המרכז למחקר בכלכלה חקלאית
THE CENTER FOR AGRICULTURAL ECONOMIC RESEARCH

Working Paper No. 9601

# Allocation and Pricing of Water at the Regional Level

by

Brill Eyal, Eithan Hochman
and David Zilberman



Rehovot, Israel, P.O.B. 12 רחובות, ת.ד. 12

Working Paper No. 9601

# Allocation and Pricing of Water at the Regional Level

by
Brill Eyal, Eithan Hochman
and David Zilberman



THE CENTER FOR AGRICULTURAL ECONOMIC RESEARCH
P.O. Box 12, Rehovot

# Allocation and Pricing at The Water District Level.

by

Eyal Brill *
Eithan Hochman **
David Zilberman ***

**December 1995**

* Ph.D. Student, Hebrew University, Department of Agricultural Economics and Management.
** Professor, Hebrew University, Department of Agricultural Economics and Management.
*** Professor, UC Berkeley, Department of Agricultural and Resource Economics.

The authors would like to thank P. Zusman, I Finkelstain, O. Hochman, A. Dinar and M. Gisser for their helpful remarks. Supported by BARD Project US-2081-91

**1. Introduction.**

Growing urban and environmental demands for water together with severe financial and political constraints on the development of new water supply sources, exert considerable pressure on the existing arrangements for the distribution and the use of water in agriculture.

In many countries, regional non profit organizations (such as water users cooperatives and semi government agencies) are responsible for obtaining and delivering water to farmers. Water pricing in many of these organizations is based on average cost pricing and is likely to lead to economic inefficiency. The costs associated with this inefficiency are likely to increase as water availability declines. Block rate pricing [Wichelns (1991a), (1991b)] and various water marketing schemes [Howe (1986)] have been important components of proposals for water reform.

This paper initially presents a framework to analyze responses of water districts (stylized regional non profit water organizations) to water supply reduction. These responses are (i) to preserve average cost pricing with administrative cut of quotas; (ii) to switch to blocked rate pricing and (iii) to reform and introduce a relative transferable water rights regime.

The main obstacle in achieving an efficient allocation of water within such an organization is the asymmetry between the information regarding the aggregate available water known to the central decision maker as opposed to knowledge at farm level which individual farmers tend not to reveal, e.g. the efficient amount of water required for each crop (see Zusman 1991). The analysis shows that reform based on relative transferable water rights may lead to welfare improvement with minimal information required, despite the reduction in overall water use. It also shows that tiered pricing does not necessarily lead to an efficient outcome. The properties of results under these three responses are compared, using a numerical example based on data from Israel.

Some of the literature on water pricing [Quirk and Burness (1979), Gisser (1980, 1983), Howe (1986) and Zilberman and Shah (1994)], recognized the sub optimality of a traditional water rights system and recommended transition to a market-like allocation of water, although their analysis did not recognize the non profit nature of water districts. The water pricing policies considered in this paper are subject to the balanced budget constraint of the water districts. Furthermore, it is assumed that the water use level prior to the water supply reduction, established water rights which must be considered in water allocation design after supply cuts. Historical usage patterns are of crucial importance in allocating water with the prior appropriation, and other water rights systems. We expanded Zusman's (1988) model of cooperative behavior to obtain optimal water pricing and the distribution formula, taking previous water use levels into account. This formulation also allows us to explicitly incorporate heterogeneity among farmers in the analysis.

It is shown that if information is perfect and trading is costless, a Hicksian barter market, in which users trade in their "initial endowments" as given to them by the management according to their historical rights, results in pareto efficiency. When trading is not costless and information is not perfect, a different exchange mechanism is suggested to achieve pareto efficiency. It is also shown that under realistic assumption, tiered pricing results in a second best allocation. Finally, an empirical example is used to demonstrate the theoretical framework.

## 2. Modeling of the Existing and Optimal System.

Let us assume that a regional water district consists of N water irrigation users. The supply of water is generated from two origins: local underground water from wells within the area and surface water imported from outside. The aggregate quantity of water used by the region is regulated by the State as follows: The volume of local underground water used is fixed, while water from outside the region can be purchased from other districts in such quantities as required, at a given price which is higher than the cost of generating local water. It is assumed that water from both sources are of the same quality.

Thus, the region faces an increasing water supply function (depicted as Mc in Figure 1), and average costs of generating water to the region (depicted as Ac in Figure 1).

Let $f^n(q_n)$ be the n$^{th}$ individual benefit from water use, measured by the dollar value obtained by application of q units of water. This benefit function may represent gross revenue, if water is the only scarce input, or revenue net of fixed input, assuming that water is the only scarce variable input. The function $f^n(q_n)$ is well behaved with $f_q^n(q) > 0, f_{qq}^n(q) < 0$. Note that the water demand function of the n$^{th}$ individual is given by $f_q^n(q)$.

The aggregate demand curve for water consists of the horizontal summation of the N individual water demand curves (see D in figure 1). For each given price, the aggregate quantities is the sum of the quantities demanded by the individuals.

**Figure 1**

*Allocation under the traditional system.*

Under the initial system, it is assumed that the water district sets a price for water that will both satisfy users' demands and balance the water district budget. The equilibrium conditions in this case are

a) $f_q(q_n^0) = w_0$ for n=1,2,.......N.

b) $w_0 = AC(Q_0)$.

where $w_0$ is the initial price of water, $q_n^0$ is the quantity of water used by the n$^{th}$ user under the initial system and $Q_0 = \sum_{n=1}^{N} q_n^0$ is the aggregate water use under the initial system. Equation (a) states that water use for the n$^{th}$ individual is where the marginal benefit from water (inverse demand) is equal to the water price. Equation (b) states that under the initial system, average cost pricing is used for the price of water. It is almost trivial to say that such a policy results in inefficient resource allocation, i.e. the quantity $Q_0$ is greater than the optimal quantity $Q_c$.

*Allocation Under The Optimal System.*

Suppose that the water district has central management which aims at developing an optimal pricing policy with the following characteristics:

a. Efficient water allocation.

b. Balanced budget.

c. Individual rationality.

d. Equity - rent distribution in proportion to historical water use.

e. Simplicity.

Properties a-c are identified as necessary to obtain efficient and sustainable economic policy design (Fundenberg and Tirol 1993). Studies of water allocation design suggest that historical rights must be recognized in the introduction of water reforms to make such reforms more equitable and thus politically acceptable (Colby 1991). Simplicity is essential for successful application.

An efficient resource allocation of water in the region is obtained by maximizing the aggregate welfare function of the water users in the region.

$$\underset{q_1,\ldots,q_n}{Max} \quad \sum_{n=1}^{N} f^n(q_n) - C(Q) \tag{1}$$

were $Q = \sum_{i=1}^{n} q_n$.

The necessary conditions which ensure the maximization in (1) consist of the n equations,

$$f_q^n(q_n) = Mc(Q) \qquad \forall n. \tag{2}$$

These equations imply that each user equates his value of the marginal product of water to the marginal costs of generating Q units of water.

