Formal and Informal Markets for Water: Institutions, Performance, and Constraints

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Water markets—either formal or informal—can be an efficient method for reallocating scarce water supplies. At the same time certain constraints can raise the transaction costs of trading water. This paper reviews the conditions necessary to establish successful water markets, identifies potential problems, and offers mitigating strategies. It also uses examples of several informal and formal water markets already in operation to illustrate these problems and the solutions to them.

One response to growing demands for limited supplies of water is to reallocate available supplies through water marketing strategies. Although marketing is not a new concept, what is new is the growing recognition that the policy of developing new water supplies to meet future needs is no longer viable. Thus government officials are more open than ever before to new ideas for improving water management. In this context estimates of the economic benefits from trading water within and among sectors illustrate the potential for relatively substantial gains from trade (Vaux and Howitt 1984; Colby 1990; Chang and Griffin 1992; Weinberg, Kling, and Wilen 1993; Rosegrant and Binswanger 1994; Hearne and Easter 1997; Thobani 1997; Diao and Roe 1998). As a result countries such as Mexico have taken the plunge and adopted water use rights and water trading strategies as part of their new policy for managing water resources. Others, such as Peru and Pakistan, are considering or have considered implementing such programs (World Bank 1995, 1997).

This article proposes that countries facing water shortages under their current water pricing systems consider water marketing as a way to reallocate water resources. We illustrate the importance of understanding a country's institutional framework before embarking on a comprehensive overhaul of water policies and review the conditions required for effective water markets. Recent studies of formal and infor-

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mal markets highlight the gains from the efficient allocation of water as well as the constraints that raise the transaction costs of trading water. As we point out, water markets can provide the appropriate economic incentives to improve the efficiency of water use and encourage the reallocation of water to higher-valued uses without encountering the traditional opposition of existing water users.

The Institutional Setting

If a country has little experience with private markets for allocating scarce goods and services, water is unlikely to be one of the first goods exposed to private market forces. In contrast, in a country that is exploring new ways to use the private market to improve the allocation of publicly managed resources, scarce water may be a good candidate for market trading, depending on one's view of the requirements for market exchanges.

There are two distinctly different opinions about the institutional setting required for efficient market exchanges: The neoclassical view posits that a legal system is required; a more pragmatic view emphasizes the importance of informal contract enforcement. Greif (1997:239–40), for example, observes:

> This neoclassical view that places the legal system at the center of contract enforcement in market economies has recently been criticized on the basis of evidence indicating that many contemporary exchange relations in the West and elsewhere are informal. The associated contract enforceability is not provided by the legal system but is based on reputation, general morality, and personal trust within social networks. Empirical evidence indicates the importance of two distinct systems of informal contract enforcement: the individualistic system of informal contracts enforcement prevalent in the West, under which the reputation and morality of the individuals are key, and the collectivist system of contract enforcement prevalent in most other societies, under which personal trust within the social network is critical.

Cooter (1997) comes to a similar conclusion in reviewing the problem of contracting and establishing a rule of law that is consistent with a country's social norms.

At least in the case of markets for irrigation water, both the formal neoclassical legal system and the informal system appear to be at work. The transfer of permanent water rights seems to require the certainty that is provided by a legally based approach in which water rights are recorded and can be defended in court. Water transfers among districts are likely to change the amount of water that is returned to streams and rivers, called the return flow, and a formal market may be required to prevent losses of return flows to downstream users. If, however, the sales are temporary, that is, for one season or less, and do not affect return flows, informal markets

based on informal water rights can suffice. These informal sales will likely be among farmers in the same water district and in many cases among farmers served by the same canal. In addition, these sales are not likely to be anonymous, and enforcement of the contracts will not be provided by the legal system but rather will be based on reputation and personal trust. This suggests that to obtain more interdistrict or interjurisdictional water trades, a country will have to develop legal water rights that can be verified and defended in court at a reasonable cost.

