine lake will be destroyed and have Kerkine Falls in its place, and that the waters of Strymon will not be possible to find their way to the sea.

In October 1991, the Greek and the Bulgarian government agreed to cooperate for the settlement of all resource and ecological disputes between the two countries. This agreement declares their "mutual intention to expand the cooperation in this sphere on a long-range basis ... and the particular attention they pay for overcoming any pollution of the Black Sea, the Mediterranean, and the river running through the territories of both countries" (p. 8). In April 1992, the two sides discussed officially issues related to Nestos. Once more the negotiations were unsuccessful since a final agreement was not reached.

The significance of the issue for Greece has resulted in the classification of all relevant information as confidential. Yet, both sides have agreed to exchange information and data to facilitate further negotiations.

The expectations about the benefits of the use of economic instruments in environmental policy are great. There is a widely held belief that environmental objectives in line with goals of sustainable development cannot be attained simply by intensifying the use of traditional direct regulatory approaches such as the collective treatment of waste water, standard-based permit policy etc, Leek and Savornin (1966). Policy makers increasingly show interest in market-based instruments, which at the European Union level, is illustrated by documents of the 5th EC Environmental Action Programme and the Commission's White Paper (CEC, 1992/3; 1993).

Giannias (1996) specifies a market-based policies according to which water users downstream pay to the water polluters located upstream their marginal value of water quantity and quality and to compute it extends the methodology for the estimation of the marginal value of water that is presented in Giannias (1997, I). Using the same analytical framework, Giannias (1996) present the possibilities for a bilateral freshwater allocation concerning the waters of Nestos River in the Balkans. This paper identifies and computes a tax that is able to support an optimum water allocation. Marginal water quantity and quality values are computed following the methodology developed in Giannias (1997, I and II).

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.[1] 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:[2]

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

where $\Sigma_i W_{i1} = W_1$

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[1] Making W_1 and Q_1 endogenous would be equivalent to allocating water to more than two countries, when W_1 and Q_1 would be at the springs.

[2] 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).

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,

$$W_2 = W_2(W_1, Y_1) \tag{6}$$

where $W_2 = \Sigma_i w_{i1} = \Sigma_i W_{i2}$.

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 $(W_1\text{-}W_2)$ and $(W_2 \text{-}W_3)$ 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:

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

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.

The activities of region 1 disregard their effects on either the volume or the quality of water available to region 2, and the typical profit maximizing firm faces the following problem:

$$\max P_{ij}\, Y_{ij} - r_{ij}X_{ij}$$
$$\text{with respect to } X_{ij}$$
$$\text{subject to (1),}$$

where, P_{ij} is the price of product i in region j, and r_{ij} are the prices of the inputs X_{ij} used by economic activity i in region j, and water treated as a free good.

Each firm will employ inputs until:

$$P_{ij} \frac{\partial Y_{ij}}{\partial X_{ij}} = r_{ij} \tag{8}$$

The absence of measures aiming to correct the externality will lead to an inefficient water allocation. Economic theory suggests that the optimal allocation of water between regions 1 and 2 can be achieved only if the joint profits are maximized, that is,

$$\max \Sigma_j \Sigma_i (P_{ij} Y_{ij} - r_{ij} X_{ij})$$

with respect to X_{ij},
subject to (1), (2), (4), (5), (6), (7)

The first order conditions for this problem are:

$$P_i1\frac{\partial Y_i1}{\partial X_i1}+\sum_{k=1}^{n}[\,P_k2\frac{\partial Y_k2}{\partial W_k2}\frac{\partial W_k2}{\partial W_2}\frac{\partial W_2}{\partial Y_i1}\frac{\partial Y_i1}{\partial X_i1}+P_k2\frac{\partial Y_k2}{\partial Q_k2}\frac{\partial Q_k2}{\partial Q_2}\frac{\partial Q_2}{\partial Y_i1}\frac{\partial Y_i1}{\partial X_i1}\,]=r_i1 \tag{9}$$

with respect to the production inputs used in region 1, and

$$P_i2\frac{\partial Y_i2}{\partial X_i2}=r_i2 \tag{10}$$

with respect to the production inputs used in region 2.

The solution to the above problem yields an optimum allocation (Y_{ij}, X_{ij}, W_{ij}, Q_{ij}, W_j, Q_j) for all economic activities in both regions which is obtained as follows.

The solutions for X_{ij}, are derived from equations (10) and (11) after substituting in them: (2) for Q_2, (4) for W_{ij}, (5) and (6) for W_j, (1) for Y_{ij}, and (7) for Q_{ij}.