Let $h(q_n, q_n^h)$ denote the payment function, i.e. the rule which determines the amount of payments by each water user where $q_n$ is the actual use of water, $q_n^h$ is the historical water use rights. At the micro level each user maximizes his water quasi-rent,

$$\underset{q_n}{\text{Max}} \quad f^n(q_n) - h(q_n, q_n^h) \qquad \forall n. \tag{3}$$

The necessary conditions for solving the individual user's optimization problem imply that each user equates the value of the marginal product of water to the marginal payment charged for the use of his water,

$$f_q^n(q_n) = h_q \qquad \forall n. \tag{4}$$

Individual rationality means that the micro level allocation rule is consistent with the optimization at the aggregate level, thus from (3) and (4) obtain

$$Mc(Q) = h_q \qquad \forall n \tag{5}$$

which implies marginal pricing.

Now, for simplicity, assume that the function has a linear form and depends on the actual use of water and the historical rights. Thus,

$$h(q_n, q_n^h) = Aq_n + Bq_n^h \qquad \forall n. \tag{6}$$

The zero profits constraint implies that the sum of payments of the N users equals the total costs of generating Q units of water, .i.e.,

$$\sum_{n=1}^{N}[h(q_n, q_n^h)] = C(Q). \tag{7}$$

Introducing (6) into (7), and using (5), B results in,

$$B = \frac{C(Q) - Mc\,(Q)Q}{Q^h} = [AC\,(Q) - MC\,(Q)]\frac{Q}{Q^h}. \tag{8}$$

where $Q^h = \sum_{i=1}^{N} q_n^h$ and AC(Q) are the average costs. Since average costs are less than marginal costs (C'>0), B is negative, and thus under the optimal pricing mechanism water users are paid for their historical water use rights. The per unit rent of historical water use rights is -B.

Rewriting equation (6),

$$h(q_n, q_n^h) = Mc\,(Q)q_n + [\frac{C(Q) - Mc\,(Q)Q}{Q^h}]q_n^h \tag{9}$$

The payment function (9) depicts the two goals of the optimal policy: The first, efficient water allocation, i.e. each user pays the marginal costs of water for the actual quantity used by him, and the second, water rent distribution in proportion to the historical water use rights.

The pricing rule (9) can be written differently. Let $s_n = \frac{q_n^h}{Q^h}$ be the share of the n[th] individual in the historical rights and $q_n^r = s_n Q$ his adjusted water rights. Thus, the allocation rule can be presented as:

$$h(q_n, q_n^h) = Mc\,(Q)[q_n - q_n^r] + Ac\,(Q)q_n^r. \tag{10}$$

According to equation (10) the individual pays average costs for his adjusted rights and when $q_n > q_n^r$ also pays the marginal costs for the difference between actual use and adjusted rights. When $q_n < q_n^r$ he receives this difference. Several payment mechanisms can be based on equations (9) and (10).

## 3. Alternative Institutional Setups.

The optimal mechanism can be applied through two different institutional setups. In both cases, it is assumed, as in several other studies, that the policy maker knows the aggregate demand and supply, but not the individual demands.

The first setup, can be referred to as the "active trading" case. Time is assumed to be divided into discreet intervals, each one of which has a fixed length (e.g. a year or season). At the beginning of each time period, the policy maker determines the optimal aggregate quantity $Q_e$ at the intersection of the aggregate demand and supply (see Fig 1) and allocates individual annual rights in proportion to the historical rights $q_n^r = s_n Q_e$. Each individual user pays for each unit of his "initial endowment" of water rights the price of $AC(Q_e)$, i.e., the average costs of generating the aggregate quantity $Q_e$. This ensures a balanced budget. Individuals are allowed to trade their water rights. Assuming a perfect competitive market with costless trading, the market will determine the equilibrium price $w_e$ (see Fig 1). At this price each water user may have an excess demand (supply) according to whether the sign of $f_q^n(q_n^r) - w_e$ is positive (negative).

Assuming also, that trading is conducted at a given place and time, the price of $w_e$ will clear the market with a rent per unit of water rights which equals $w_e$-$AC(Q_e)$.

Note that such a market, which follows the description of a barter market as described by Hicks in "Value and Capital" (1937), results in characteristics of the optimal system as described in section 2.

The second setup can be referred to as the "passive trading" case. At the beginning of each time period, the policy maker determines and announces the optimal price, $w_e$, at the intersection of the aggregate demand and supply (see Fig 1). Each individual applies the amount of water, $q_n^e$ according to his individual demand at $w_e$. The summation of all the quantities, $q_n^e$, used during the time period, will result in an aggregate quantity $Q_e$. At the end of the time period the decision maker calculates the imputed price of a unit of water rights that equals $r=w_e-AC(Q_e)$. The policy maker also calculates the periodical individual water right as $s_n^r Q_e$. For each period the individual will be entitled to receive $s_n^r Q_e r$. Thus , the total water expenditure of the $n^{th}$ individual will be

$$q_n^r AC(Q_e) + r(q_n^e - q_n^r). \qquad (11).$$

Note that *ex-post* (at the end of the period) a water user is a "buyer" ("seller") of water according to whether the sign of $(q_n^e-q_n^r)$ is positive (negative), and he pays (receives) the amount $r(q_n^e-q_n^r)$. Thus, the "passive" market mechanism has the characteristic whereby the participant buyer (seller) does not have to pursue a matching seller (buyer).

In the second institutional setup, a unique market place is not needed. Each user determines his water use at the price determined by the central management. In both cases the distribution of the water use rights is predetermined according to historical shares [e.g., riparian rights along a river, see Anderson (1984)]. However, in the first setup, the periodical water rights result from the policy maker's *ex-ante* estimation of $Q_e$, while in the second setup, the periodical water rights result from the *ex-post* summation of the quantities used by the individual water users at a unique price, $w_e$, as announced by the policy maker.

Water markets exist in some cases, e.g., the water law in New Mexico allows trading in consumptive use of surface water rights. However, in other cases, the institutional water trading is absent. Therefore in such cases, there is a need for the construction of new trading channels, legislative framework and detailed registration of the bilateral transactions. Hence, active trading requires higher transaction costs than passive trading.

**Effects of income distribution.**

The following discussion deals with an analysis of the effects of income distribution resulting from the implementation of policy reform. Let the first (current) policy be indexed by 0, and the second policy (post reform) be indexed by 1. Thus, under the traditional policy, the aggregate quantity of water used is $Q_0$, and its price equal to $AC_0$. The reform results in an increase of the price of water from $AC_0$ to $w_e$. As a result, the aggregate quantity and the average costs decreas respectivaly to $Q_1$ and $AC_1$. Also, given the historical shares, each of the n individual water use rights decreases from $q_{n0}^r$ to $q_{n1}^r$.

