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**Price Evaluation and Allocation of Water under
Alternative Water Rights Systems**

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Title

PRICE EVALUATION AND ALLOCATION OF WATER UNDER ALTERNATIVE
WATER RIGHTS SYSTEMS

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Summary Report of BARD Project US-2081-91

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Summary Report of BARD Project US-2081-91

Abstract (*approximately 200 words*)

This project developed conceptual and empirical frameworks to analyze the water management policies as water scarcity increases. The analyses showed that increased scarcity will tend to encourage a transition from systems in which water is allocated administratively to water trading. However, transaction costs and political economy considerations placed barriers on the introduction of markets. The recent droughts both in Israel and California were shown to cause an increase in water use efficiency by adoption of modern technologies and improvement of water conveyance systems. The drought led to institutional innovations and an increased reliance on trading as mechanisms for water allocation. Case studies from both countries demonstrate that reducing barriers to water trading and increasing farmers' flexibility in exchange of water will lead to efficient outcomes and much better uses of existing water resources.

Summary Report of BARD Project US-2081-91

Objectives

The objective of this project was to develop a framework to analyze the transition from water rights regimes toward more marketlike allocation of water. In the beginning, the intention was to emphasize the problems associated with the transition from the prior appropriation system towards markets, emphasizing the problems of uncertainty, dynamics, and distribution. Some of these objectives were achieved. We developed an analytic and empirical framework to analyze the outcomes under water markets and compare them to outcomes under the prior appropriation. However, over the last two years some very important developments in water management regimes have occurred, both in California and in Israel.

First, the Central Valley Project Improvement Act of 1991 (the Bradley-Miller Bill) introduced a form of market for water allocation, recognizing environmental uses as beneficial uses of water and, thus, altering dramatically the way water is managed in California. Furthermore, the new proposed water quality standards for the San Francisco Bay and Delta have further ramifications with respect to water allocation in California. These regulations contribute to the erosion of traditional water rights regimes and the transition towards new systems for water allocation. Finally, the recent drought in California led to the introduction of a water bank, thereby setting a precedent for the introduction of water trading arrangements.

We were actively involved in policy analysis associated with all these phenomena, and they affected our perspective on water management and altered the course of this research. In particular, they raised new issues pertaining to the alternative ways transition

to markets can be implemented and the relationship between individual growers and water districts in terms of water use and water trading.

Israel has also gone through many changes, although these have been less subtle than changes in the United States. In particular, the use of tiered pricing and several alternative mechanisms for trading have become more prevalent in Israel. Furthermore, equity considerations play a growing role in Israeli water policy design and have implications for the type of analysis we conducted.

This report presents several research outcomes. First, it presents the background and outcomes of research undertaken in the United States, and then it presents the outcomes of research done in Israel. We should emphasize that it is somewhat artificial to separate the research done in these two countries. There was a lot of close cooperation. For example, there is a joint paper, "A Spatial Model of Optimal Water Conveyance," written by Chakravorty, Hochman, and Zilberman. Furthermore, an Israeli graduate student, Eyal Brill, was supported by this project. He coauthored some of the major papers and visited the United States. Brill, Hochman, and Zilberman worked together in developing a modeling framework that had some interesting results; hopefully, this will lead to further cooperation in the future. Furthermore, Zilberman and Hochman on several occasions visited one another. Some of the visits were financed by the project and some by other sources. Several themes appear in almost all publications that resulted from this project. They include emphasizing the importance of technological choice in water management, addressing issues of equity, and, above all, emphasizing the importance of heterogeneity between farmers as well as between regions.

California Results: Background

California went through a severe drought during the period between 1987 and 1991, and this drought led to outcomes that are consistent with economic analysis, including increased adoption of modern irrigation technologies, increased groundwater pumping, switches in price and quality, increased cultivation of high-value crops, increased reliance on mechanisms such as tiered pricing to increase water use efficiency, and finally, the introduction of the water bank. A recent study by Zilberman et al. (1993), *How California Responded to the Drought*, documents these outcomes and is now being resubmitted to a journal.