Informal water markets work fairly well for groundwater as long as recharge to streams is adequate and the market has a sufficient number of sellers (Palanisami and Easter 1991; Shah 1993; Saleth 1998). The "tit for tat" game-theory enforcement strategy appears to work; if farmers do not pay, their future supplies will be cut, and if a seller does not deliver, the buyer can use another supplier. In one area of Gujarat, India, farmers have pipelines from three or four different suppliers coming to their fields (Shah 1993), and they can buy from the supplier who offers the best price and service. Shah found that "while the main beneficiaries of private investments in pipelines have been the buyers of water, early operators in the water business were motivated mainly by the desire to establish monopoly positions and to overcome topographical constraints in supplying water to a large command" (pp. 61–62). In other words, although sellers are motivated by profits to sell water, the buyers may be the big beneficiaries.

If a country decides to establish a formal water market, the community of users needs to support the concept as fair and beneficial. Thus the law must be written so that the resulting allocation of rights is equitable. If the economic rents from water trading are concentrated in the hands of a few individuals or the negative effects on third-party users are large and unmitigated, the community is not likely to obey the law. Cooter (1997:214) notes that "a modern economy needs effective laws to promote cooperation among people. Yet, states enact many laws that few people obey. People tend to disobey, or obey out of fear, laws that are not consistent with social norms and to obey laws that reflect social norms." In Pakistan, for example, farmers tend to disobey the law against trading canal water. In contrast, the 1981 Chilean water law that establishes private water use rights is widely obeyed because Chile not only has a long record of private water development but also allocates water rights based on past use (Hearne 1998b).

Conditions for Effective Water Markets

Thus effective formal markets are dependent on some basic institutional and organizational arrangements to overcome a number of potential market constraints and to prevent other associated problems from developing (see Garrido 1998a:tables 1 and 2). For example, tradable water rights or water use rights need to be separated from

land rights. In many cases, institutional arrangements will also be needed to deal with third-party effects that result from changes in return flows or declining economic activity in the region in which water sales originate. Adequate management and infrastructure will be needed for trades that are not in the immediate vicinity, such as trades between users on different canals. Countries must consider establishing mechanisms to prevent monopoly control over water and to avoid the overexploitation of groundwater. In both cases, however, these problems can be dealt with through the manner in which water rights are designed, quantified, allocated, monitored, and enforced (box 1). How to do this effectively for groundwater is a particularly vexing problem in many developing and industrial countries.

Box 1. *Constraints on Effective Trades in Unregulated Water Markets*

Potential problem[a]	*Frequency*[b]	*Mitigating strategy*
Third-party effects from a decline in output and employment in the water exporting area (1, 2, 3, 6, 7)	F	1. Require review and approval of transactions by public agency. 2. Establish a fund to compensate third parties damaged in trading, financed by levies on water transactions. 3. Limit trades to a percentage of water rights in a given area or community. 4. Revise water rights downward. 5. Grant water rights to those using return flows. 6. Limit trading outside the river basin or sector to consumptive water use. 7. Open litigation to nonholders of water rights. 8. Tax or ban trading from upstream to downstream users. 9. Set minimum instream flows to maintain aquatic ecosystems. 10. Require buyers to pay a fee for the costs imposed on the irrigation system from which water is transferred. 11. Require lending agency to clear permanent water sales. 12. Adjudicate groundwater rights. 13. Tax groundwater sales based on their scarcity value. 14. Limit trading in areas with rapidly declining groundwater stocks. 15. Provide for regulation of monopolies or expand supply options. 16. Aid small rights holders with legal fees and registration.
Reduction or changes in return flows along with any changes in water quality (1, 3, 4, 6, 8, 9)	F	
Added incentive to overdraft open-access groundwater stocks, damage the aquifer, and increase pumping costs (3, 4, 10, 12, 13, 14)	I	
Increased costs of irrigation system for the remaining farmers (3, 10)	I	
Drop in land values (3, 11)	I	
Market power for large-scale buyers or sellers (1, 3, 15, 16)	I	

a. Numbers in parentheses refer to appropriate mitigating strategies.
b. I, infrequent; F, frequent.