**Figure 2**

Figure 2 illustrates the effects of income distribution in the case of two individual users. The demand curves of users *i* and *j* are denoted respectively as $f_q^i$ and $f_q^j$ where user *i* is more efficient. Obviously, no one would be adversely affected by the reform if the following holds,

$$(w_e-AC_0)q_{n0}^r=(w_e-AC_1)q_{n1}^r. \tag{12}$$

A necessary condition for (12) is that the arc elasticity of the AC curve is equal to 1. (which also implies that the elasticity of the cost curve equals 2) [(1)].

The income impact on each of the two individuals, depends on whether or not condition (12) holds.

---

[1] Note that the average cost elasticity equals to $\frac{\partial AC}{\partial Q}\frac{Q}{AC}=\frac{MC}{AC}-1=\lambda-1$ where λ is the cost elasticity.

(I). If it does, it can be verified from figure 2 that user *j* benefits more than user *i* from the reform.

Proof: a. The case of equal historical shares of *i* and *j*.

Given that the elasticity of the AC curve equals 1, the area of the rectangular *fghd* (which measures the increase in water rent resulting from the reform for each of both users) equals the area *cdak*. Since the area *aed*<than area *abcd*<the area *cdak*, both users benefit from the reform, but user j benefits more than *i*.

b. The case of unequal historical shares of *i* and *j*.

In this case user *j* benefits from the reform <u>relatively</u> more than *i*. It can be easily verified by normalizing the water use rights of both users to 1 and using the procedure as in a.

*(II)* If, however, condition (12) does not hold and the elasticity of the AC curve is smaller, some of the users are worse off as a result of the reform. The relative reduction in the regional water rent can be measured by $\alpha = r_1 Q_1 / r_0 Q_0 < 1$. The smaller the elasticity of the AC, i.e., the lower the value of $\alpha$ will be, the larger the number of users that are disadvantaged. An application based on data collected from a region in Israel (see section 5) demonstrates the potential resistance against the reform for various levels of $\alpha$.

## 4. An alternative pricing policy- tiered prices.

Block pricing, a common pricing method in the electricity and gas utilities, was introduced recently as tiered pricing in some water districts in Israel and California. This pricing mechanism[2] consists of a two step payment function as follows,

$$h(q,q^r) = \begin{cases} w(q-\gamma q^r)+\delta w\gamma q^r & if[q(w)\geq \gamma q^r] \\ \delta wq & if[q(w)<\gamma q^r] \end{cases} \tag{13}$$

where $q_n^r$,w,$\gamma$ and $\delta$ determined by the water district management. The first two parameters, $q_n^r$ and w respectively measure: the assigned water quota of the n[th] individual user and the price of water, and the two last are parameters between 0 to 1.

This payment function is linear in q in two segments with a kink at $\gamma q_n^r$. The individual user pays a reduced price, $\delta$w, for the first $\gamma$ percent of his water quota $q_n^r$, and full price, w, for the additional applied water, $(q_n-\gamma q_n^r)$ [3]. This payment function should be compared to the payment function described by equation (9), which is linear over the whole range of $q_n$.

Note that at the individual user level, rational behavior for a given values of $q_n^r$,w,$\gamma$ and $\delta$ may lead to inefficient allocation of water. This can be verified by applying the individual optimization conditions (see equations (4) and (5)) to the case of the tiered pricing, deriving three types of behavior by the individual users:

| | | |
|---|---|---|
| Type j : $f_q^j(\gamma q_j^r) < Mc(Q)$. | where $q_j^e<\gamma q_j^r$ | (14a) |
| Type k : $f_g^k(\gamma q_k^r) \geq Mc(Q) \geq f_g^k(q_k^r)$ | where $\gamma q_k^r<q_k^e<q_k^r$ | (14b) |
| Type i : $f_q^i(q_i^r) > Mc(Q)$. | where $q_i^r<q_i^e$ | (14c) |

[2] The implementation of tiered pricing may be much more complex. Here we use a simple general form. Most of the results obtained here are preserved for other forms of tiered pricing.
[3] The payment function may include a third segment where water use in excess of the water quota $q_n^r$ will be charge an extra fine.

where $q_j^e, q_k^e, q_i^e$ are the optimal quantities used by each type of individual user. Figure 3 depicts three representative members of the corresponding

**Figure 3**

behavioristic groups. While the individual users in groups of type k and i apply their water efficiently, i.e., $f_q^k(q_k^e)=Mc(Q_e)$ and $f_q^i(q_i^e)=Mc(Q_e)$, those in group type j apply their water inefficiently, i.e., $f_q^j(q_j^t)=\delta Mc(Q_e)$. Thus, the inefficient allocation of water by the representative member of type j in Figure 3 results in a waste of $(q_j^t-q_j^e)$ and a welfare loss measured by the triangle *abc*. In general the corresponding losses of water and welfare by the users of type j group can be calculated from

$$\sum_{j=1}^{J}(q_j^t - q_j^e) \tag{15a}$$

and

$$\sum_{j=1}^{J}\int_{q_j^e}^{q_j}[f_q^j(q) - MC]dq . \tag{15b}$$

As was characterized in section 2, the regional water district management follows the efficiency rule w=Mc which determines the efficient aggregate quantity $Q_e$, subject to the balanced budget constraint. The water quotas $q_n^r$ of each of the individual users are determined exogenously by the management relatively to the historical water rights subject to

$$Q_e = \sum_{n=1}^{N} q_n^r . \tag{16}$$

The choice of the parameters is subject to the balanced budget constraint in (7), i.e., $0 \le \delta \le \frac{AC(Qe)}{MC(Qe)}$ and $[1-\frac{AC(Qe)}{MC(Qe)}] \le \gamma \le 1$.

Maximum reduction of inefficient use of water by type j users can be achieved by choosing either (a) δ=0 and $\gamma = [1-\frac{AC\,(Qe)}{MC\,(Qe)}]$ and/or (b) allowing trading in water rights. Note that the effectiveness of condition (a) is reduced as the heterogeneity of water requirements among crops[4] and among users is increased. In the case of water trading, efficient allocation implies

$$\sum_{j=1}^{J}(\gamma q_j^r - q_j^e) = \sum_{i=1}^{I}(q_i^e - q_i^r) \tag{17}$$

The quantities scheduled for sale by type j individuals must equal the quantities scheduled for purchase by type i individuals. Note that for the type k users the following inequality holds

$$\sum_{k=1}^{K} q_k^r > \sum_{k=1}^{K} q_k^e . \tag{18}$$

Therefore, by using (17) and (18), it can be verified that

$$\sum_{n=1}^{N} q_n^r > \sum_{n=1}^{N} q_n^e . \tag{19}$$

which contradicts (16). Note that information on the distribution of type j,k and i is needed for complete efficient allocation given the constraint in (19). Thus, more information is needed for efficient implementation of tiered pricing then the information needed for the implementation of a market mechanism.

---

[4] This can be verified by examining the table in appendix A.