Another important event was the introduction of the Bradley-Miller Bill. This Bill required that 800,000 acre-feet of water used for agricultural and municipal uses be diverted to environmental uses. The Bill also allowed transfer of water from the agricultural sector to the urban sector with some limitations. However, there are several ways in which it can be implemented, and analysis of its impacts is of significant interest to policymakers in California and elsewhere. The recently proposed water quality standards for the San Francisco Bay and Delta also increased the amount of water slated to be moved to environmental amenities by about ^{600 $\times 10^6$ m³} 500,000 acre-feet in normal years, and analysis of the impacts of the proposal is again of relevance to policymakers and others involved with and interested in water issues.

As the legal barriers to trade in California decline, there is a growing tendency to trade water within and between districts. Understanding the differences in trading mechanisms and institutions is challenging intellectually and important from economic and policy perspectives.

Outcomes

A key issue in understanding a change in water use is the understanding of adoption of modern irrigation technologies. Shah, Chakravorty, and Zilberman developed a first dynamic framework to analyze the diffusion of modern irrigation technologies in a case of ground water systems where resources become more scarce over time. Their analysis showed that increased scarcity of water leads to an S-shaped adoption process of modern irrigation technologies and also a similar inverted S-shaped process of declining water use over time. Increased scarcity will also lead to an introduction of institutional innovations including a transition from existing arrangements of water rights to water queuing.

The economics of transition from queuing to marketing is addressed in "Resource Conservation and the Transition from Queuing Rules to Markets: The Case of Surface Water," by Shah and Zilberman. The paper develops an analytical framework to analyze the transition from queuing to markets and its impacts on technological change. The model develops a technology choice model under both queuing and markets. The resource allocation model under markets is quite complex. It requires optimization with discrete choice variables, and that leads to water demand and output supply functions that are step functions. They have segments that correspond to unique optimal technologies and segments that correspond to a mixture of two optimal technologies. As water prices increase, the optimal technology improves. The analysis shows that under queuing there may be under utilization of land and excessive reliance on traditional technologies, and transition to water trading may lead to increases in output, reduction in output price, and adoption of modern technology. The paper recognizes that transaction costs associated with markets may serve as obstacles in the transition from queuing to markets. In some cases, when both the water-land ratio and transition costs are relatively high, outcomes

under queuing may be more efficient because the extra transaction costs may be greater than the gains in consumer and producer surplus associated with water trading. The paper uses a numerical example based on California cotton data that demonstrate situations under which transition to water trading from queuing will be inefficient and other situations where such a transition will improve efficiency. It also identifies conditions under which producers may object to queuing, even though it may be superior socially. Finally, it analyzes the role of input demand and transaction costs on technology adoption and gains from transition to water trading.

Another paper, "Changes in Water Allocation Mechanisms for California Agriculture," by Zilberman, MacDougall, and Shah, presents an intuitive explanation of the economics of transition from prior appropriation systems to water trading and uses data from the San Joaquin Central Valley to estimate the impact of water supply reduction associated with implementation of the Bradley-Miller Bill. It shows that, if trading is allowed, the impact will mostly be through the reduction of acreage of low-value crops such as alfalfa and rice, and the costs will be much lower than if trading between regions is not allowed. Another paper, "Water for California Agriculture: Lessons from the Drought and New Water Market Reform," by Zilberman et al. (1994), presents a summary of the main findings of our work on water over the last several years, including our analysis of the impacts of the drought as well as the recent water policy reforms. These papers argue that implementation of new water quality standards, as well as the Bradley-Miller Bill, will determine outcomes. If trading is not allowed between agricultural regions but is only allowed within regions, the cost may be three times as much as if trading within and between regions is allowed. Furthermore, the papers argue that, to some extent, reforms do not go far enough. They encourage trading between contractors but do not support

trading among people who belong to different water systems. For example, if trading between prior appropriators and contractors is allowed, this will reduce significantly the cost of compliance with water quality regulations in California.