In many cases, governments will also need to reserve or buy some of the water rights to preserve instream uses that have strong "public good" characteristics, such as recreation, fish production, and the preservation of aquatic environments.[1] As Howe (1998) points out, preservation has become a growing concern in the western United States as the demand for recreation and environmental services has grown. California has even reallocated water from irrigation to improve instream flows into the San Joaquin–Sacramento delta that will help preserve aquatic environments in the delta (Archibald and Renwick 1998; Howitt 1998).

Adequate information concerning water supplies and demands is a basic requirement for the efficient operation of markets. In Chile, for example, water user associations were essential in providing such information (Hearne 1998b). The central government generally has a comparative advantage in obtaining water supply data, although the users are better able to determine their own demand. User associations with access to such data can be important conduits for information. Asymmetric information is much less of a problem for water markets with strong user associations, but farmers may withhold information about their willingness to buy or sell water in order to obtain more favorable prices.

Informal water markets may be a good alternative, particularly if water allocation at the local level is a problem and the transaction costs of establishing formal markets are high (meaning the costs of enacting legislation, establishing institutional and organizational arrangements for markets, implementing trade arrangements, and monitoring and enforcing trades). Besides allowing water to be sold to the most productive farmers, informal markets would give all farmers an incentive to use their water more efficiently.

Gains from Water Markets and Organizational Constraints

The informal water markets that have evolved suggest that water users will buy and sell water even if such transactions are illegal or discouraged by governments (Renfro and Sparling 1986; Shah 1993). Problems arise when governments are asked to help develop formal markets or allow informal markets to develop, particularly within government-constructed irrigation projects. Because these are subsidized projects, many government officials maintain that the users should not be able to sell the water at a profit and that poor farmers will be disadvantaged because they will lose access to the water unless they pay higher prices. (Both Meinzen-Dick 1998 and Saleth 1998 dispute this claim, however.) Thus, even though water markets can change the incentives for water users and improve allocation, organizational constraints may prevent their introduction (box 2).

One prerequisite for water marketing is some type of water or use right that can be bought or sold separately from ownership of the land. Such rights may be difficult to establish and are likely to be resisted by public water agencies that fear they will lose a

Box 2. *Constraints That Raise Transaction Costs in Unregulated Markets*

Potential problem[a]	*Frequency*[b]	*Mitigating strategy*
Incomplete or poorly defined water rights that are not separate from land (1, 2, 8, 10)	W	1. Register and secure water rights. 2. Use proxies of water use (land area and use) to define water rights.
Inadequate infrastructure, including conveyance and storage systems (3)	F	3. Invest in infrastructure. 4. Provide management training for irrigation agencies.
Inadequate water management, lack of water user associations (WUAs), or both (4, 5)	F	5. Provide water users incentives to organize WUAs. 6. Carry out education program explaining the benefits of water markets.
Imperfect or asymmetric information about trading (5, 9, 10)	I	7. Tax unused water rights
The granting of more water rights than warranted by existing supplies (11, 12, 13)	I	8. Keep up-to-date single basinwide water rights registries. 9. Use public agencies or WAUs as clearing-houses for trades.
Sleeper or inactive water rights that might be sold and activated by water markets (7)	I	10. Aid small water rights holders with free legal protection and information.
Inappropriate initial allocation of water rights that causes conflicts among water users (14)	F	11. Encourage spot and option markets for water. 12. Revise all water rights downward.
Reallocation by government agencies of water among and within sectors without compensating original users (1, 4, 16)	F	13. Define two types of rights with one senior to the other. 14. Base allocation of water rights on past use and conduct an auction for any surplus.
Opposition from farmers and environmental groups (6, 10, 15; also strategies 3, 6, 7, 8, 9, 10, 15 from box 1)	F	15. Use part of the water traded to enhance stream flows. 16. Base water rights on shares of the water supply rather than on absolute volumes.

a. Numbers in parentheses refer to appropriate mitigating strategies.
b. I, infrequent; F, frequent; W, widespread.

great deal of power if they allocate water rights to users. Giving users water rights means that system operators (the government officials) have the responsibility to deliver water more or less when the users want it. In contrast, a government agency that retains the water rights can dictate the conditions under which farmers will receive water, including (in some cases) the necessary side payments. Making the water rights tradable creates an even greater dilemma for government agencies. To prevent loss of control over tradable water rights, the National Water Commission in Mexico and some of the water districts in the western United States limit trading among water districts. In Mexico a water user must obtain special government approval to sell water outside the district or jurisdiction, and any profits from the sale must accrue to the district and not to the seller. This regulation discourages interdistrict trading, but it also reduces the chance that trades will have deleterious third-party effects.