## 5. An application.

Empirical data collected from a region in Israel (Hasharon region) is used for an application of the transferable rights mechanism presented in sections 2-4. The table in appendix A contains data for forty major crops in the region, for the year 1991. Each row in the table depicts the data for one crop. The crops are listed in descending order according to the average rent per $m^3$ of water, based on data made available by the Israeli Ministry of Agriculture.

The farmers in the Hasharon region are organized as a water cooperative. Of a total consumption of 65 million $m^3$ per year, approximately 30 million are generated by wells within the region. The average costs of pumping a cubic meter of water from a local well is 0.43 NIS. Surface water is imported from outside the region via the national aqueduct at the price of 0.65 NIS per cubic meter of water.

The quasi-rent which results from the application of one $m^3$ water to a given crop are the profits derived by deducting the average costs from the average revenue of a given crop. The obtained quasi-rent is multiplied by the total amount of water applied to the crop, and is registered in column 6 of the Table. The welfare generated by the current policy (33,894 thousand NIS in Table 1), is obtained by summing up the crops in column 6 in appendix A.

In the following analysis we assume a fixed water-land ratio for each individual crop. We examine simulations of three policies aimed at achieving the optimal use of 31,000 thousand $m^3$ of water: administrative reduction of the water quotas, the implementation of the quasi-market mechanism and a tiered pricing policy.

**Administrative cut of the water quotas:** The allocation of water in the region (31,562 thousands $m^3$) is obtained through administrative allocation of the water quotas. In order to achieve this goal, the amount of water for each of the crops is reduced by a fixed proportion. This yields a total irrigated area of

47,691 dunams and a total welfare of 19,877 thousand of NIS (see policy 1 in Table 1).

**The implementation of tiered pricing policy:** Let us assume that as a result of the implementation of a tiered pricing policy all crops with a value of marginal product less then 0.65 NIS, will reduce the amount of water by 20 percent. In terms of the table in appendix A all crops listed below row 31 reduce water usage by 20 percent. The total amount of water used under this scenario will be 58,219 thousands $m^3$ and the total welfare will be 37,538 thousand of NIS. If the reduction of water usage among low value crops will be 30% the total amount of water usage will be 54,887 thousands $m^3$ and the total welfare will be 39,360 thousand of NIS. Although the tiered pricing policy doubles the aggregate welfare as compared to the initial allocation, it still remains considerably below the first best allocation achieved by policy 3. Note also that the inefficiency in the allocation of water under policy 2 results in a waste of 26 million cubic meter and a low profit rate of 0.64 NIS per cubic meters compared to the optimal profit rate of 1.65 NIS in policy 3.

**The implementation of a market mechanism.**

An efficient allocation, using the proposed reform, results in a demand for a quantity of 31,562 thousand $m^3$ of water at a price of 0.65 NIS. The total irrigated area of 48,119 dunams yields a total welfare of 52,116 thousand NIS.

Each unused cubic meter of water use right is compensated by 0.21 NIS, while the price of a cubic meter used within the water use right is 0.44 NIS. Thus, the reservation price of each applied cubic meter within the water use rights is equal to 0.65 NIS, which is also the efficient price.

Policy 3 results in pareto optimal allocation and it is superior to the other two policies. It yields highest aggregate profits water and land rents and it results in the lowest aggregate quantity of water demanded and used. Therefore, it is plausible that policy 3 generates the least resistance.

**Table 1: Different policies of water allocation.**

| | | Current situation | Policy 1: Administrative Quotas | Policy 2: Tiered prices. | Policy 3: market mechanism |
|---|---|---|---|---|---|
| Total water used | (1000*m$^3$) | 64,884 | 31,562 | 58,219 | 31,562 |
| Irrigated area | (dunam) | 98,040 | 47,691 | 88,056 | 48,119 |
| Welfare | (1000*NIS) | 33,893 | 19,877 | 37,538 | 52,116 |
| Profit / m$^3$ | (NIS) | 0.52 | 0.62 | 0.64 | 1.65 |
| Average costs | (NIS) | 0.55 | 0.44 | 0.54 | 0.44 |

However, this is not always the case. It is possible that hydrological constraints enforce reduced usage of the local aquifer water. In this case, the reduction in the water rents endangers the feasibility of trading in water use rights, i.e. some of the farmers will be worse off under policy 3 (see section 3 above). We assume that the resistance to policy 3 is correlated to the relative decrease of the farmers' income, i.e. $\alpha = {r_1 Q_1}/{r_0 Q_0} < 1$.

Table 2 depicts the percentage of crop area, whose income is reduced by more than a certain value for a given reduction of water rents. To illustrate, for a share of 4.33 percent of the crop area, a reduction of 20 percent in the water rents ($\alpha = 0.8$), will result in a reduction of more than 5 percent of the income.

**Table 2: Percentage of crop area which violates the feasibility condition, under several scenarios.**

| | Critical values | | | |
|---|---|---|---|---|
| Reduction in rents | **1%** | **5%** | **10%** | **20%** |
| $\alpha$=0.9 | 21.7% | 1.76% | 0% | 0% |
| $\alpha$=0.8 | 29.13% | 4.33% | 1.76% | |
| $\alpha$=0.7 | 46.38% | 7.64% | 4.33% | 0.17% |
| $\alpha$=0.6 | 47.83% | 20.83% | 4.37% | 2.65% |

A detailed description of the calculations that led to table 2 appears in appendix B.

## 6. Concluding remarks.

This paper deals with the problem of water allocation and pricing at the regional level which is characterized by common property ownership of the water and a given distribution of water use rights. Such an institutional setup often results in administratively inefficient pricing and allocation systems.

Economists suggest water markets as a possible remedy, but in the absence of well defined property rights and high transaction costs, this solution could result in a market failure. According to Coase (1992) "if the costs of making an exchange are greater than the gains which that exchange would bring, that exchange would not take place, and the greater production that would flow from specialization would not be realized". The “passive” mechanism designed in this paper enables a trade of water use rights with low transaction costs. The quasi-market mechanism enables an efficient allocation with minimal losses by the farmers and therefore minimal resistance by them. This is made possible by increasing the welfare resulting from the use of water. The greater the “pie” the easier it is to redistribute it between the farmers. In the long run the increased “pie“ enables the diversion to higher value products and water saving technologies.

Water institutions and their laws in many states, e.g. Israel and California, do not allow trading in water use rights. Tiered prices have recently been suggested as an efficient pricing method. It is shown in this paper that under reasonable assumption tiered prices lead to a “second best” solution. The implementation of the above trade mechanism results in an efficient pareto allocation and does not require new water legislation. The designed mechanism can be useful in other price pooling systems, such as in the case of production and marketing boards. Set aside programs are often suggested as a policy tool, but they face difficulties of implementation. The present paper attempts to remove some of these obstacles.