The modeling framework that analyzes the impact of water quality regulations is presented in Sunding et al. This study uses three models to assess the impacts of the Bradley-Miller Bill and water quality regulations in California. The different models vary in their specification of technology, their modeling of technology adoption, and, especially, in the degree of heterogeneity with which the industry is analyzed. All models show similar results. The introduction of trading within a large region may reduce substantially the cost of complying with water quality regulations, and implementation may have more impact on the cost than the amount of aggregate water reduction in California.

Israel Results: Background

The current system of water institutions in Israel consists of the following:

- a. Water is owned by the state of Israel according to the water law (1959).
- b. Water is allocated administratively by the Israeli water commission according to water use rights. Sixty percent of the water supply is done by "Mekorot" which is a public agency run by the government. The rest of the water is supplied by regional cooperatives.
- c. Prices are determined once a year by a legislative committee appointed by the "Keneset." Recently, a system of tiered pricing was introduced to determine several levels of prices. The levels are according to the water used out of the allocated quota.

During the years 1989-1991, a severe drought forced an administrative reduction of the water quotas by 40 percent. Scarcity of water together with increasing demand by the urban sector created the need for the development of additional water resources. Additional water resources can be made available by one of the following: the adoption of water-

saving technologies; the introduction of filter systems for recycling of sewage; water desalinization; and increasing the efficiency water allocation among users.

In the summer of 1994, a committee was appointed by the ministers of Agriculture and the Treasury. The task of this committee was to offer reforms in Israeli water law and to suggest the needed changes in organizations. The focus of our research was to identify ways and means to increase the efficiency of water pricing and allocation mechanisms, both at the regional and national levels.

Description of Research

In the research program we pursued both conceptual and empirical goals.

Allocation of Water Over Space Using a Central Water Aqueduct

The conceptual work is reported in a paper, "A Spatial Model of Optimal Water Conveyance," that will be published in *JEEM*, March 1995. This paper develops a spatial model to determine optimal conveyance investment, water allocation, and investment in firm-specific conservation technology. The efficiency and distribution characteristics of the optimal solution are compared to projects with well-developed water markets and spatially uniform water prices, both with sub-optimal conveyance. A numerical illustration is provided. An Israeli database consisting of data gathered from more than twenty areas will be used for the simulation of this model. The results of the simulation will be available by December 1994 (as a chapter in Eyal Brill's Ph.D. dissertation).

The Implementation of Water Markets

The construction of water markets in Israel faces the following obstacles:

- a. The current water law in Israel do not allow trading in water quotas. Modifications in the current law will be time consuming and will involve high transaction costs.
- b. The imputed price of a water quota in a family type farm is relatively low and, hence, farmers lack incentives to participate in a conventional "active" water market.
- c. Institutional and social constraints prevent the transfer of water rights between sectors such as Kibbutzim and Moshavim, Arabs and Jews.
- d. Historically, the acquisition and development of the land and water resources in the settlement of the Jews in Israel was financed by raising public capital in the *Diaspora*. This created a perceptions and norms according to which land and water are national resources. The allocation of these resources to the individual settlers was done via a mechanism of water and land use rights. Thus, individuals are reluctant to trade in use rights being afraid from governmental confiscation.

The paper, "The Allocation of Water at the Regional Level," presents a quasi-water-market mechanism which attempts to answer some of the shortcomings described above. It offers a trading mechanism with low transaction costs, which results in efficient allocation and also takes into account the heterogeneity of the water-crop relationships, and does not rely on information about individual water demands. It results in a Pareto-efficient solution which separates the allocation of water from the distribution of income. Water is allocated according to the unique efficient price, while income is distributed according to the water use rights.

The implementation of the "passive" market mechanism is possible within the framework of the current Israeli water law.