Even if the users set up and hire the management unit that allocates water, the unit may have an incentive to use monopolistic power and discourage water trades with other jurisdictions. If too much water is transferred out of the district, the resulting shortage may reduce economic activity and make the irrigation system—or parts of the system—difficult to operate effectively. Once most of the farmers along a canal have sold their water, the few remaining farmers who own water rights on the canal may be difficult and expensive to serve. Thus, although water markets may change user incentives and encourage efficiency, the management of the system may prevent trades or raise the transaction costs of interdistrict or interjurisdictional trades.

Cooter (1997) argues that an organization seeking to maximize the wealth of its members will behave monopolistically toward outsiders but efficiently toward insiders. By fixing prices, establishing jurisdictional territories, and withholding information from the public, the organization will seek to create monopoly power for its members in dealing with nonmembers. These motivations may affect water user organizations and other water entities that can use their infrastructure as a monopolistic tool to block trades to outsiders. Water user organizations can either say that their canals are used to capacity or charge such high transmission fees that the trades become unprofitable.

The organizational problem appears to involve two important aspects: the resistance to trading water between or among districts or jurisdictions, and the problem of establishing water rights and giving the users more control. Other problems that raise transaction costs include legal challenges by third parties claiming they might be damaged by a transfer, the lack of sufficient infrastructure to transfer water among potential buyers, and the lack of an effective means for verifying and enforcing water rights. The question is whether taking action to reduce these transaction costs is in the best interests of a country. If the answer is even a tentative "yes," then the second question is how to lower these costs.

Potential Problems and Mitigating Strategies

Clearly, one should not go to the expense of establishing water markets if water is not scarce or likely to become scarce in the foreseeable future. In Chile, for example, where water markets have been encouraged, there is no trading in the southern region because water is not scarce in that area. Water markets will be active only in regions where water is scarce.

Formal water markets are less likely to develop if they are constrained by the high cost of institutional development and by the absence of the management and infrastructure needed to implement trades. In areas where it is costly to establish, allocate, and enforce water rights, markets will be slow to develop. This has been an important factor in South Asia, where the presence of many small, fragmented farms makes it difficult to establish individual water rights. In such cases, water rights may have to

be allocated to water user associations, as they are in in Mexico, or to villages. If water trading is really to expand, these countries may also need to take steps to improve both their infrastructure and their system management. Yet most of these latter improvements are needed even without the desire to establish markets.

In South Asia there has also been a general aversion to markets, especially for allocating basic resources such as water and land, because of the belief that markets will disadvantage low-income farmers. In practice, as Saleth (1998) and Meinzen-Dick (1998) show, even "poor" farmers benefit from market exchanges. Clearly, if there are too few sellers, buyers may be disadvantaged, but Saleth and Meinzen-Dick point out that social conditions in India and Pakistan, for example, tend to mitigate against such exploitation. Saleth finds little or no price discrimination in mature water markets or in situations where kinship and social relationships are strong.

One of the biggest problems in establishing water markets in irrigated areas concerns issues associated with changes in return flows and water-related economic activities. These issues are important in California, as discussed in Archibald and Renwick (1998) and Howitt (1998). When water is transferred into other sectors or out of a river basin, governments need to have mechanisms in place that require the traders to take these third-party effects into account. Archibald and Renwick note, however, that these mechanisms must be carefully designed or they will foreclose many socially beneficial water trading opportunities. Thus the government must ensure that the appropriate institutional and organizational arrangements are in place. Clearly, a strong legal system is an asset in establishing such arrangements. Other key assets are a history of private irrigation development, strong water user associations, and appropriate conveyance and storage systems. Hearne and Easter (1997) illustrate how investments in storage capacity and a flexible infrastructure lower the transaction costs of water trading in Chile.