# Appendixes.

**A. Individual crops budget data - Hasharon region 1992.**
**Column definition.**

(1) Average rent per $m^3$ ( NIS )
(2) Total cultivated land for each crop (Dunams).
(3) Applied water for 1 dunam of crop. ( $m^3$)
(4) Total applied water for each crop. ($m^3$ x 1000 ), [(2)x(3)]
(5) Accumulated water for the region. ($m^3$ x 1000 )
(6) Income per crop. (NIS x 1000 ), [(1)x(4) - water costs]

| Crop* | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Wax flower | 4.90 | 920 | 600 | 552 | 552 | 2,392 |
| Roses | 4.41 | 920 | 1,000 | 920 | 1,472 | 3,536 |
| "Almog" Peaches | 3.31 | 89 | 400 | 36 | 1,508 | 98 |
| Potatos | 2.99 | 17,130 | 630 | 10,792 | 12,300 | 26,154 |
| "Grand" Apple | 2.98 | 121 | 750 | 91 | 12,390 | 219 |
| Miniature Mango | 2.82 | 228 | 600 | 137 | 12,527 | 308 |
| Mango | 2.60 | 228 | 600 | 137 | 12,664 | 278 |
| Ruscus | 2.56 | 920 | 900 | 828 | 13,492 | 1,651 |
| "Bebkock" Peaches | 2.14 | 89 | 500 | 45 | 13,536 | 70 |
| "Delicious" Apple | 2.13 | 121 | 750 | 91 | 13,627 | 142 |
| Carnation | 1.83 | 920 | 1,600 | 1,472 | 15,099 | 1,860 |
| Ground Nuts | 1.80 | 1,001 | 400 | 400 | 15,500 | 494 |
| Gypsophila | 1.77 | 920 | 965 | 888 | 16,387 | 1,068 |
| Sumflower (Type A) | 1.67 | 406 | 150 | 61 | 16,448 | 67 |
| "Rid" Avocado | 1.63 | 1,476 | 700 | 1,033 | 17,481 | 1,099 |
| Orange | 1.52 | 121 | 750 | 91 | 17,572 | 87 |
| "Hof" Ground Nuts | 1.44 | 1,000 | 500 | 500 | 18,072 | 437 |
| Easy Peeling Citrus | 1.35 | 9,253 | 750 | 6,940 | 25,012 | 5,437 |
| "Swilling" Peaches | 1.31 | 89 | 500 | 45 | 25,056 | 33 |
| "Armoza" Peaches | 1.30 | 89 | 550 | 49 | 25,105 | 36 |
| Persimmons | 1.29 | 1,781 | 650 | 1,158 | 26,263 | 838 |
| Sunflowers (Type B) | 1.23 | 405 | 100 | 41 | 26,304 | 27 |
| Seed Tomatos | 1.23 | 861 | 350 | 301 | 26,605 | 200 |
| "Hus" Avocado | 1.09 | 1,476 | 700 | 1,033 | 27,638 | 541 |
| Chickpea (Garbonzo beans) | 1.07 | 672 | 120 | 81 | 27,719 | 41 |
| "Horshim" Avocado | 0.96 | 1,476 | 700 | 1,033 | 28,752 | 407 |
| "Etinger" Avocado | 0.85 | 1,476 | 700 | 1,033 | 29,785 | 293 |
| Bulgarian Chickpeas | 0.81 | 672 | 120 | 81 | 29,866 | 20 |
| Corn | 0.80 | 1,111 | 500 | 556 | 30,421 | 130 |
| "Nevel" Avocado | 0.74 | 1,476 | 700 | 1,033 | 31,454 | 179 |
| "Port" Chickpea | 0.68 | 672 | 160 | 108 | 31,562 | 12 |
| Seedlings Tomato | 0.62 | 71 | 350 | 25 | 31,587 | 1 |
| Pecan Nuts | 0.60 | 2,124 | 750 | 1,593 | 33,180 | 53 |
| Sorghum | 0.51 | 672 | 100 | 67 | 33,247 | -4 |
| "Pima" Cotton | 0.40 | 1,042 | 520 | 542 | 33,789 | -90 |
| Irrigated Cotton | 0.39 | 1,042 | 400 | 417 | 34,206 | -74 |
| "Jonathan" Apples | 0.38 | 121 | 750 | 91 | 34,296 | -17 |

| | | | | | | |
|---|---|---|---|---|---|---|
| "Akkala" Cotton | 0.35 | 1,042 | 480 | 500 | 34,797 | -108 |
| "Fuerte" Avocado | 0.33 | 1,476 | 700 | 1,033 | 35,830 | -244 |
| Spanish Chickpeas | 0.26 | 672 | 200 | 134 | 35,964 | -41 |
| Wheat | 0.23 | 504 | 220 | 111 | 36,075 | -37 |
| "Shamouti" Oranges | 0.05 | 41,155 | 700 | 28,809 | 64,884 | -14,880 |

## B. The derivation of the results in table 2 using data in appendix A.

To demonstrate the use of the data in appendix A in deriving the results in table 2, consider the case of $\alpha$=0.8 ( second row in table 2). Let us start with crop 1 in appendix A: Water rent per cubic meter is 4.9 NIS. Policy 0 results in a profit per crop of 2.4 million NIS. This number is derived by using AC=0.55 NIS, deducting it from the water rent (4.90), and multiplying by the amount of water used by the crop (552 thousand of cubic meter), i.e. [( 4.90 - 0.55) x 552=2401 thousand NIS].

The transition to policy 1, will result in the same profits, 2.402 million NIS, if $\alpha$=1. These profits are obtained from two sources: the first, from (4.90 - 0.43) x 268.51 = 1200.25 thousand NIS, and the second, from the water use in excess of the reduced 268 thousand cubic meter water rights, i.e. 552-268=283.

Thus, the profits from the second source are equal to (4.90-0.65)x283=1,204 thousand NIS. Note that 1200 + 1204 = 2,404.

For $\alpha$=0.8, AC is increased from 0.43 NIS to 0.46 NIS, and the profits for the above individual crop are reduced to 2,396 thousand NIS, i.e. a reduction of 0.2 percent in the crop profits.

The same calculations are illustrated for all crops. Then, in table 2, the percentages of crop area whose income was reduced by 1,5,10 and 20 percent are reported in the corresponding columns in the second row. Thus, for example, in the second row, ($\alpha$=0.8), 4.33 percent of the cultivated area consists of crops that suffered a reduction of at least 5 percent in income.

# Bibliography

Anderson, L., T. (1984). "Water Rights, Scarce Resource Allocation, Bureaucracy and the Environment". Harper&Row Publishers Inc.

Burness, H., Stuart, and James P. Quirk. "*Appropriative Water Rights and the Efficient Allocation of Resources*". The American Economic Review. March, (1979).

Chakravorty, U., E. Hochman, and D. Zilberman "Conveyance Losses and Water Markets". Journal of Environmental Economics and Management". (JEEM May 1995).

Coase R. (1992). The Institutional Structure of Production. The American Economic Review. Sep 1992.

Fundenberg Drew and Jean Tirol (1993). Game Theory. The MIT Press. pp 268-275.

Gisser, M. and Sanchez, D.,A., (1980). Competition Versus Optimal Control in Groundwater Pumping, *Water Resources Research*, 16, pp. 638-642.