Given the solutions for X_{ij}, we subsequently obtain:
a) The allocation of Q_{ij} from (7),
b) The allocation of W_{ij}, W_j from (4), (5), and (6), and
c) The allocation of Y_{ij} from (1).

The first order conditions presented in equation (8), and equations (9) and (10) are different, because externalities are present, and, therefore, price taking profit-maximization behavior will not necessarily lead to an efficient allocation of resources.

An optimum tax policy for efficient water quantity and quality allocation

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 offer a Pareto optimum allocation of water if externalities are present.

An optimal water quantity and quality allocation is possible if an optimum tax is imposed in the market of region 1. The optimum tax of the ith activity in country 1 is given by:

$$\sum_{k=1}^{n}\left(P_k 2 \frac{\partial Y_k 2}{\partial W_k 2}\frac{\partial W_k 2}{\partial W_2}\frac{\partial W_2}{\partial Y_i 1} + P_k 2 \frac{\partial Y_k 2}{\partial Q_k 2}\frac{\partial Q_k 2}{\partial Q_2}\frac{\partial Q_2}{\partial Y_i 1}\right) \qquad (11)$$

When this policy is deployed, the typical profit maximizing firm in region 1 employs the X_{ij} combinations that satisfy (8). Substituting (11) into (8) shows that the conditions for optimality in (9) and (10) are satisfied.

The water of Nestos river is of low quality so that it is suitable only for irrigation. Based on the theoretical premises of the model, it is possible to estimate the optimum tax that can support an efficient allocation.
The allocation supported by the above tax policy 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.

Estimating the optimum tax

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 premises of the model, it is possible to support an optimum water allocation if we can apply the policy specified above.

To evaluate the social price given in (11), we concentrate on the corn and vegetable production in a sample of 122 communities in Northern Greece. 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 estimate (11), we assume that the corn and vegetable production is of the following functional form:[3]

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

where, p = c, v (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 community i 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
α_{pi2}, and β_{pi2} are two parameters that are specific to each community.

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[3] The same production function is also used in Giannias and Lekakis (1996). However, they assume that water quality in country 2 is a constant and that water quality and quantity are constraint by the simpler equations: $Q = Q_1 + Q_2$ and $W = W_1 + W_2$, respectively, which are special case of the more general formulation of this paper, where W and Q are two exogenous constants.

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

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

It is assumed that β_{pi2}/α_{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 $A = B\ C\ \beta_{i2}\ Q_2{}^{g}/\alpha_{i2}$, and C, e, f, and g are parameters.

The demand for land devoted to corn and vegetable production, equation (12), is estimated 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.

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:

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

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

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 quality of the water that is eventually allocated to each activity is affected by its distance from 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.[4] 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.

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[4] A relationship which is determined by the characteristics of the location of each activity, too.

Finally, it is assumed that: $W_{i2} = W_2/n$, $Q_{i2} = Q_2/(D_1\ D_2)$, $W_2 = W_1/Y_1$, and $Q_2 = Q_1/Y_1$. These assumptions, the above marginal product value equations, equations (13) and (14), a \$ 120 per ton price of corn, a \$ 200 price of vegetables, a 1,200 Kgr/stremma yield of corn, a 2,000 Kgr/stremma yield of vegetables, and equation (11) imply that the social price of the product produced on the Bulgarian side of the Greek-Bulgarian borders around Nestos river will be 0.00027 USD less than its market price, that is,

$$\sum_{k=1}^{n}\left(P_k2\, \frac{\partial Y_k2}{\partial W_k2}\, \frac{\partial W_k2}{\partial W_2}\, \frac{\partial W_2}{\partial Y_i1} + P_k2\, \frac{\partial Y_k2}{\partial Q_k2}\, \frac{\partial Q_k2}{\partial Q_2}\, \frac{\partial Q_2}{\partial Y_i1}\right) = -\ 0.00027USD$$

The latter implies that the optimum tax that should be imposed in region 1 must be equal to 0.00027 USD per unit of product.[5] If the two sides agree upon such a tax scheme an optimum water quantity and quality allocation will be supported.

Conclusions

A theoretical model is developed to investigate the possibilities of incorporating aspects of water quality in the analysis and specify simultaneously an optimal allocation through a regulatory mechanism that imposes a tax on the product produced in region 1. The analysis shows the procedure needed to obtain computationally this policy. Finally, the available data suitably processed through a standard econometric model provide some first estimates of the tax that will be able to support an optimal allocation in equilibrium.

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[5] This price is less than the 0.032 USD price that was estimated in Giannias and Lekakis (1996) who estimated a simpler model using the same data on only one crop (corn) and not taking into consideration any water quality variation in their empirical work.

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

$R^2 = 70.6$

$N = 88$

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