In contrast, Hearne (1998a) shows how too much government involvement in reallocation decisions can prevent water markets from developing. In Mexico the National Water Commission has foreclosed any possibility of intersectoral market exchanges in several regions. A better strategy may be for the commission to act as a broker in facilitating water trades. That approach would mean a major change in the commission's function and is not likely to occur without strong political pressure from farmers and other interested parties.

Because the physical, institutional, organizational, and technical conditions that affect the performance of potential water markets vary so much, it is difficult to predict what will happen if water markets are introduced in a new area. The use of experimental markets, as suggested in Dinar and others (1998), may be a low-cost first step toward developing and evaluating alternative institutional arrangements. Although not widely used for water resources, experimental markets can capture some of the complexities involved in water markets.

Experience with Water Markets

Formal water markets specify the volume and share of water to be sold, either for a set period of time or permanently. Informal markets usually involve the sale of unmeasured flows of surface water from a canal for a set period of time or of water pumped from a well for a set number of hours. Although the units sold in informal markets may not be metered, both the buyer and the seller have good information about the volume transferred. The key difference between the two markets is the way in which the trade is enforced. If the users must self-enforce trades because no formal water rights exist that can be enforced through the legal or administrative system, the market is informal. Formal water markets are usually found in North and South America, whereas informal markets are prevalent in the irrigated areas of South Asia.

Informal Markets

Groundwater markets are important for agricultural production and the distribution of water throughout the irrigated areas of South Asia. Saleth (1998) estimates that 20 percent of the owners of the 14.2 million pumpsets in India are likely to be involved in water trading. This means that water markets are providing water for about 6 million hectares, or 15 percent of the total area irrigated by groundwater. In Pakistan a survey reported that 21 percent of well owners sold water (NESPAK 1991).

In areas where dependable precipitation recharges the groundwater, the benefits of buying and selling water from tubewells have increased farmers' income and production. The economic gains from groundwater markets reflect improved efficiency in pump management, in reducing conveyance losses, and in farm-level water use. These markets also increase access to irrigation, especially for smaller-scale farmers who do not own tubewells and cannot afford to invest in a well without a market for their water.

Meinzen-Dick (1998), in one of the few studies estimating the economic returns from access to water markets, found that water markets increased the availability and reliability of water supplies. Both yields and income rose for those who purchased water, particularly for those who also had access to canal water supplies. The highest yields and income, however, were still found among farmers who owned their own tubewells and had access to canal water.

PREVENTING OVERDRAFTS. Given that markets for the sale of groundwater draw on an open-access resource (that is, one that is available for capture to anyone who has access), it is not surprising that problems arise in areas with high demands and limited supplies. Farmers have an incentive to ignore the scarcity and buffer stock value of the groundwater and pump until their cost of pumping equals the market

price of water (Ramasamy 1996).[2] Over time, the cost of pumping and the price of water rise as the groundwater level declines. For example, the overdraft (that is, water use in excess of recharge) in the Coimbatore District of India is almost 5,000 cubic meters a year. Ramasamy estimates that if the overpumping continues, it will mean a drop in total net returns to farmers of between $42 million and $69 million, a result of the increased costs of power necessitated by increased pumping and additional investment to deepen wells. Here is a case where informal markets may exacerbate the problem, and formal markets may not work any better unless water rights can be established and enforced in strict quantity terms. The problem is not the water markets but the lack of exclusive property rights for groundwater. To establish such rights, the number of wells and the amount of water to be pumped would have to be agreed on and restricted. Such restrictions are probably unrealistic without strong support in the irrigation community. If exclusive water rights can be established, however, the water market should reflect the scarcity value of water and help restrain overpumping.