Gisser, M., R. N. Johnson (1984). "*Institutional Restrictions on the Transfer of Water Rights and the Survival of an Agency*". "Water Rights, Scarce Resource Allocation, Bureaucracy, and the Environment". Harper & Row , Publishers, Inc.

Hicks, J. R., "Value and Capital", Oxford Press (1939).

Howe, W.C., D.R. Schurmeier, W. Douglas (1986). "*Innovative Approaches to Water Allocation:The Potential for Water Markets*". Water Resources Research, Vol. 22 no 4. pp 439-445.

Rausser G. and Zusman P. (1991). "*Organizational Failure and the Political Economy of Water Resources Management*". The Economics and Management of Water and Drainage in Agriculture, ed. A. Dinar and D. Zilberman. Norwell, Massachusetts: Kluwer Academic Publishers, 1991.

Rosen, D., M. (1989). "*Property Rights And Public Choice in Water Districst:An Application to Water Markets*". Ph.D. dissertation. University of California at Berkeley.

Smith, T., Rodney (1984). " The Economic Determinants and Consequences of Private and Public Ownership of Local Irrigation Facilities. " WaterRights ,Scarce Resource Allocation, Bureaucracy, and the Environment ". Harper & Row, Publishers, Inc.

Tsur Y. and A. Dinnar (1995). Efficiency and Equity Considerations in Pricing and Allocating Irrigation Water. World Bank, Policy Research Working Paper No 1460.

Wichelns, Dennis (1991a). "*Increasing Block-rate Prices for Irrigation Water Motivate Drain Water Reduction.*" The Economics and Management of Water and Drainage in Agriculture, ed. A. Dinar and D. Zilberman.Norwell, Massachusetts: Kluwer Academic Publishers.

Wichelns, Dennis (1991b). "*Motivating Reductions in Drain Water with Block-Rate Prices for Irrigation Water*". Water Resources Bulletin, August 1991.

Zilberman D. and Shah F. (1994). "*Queuing Vs Markets in Water Resource Allocation* " . Department of Agricultural and Resource Economics, University of California at Berkeley. ( In press ).

Zusman Pinhas (1988). *"Individual Behavior and Social Choice in A Cooperative Settlement".* The Magnes Press, The Hebrew University. pp58-64.

Zusman Pinhas (1991). A Conceptual Framework for a Regulatory Policy of the Israeli Water Resources. The Center For Agricultural Economic Research. Hebrew University. Working paper No 9108.