The current system of water pricing in Israel is based on block prices. The heterogeneity of the individual farmers and, hence, their demand for water generated inefficient use of water. It is shown in the paper that under such conditions an over subscription of quotas is needed in order to achieve efficient allocation of water. During the next research year, the Hashron regional application will be extended to other regions in Israel.

The paper is structured as follows: Section 2 proposes a two-goal pricing mechanism for efficient equitable allocation at a water district level. Section 3 examines the efficiency, fairness, and applicability of the payment mechanism. In section 4 the designed pricing mechanism is compared with the tiered price method. Section 5 empirically applies the test of political feasibility to a particular field data. Section 6 concludes the paper with a few remarks.

Political Economy of the Water

The allocation process of water within organizations such as water cooperatives and water districts involves political pressure by interest groups. The lobbying may involve bargaining over water price or water quotas.

A conceptual framework for analyzing the efficiency of various allocation mechanisms of water under bargaining is presented in the manuscript, "The Allocation of Common Resource Under Bargaining."

The main results of the paper are:

- a. The Coase theorem is preserved only in the case when property rights are well defined and the political power is equally distributed between the participants

under bargaining. In this case, a supporting *dual* price mechanism can be designed to achieve a "first best" allocation.

- b. On the other hand, the Coase theorem does not hold when property rights are well defined if the bargaining is over the aggregate quantity¹ and/or the political power is unequally distributed.
- c. When property rights are not defined, for a given elasticity of supply and an equal distribution of political power, a price mechanism yields better (inferior) allocation than a quota mechanism, whenever the demand is relatively elastic (inelastic).
- d. When property rights are not defined, price mechanism allocates a larger aggregate quantity of the resource than an administrative quota mechanism.

The results obtained in the papers will be used during the next research year to rank and compare existing mechanisms and to suggest reforms in the existing water laws in Israel and California.

¹Note that there is one exception, when the distribution of the property rights matches exactly the primal solution of (a).

List of Publications

- Brill, Eyal, Eithan Hochman, and David Zilberman. "Allocation and Pricing at the Water District Level." Hebrew University of Jerusalem, October, 1995.
- Chakravorty, Ujjayant, Eithan Hochman, and David Zilberman. "A Spatial Model of Optimal Water Conveyance," *Journal of Environmental Economics and Management*, Vol. 29, No. 2 (March, 1995), pp. 25-41.
- Shah, Farhed, and David Zilberman. "Resource Conservation and the Transition from Queuing Rules to Markets: The Case of Surface Water." Working Paper, Department of Agricultural and Resource Economics, University of California, Berkeley. August, 1994.
- Shah, Farhed, David Zilberman, and Ujjayant Chakravorty. "Technology Adoption in the Presence of an Exhaustible Resource: The Case of Ground Water Extraction," *American Journal of Agricultural Economics*, Vol. 77, No. 2 (May, 1995), pp. 291-299.
- Sunding, David, David Zilberman, Richard Howitt, Ariel Dinar, and Neal MacDougall. "Modeling the Impacts of Reducing Agricultural Water Supplies: Lessons from California's Bay/Delta Problem." Department of Agricultural and Resource Economics, University of California, Berkeley. August, 1994.
- Zilberman, David, Ariel Dinar, Neal MacDougall, Madhu Khanna, Cheryl Brown, and Federico Castillo. *How California Responded to the Drought*. Report, Department of Agricultural and Resource Economics, University of California, Berkeley. 1993.

Zilberman, David, David Sunding, Richard Howitt, Ariel Dinar, and Neal MacDougall,

"Water for California Agriculture: Lessons from the Drought and New Water Market Reform," *Choices* (Fourth Quarter, 1994), pp. 25-28.

Zilberman, David, Neal MacDougall, and Farhed Shah, "Changes in Water Allocation

Mechanisms for California Agriculture," *Contemporary Economic Policy*,

Vol. 12, No. 1 (January, 1994), pp. 122-133.