Figure 1

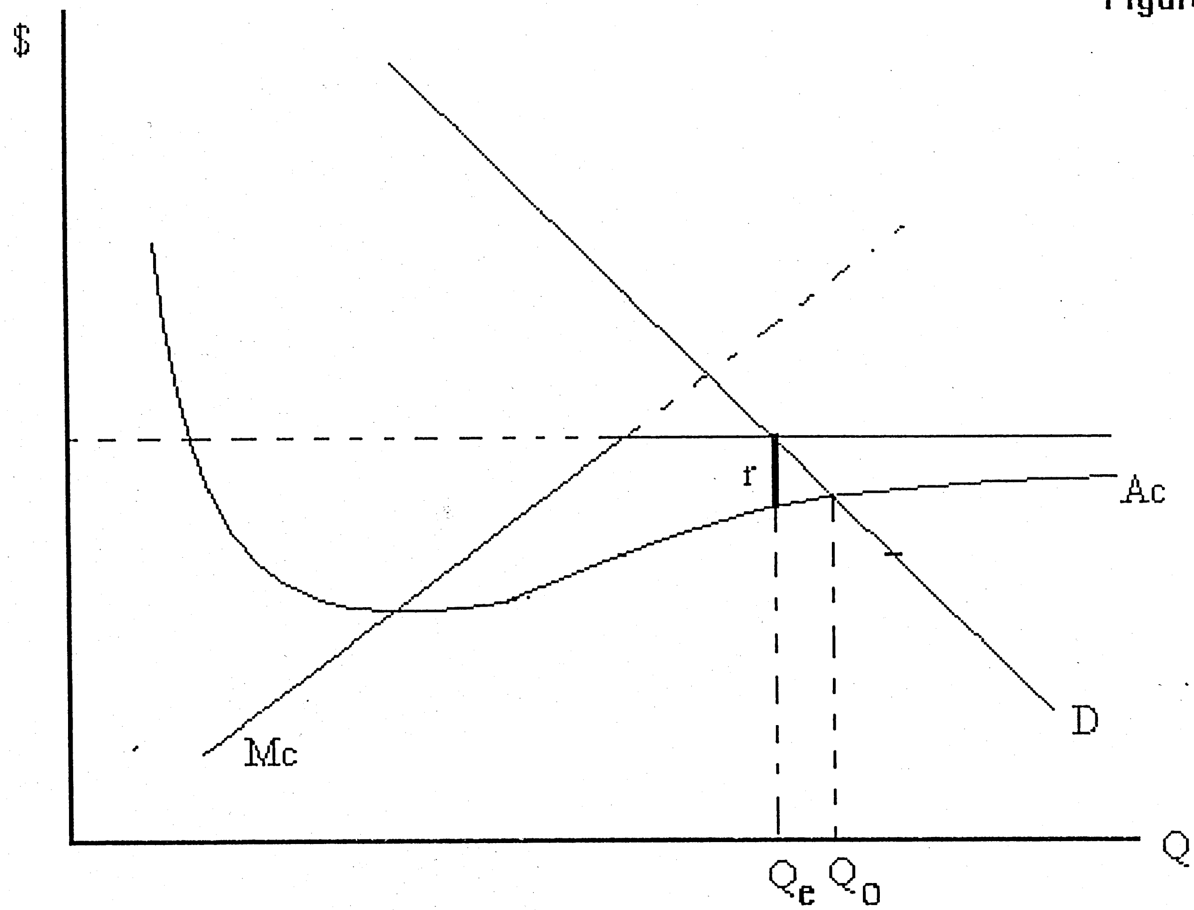


Figure 2

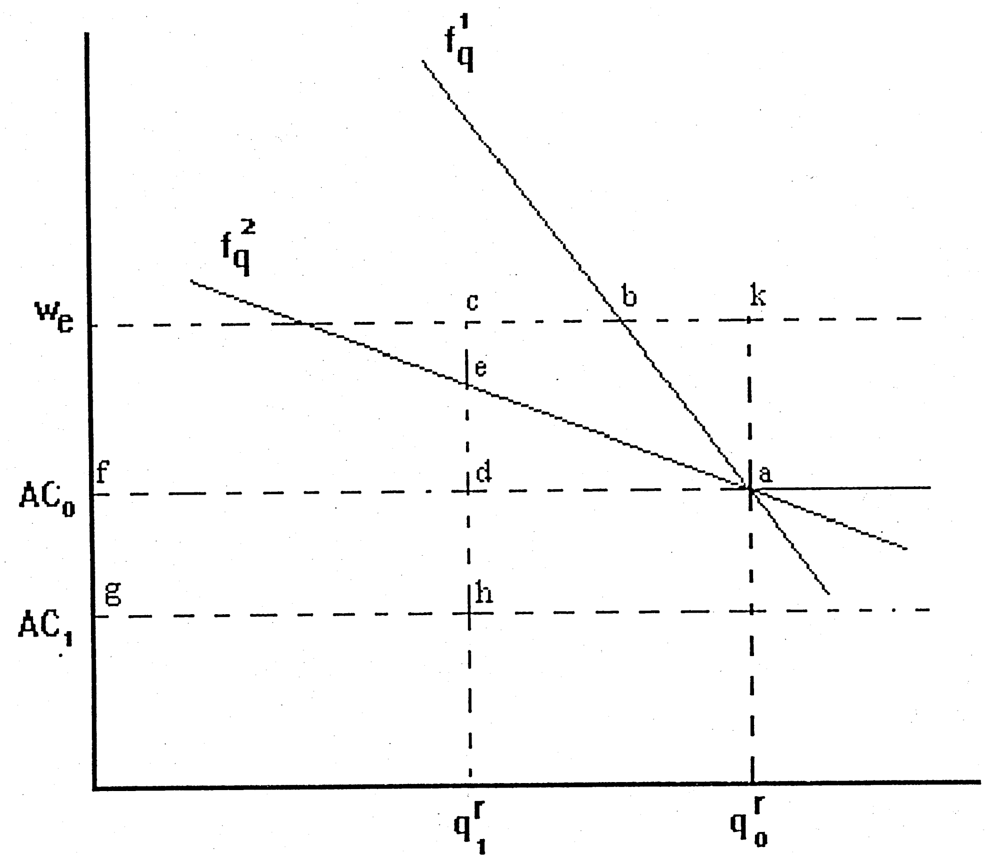
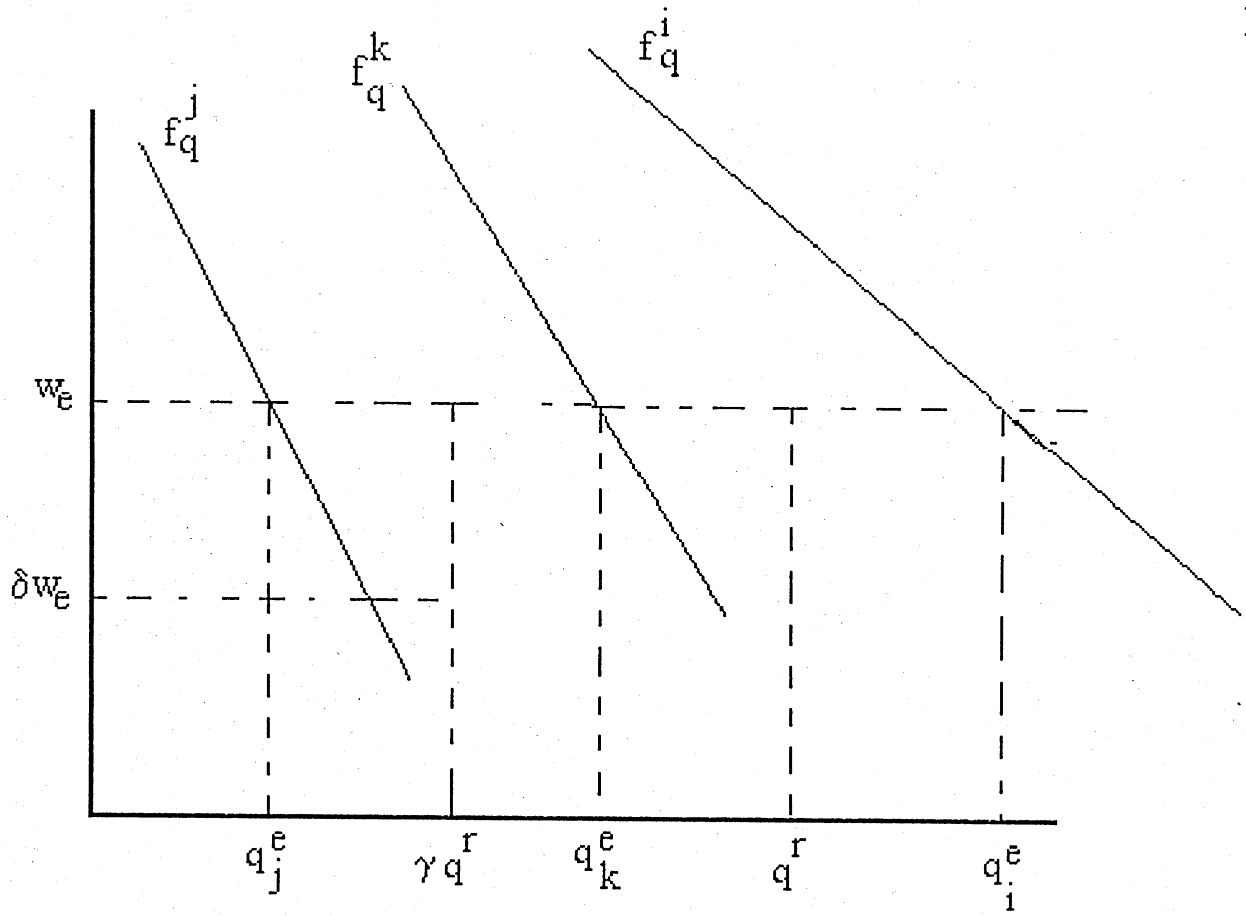


Figure 3



# PREVIOUS WORKING PAPERS

8701 Dan Yaron, Ariel Dinar and Aharon Ratner - **The Applicability and Usefulness of Cooperative Game Theory in the Analysis of Equity Issues in Regional Water Resource Problems.**

8702 Yoav Kislev and Arie Marvid - **Mishorim--A Regional Cooperative of Moshavim (Hebrew).**

8703 Eli Feinerman and Paul B. Siegel - **A Dynamic Farm Level Planning Model for Optimal Feedlot Production and Marketing: An Illustration for a Situation in Israel.**

`8704 David Bigman - **Optimal Provision of Public Goods: Normative and Bargaining Solutions.**

8705 David Bigman and Paul D. McNelis - **Indexation, Contract Length and Wage Dispersion under Rapid Inflation: The Israeli Experience 1979-1984.**

8706 Haim Levy and Zvi Lerman - **Testing the Predictive Power of Ex-Post Efficient Portfolios.**

8707 Haim Levy and Zvi Lerman - **Internationally Diversified Bond and Stock Portfolios.**

8801 David Bigman, Nir Becker and Hector Barak - **An Economic Analysis of Wheat Growing in the Northern Negev and an Evaluation of the Drought Compensation Program** (Hebrew).

8802 Csaba Csaki - **Hungarian Agricultural Policy in the 80's: Economic Management and Organization of the Hungarian Agriculture.**

8901 Arye Volk - **Factors Affecting Growth of Debt on the Family Farms in a Moshav** (Hebrew).

8902 Yoav Kislev, Zvi Lerman & Pinhas Zusman - **Experience with Credit Cooperatives in Israeli Agriculture.**

8903 Zvi Lerman - **Capital Structure of Agricultural Cooperatives in Israel.**

8904 Yoav Kislev, Zvi Lerman and Pinhas Zusman - **Credit in the Moshav-Experience and Lessons** (Hebrew).

8905 Pinhas Zusman - **A Conceptual Framework for the Economy of the Moshav and its Structure** (Hebrew).

8906 Shlomo Yitzhaki - **On the Sensitivity of a Regression Coefficient to Monotonic Transformations.**

8907 Yair Mundlak - **Sources of Input Variations and the (in) Efficiency of Empirical Dual Production Functions.**

8908 Eli Feinerman and Meira S. Falkovitz - **An Agricultural Multipurpose Service Cooperative: Pareto Optimality, Price-Tax Solution and Stability.**

9001 Zvi Lerman and Caludia Parliament - **Performance of U.S. Agricultural Cooperatives: Size and Industry Effects.**

9002 Yoav Kislev - **The Economic Organization of Citrus Production in Israel** (Hebrew).

9003 Zvi Lerman and Claudia Parliament - **Comparative Performance of Food-Processing Cooperatives and Investor-Pwned Firms in the U.S.A.**

9004 Alan Swinbank - **Europe After 1992 and Implications for Fresh Produce From Israel.**

9005 Ziv Bar-Shira - **A Non-Parametric Test of the Expected Utility Hypothesis.**

9006 Yoav Kislev - **The Water Economy of Israel** (Hebrew).

9101 Yoav Kislev and Willis Peterson - **Economies of Scale in Agriculture: A Reexamination of the Evidence.**

9102 van Dijk G. and C.P. Veerman - **The Philosophy and Practice of Dutch Co-operative Marketing.**

9103 Eli Feinerman and Ariel Dinar - **Economic and Managerial Aspects of Irrigation with Saline Water: The Israeli Experience.**

9104 Yoav Kislev - **Family Farms, Cooperatives, and Collectives.**

9105 Pinhas Zusman and Gordon C. Rausser - **Organizational Equilibrium and the Optimality of Collective Action.**

9106 Yoav Kislev - **The Economics of Water Resources - Principles and their Application** (Hebrew).

9107 Dan Yaron, Ariel Dinar and Hillary Voet - **Innovations on Family Farms: The Case of the Nazareth Region in Israel.**

9108 Pinhas Zusman - **A Conceptual Framework for a Regulatory Policy of the Israeli Water Resources** (Hebrew).

9109 Eitan Hochman and Oded Hochman - **A Policy of Efficient Water Pricing in Israel.**

9110 Dan Yaron - **Water Quota Allocation and Pricing Policy in Agriculture** (Hebrew).

9201 Yujiro Hayami - **Conditions of Agricultural Diversification for Economic Development.**

9202 Pinhas Zusman and gordon C. Rausser - **Endogenous Policy Theory: The Political Structure and Policy Formation.**

9203 Domingo Cavallo - **Argentina's Recent Economic Reform in the Light of Mundlak's Sectorial Growth Model.**

9204 Pinhas Zusman - **Participants' Ethical Attitudes and Organizational Structure and Performance.**

9205 Pinhas Zusman - **Membership Ethical Attitudes and the Performance and Survivability of the Cooperative Enterprise.**

9206 Yoav Kislev - **The Cooperative Experience in Agriculture: International Comparisons.**

9207 Robert M. Behr - **Developoment and Prospects of World Citrus Markets.**

9208 Zvi Lerman and Claudia Parliament - **Financing of Growth in Agricultural Cooperatives.**

9209 Claudia Parliament and Zvi Lerman - **Risk and Equity in Agricultural Cooperatives.**

9210 Csaba Scaki and Zvi Lerman - **Land Reform and Farm Sector Restructuring in the Former Soviet Union and Russia.**

9301 Zvi Lerman, Evgenii Tankhilevich, Kirill Mozhin and Natalya Sapova - **Self-Sustainability of Subsidiary Household Farms: Lessons for Privatization in Russian Agriculture.**

9302 Ayal Kimhi - **Optimal Timing of Transferring the Family Farm from Father to Son.**

9303 Ayal Kimhi - **Investment in Children, Selective Off-Farm Migration, and Human Capital of Future Farmers: A Dynastic Utility Model.**

9304 Meira S. Falkovitz and Eli Feinerman - **Optimal Scheduling of Nitrogen Fertilization and Irrigation.**

9305 Shlomit Karidi-Arbel and Yoav Kislev - **Subsidies and Planning in Broilers--the 1980s.** (Hebrew).

9401 Karen Brooks and Zvi Lerman - **Restructuring of Socialized Farms and New Land Relations in Russia.**

9402 Karen Brooks and Zvi Lerman - **Changing Land Relations and Farming Structures in Former Socialist Countries.**

9403 Vardit Heber and Yoav Kislev - **The Protection of Domestic Production in Agriculture - Three Product** (Hebrew).

9404 Eyal Brill and Eithan Hochman - **Allocation and Pricing of Water Under Common Property at the Regional Level** (Hebrew).

9405 Yacov Tsur and Eithan Hochman - **The Time to Adopt: Count-Data Regression Models of Technology Adopting Decisions.**

9406 Shuky Regev - **Farm Succession--The Legal Aspect** (Hebrew).

9407 Yoav Kislev - **A Statistical Atlas of Agriculture in Israel, 1994 Edition** (Hebrew).

9408 Eithan Hochman and Eyal Brill - **Homogeneity and Heterogeneity of Bio-Resources in Economic Models.**

9409 Eyal Brill and Eithan Hochman - **Allocation and Pricing of Water with Common Property at the Regional Level.**

9501 Kwang ho Cho - **An Economic Diagnosis and Decision Model of Dairy Farming.**

9502 Shuky Regev - **Farm Succesion in the Moshav - A Legal Examination.**

9503 Naomi Nevo - **Inter-Generational Transfer of Farms in Moshavei-Ovdim: An Ethnographical Enquiry.**

9504 Menahem Kantor - **Water Issues in Israel Towards the Next Century** (Hebrew).

9505 Ayal Kimhi - **Estimation of an Endogenous Switching Regression Model with Discrete Dependent Variables: Monte-Carlo Analysis and Empirical Application of Three Estimators.**

9506 Zvi Lerman - **New Style of Agriculture Cooperatives in the Former Soviet Union.**

9507 Dan Yaron - **Israel Water Economy - An Overview.**

9508 Israel Finkelshtain and Yoav Kislev - **Prices *vs.* Quantities: The Political Perspective.**

9509 Eyal Brill and Eithan Hochman - **Allocation of Common Resources with Political Bargaining.**

9601 Eyal Brill, Eithan Hochman and David Zilberman - **Allocation and Princing of Water at the Regional Level.**