Blomquist (1995) reports on one case where the demand for water is increasing and the community of water users has been able to stop the overdraft. In the dry Los Angeles metropolitan area in southern California, pumping is metered and taxed so that users have an incentive to shift from local groundwater to more expensive but more plentiful imported water. Surface and imported water are stored and used to recharge the groundwater in the basin. One result has been a halt in saltwater intrusion from the ocean in the area's coastal groundwater basins. In some of these basins, pumping rights have been defined, limited to the basin's average recharge, and made transferable to other users through sales.

A more typical case, reported by Shah (1993), is in coastal Gujarat, India. Here, the overdraft of coastal aquifers has caused a decline in groundwater supplies in some areas and saltwater intrusion in others. Shah argues that any effective reduction in this overdraft is unlikely without good local leadership and the involvement of water user groups. He argues that "legal, quasi-legal, and organizational instruments of public policy will not, on their own, succeed in securing the compliance of farmers unless they are accompanied by measures aimed at affecting private returns to irrigation . . . or unless the structure of property rights on the water resource itself is drastically reformed (p. 147)." Similarly in Pakistan, Meinzen-Dick (1998:218) doubts "whether government would have the institutional capacity to regulate sales among hundreds of thousands of private tubewells, and if it had such capacity, it is unclear what such direct intervention could achieve."

Yet in both India and Pakistan, any effect that water markets might have on the overdrafting of groundwater is much less than the effect of subsidized electricity. The zero or near-zero marginal cost of pumping means that farmers have an incentive to use water to the point where the marginal value of production is close to zero. This, of course, encourages farmers who can sell water to use their wells at close to

full capacity. The low power rates not only create overdrafting problems but also waste electricity in countries without adequate power.

As noted above, water markets can actually help solve the overdrafting problem by increasing the incentives for efficient water use and making it possible to purchase water from areas where water is abundant. The ability to find another source of water, but at a higher marginal cost, can help promote community action for self-regulation and demand management. Shah (1993) cites a case in coastal Gujarat where self-regulation became possible when additional new supplies were piped into the area.

Overdrafting tends to be concentrated in coastal areas of India and Pakistan and in the hard rock areas of southern India. In many of the northern areas, pumping actually improves growing conditions by lowering the water table below the root zone (Shah 1993; Meinzen-Dick 1998). In cases where water tables are high or recharge rates are rapid, water markets are not likely to cause negative externalities except possibly temporarily if neighboring wells are too close or deep tubewells interfere with shallow wells. Where these externalities are small, personal trust and reputation may be enough to foster competitive informal water markets. This is particularly true where farmers own a number of separate plots that cannot be served by the same well. In such cases, most water sellers are also buyers because most farmers who own a well are able to irrigate only their large plots and must purchase water to irrigate other plots (Shah 1993; Meinzen-Dick 1998; Saleth 1998). In addition, their wells are likely to be underutilized unless they can sell water. Yet because of the costs of conveying water and the need for cooperation from neighboring farmers when water is to be conveyed any distance, high transaction costs can restrict trades in areas with only a few wells and prevent water markets from being competitive.

COUNTERING MONOPOLY PRICING. This raises the other concern about water markets, the potential for monopoly pricing and discrimination. Groundwater markets are somewhat confined by the physical limits of the location and supply of groundwater. Still, pipelines can extend markets, and the investment costs of new wells should put a limit on monopoly power. An abusive monopolist who raises prices too high will find others investing in wells and undercutting the price. Shah (1993) notes a lack of balance between the numbers of buyers and sellers in areas with high-capacity wells, where one seller may serve as many as 70 or 80 buyers. He fails to say how many sellers the average individual buyer can access. Monopoly pricing may be avoided if the buyers can purchase water from three or four sellers—so long as the sellers do not collude.

The evidence on monopoly pricing is mixed. In a 1991–92 survey in Pakistan, Meinzen-Dick (1998) found that sellers were pricing water at little more than the cost of pumping. The two most common ways of charging for groundwater are a flat charge per hour of pumping (ranging from $0.57 to $3.27 an hour, depending on

the pump type, capacity, and location) and arrangements whereby the buyer supplies the diesel and motor oil for the pump and pays an additional fee of $0.16 to $0.24 an hour to the well owner to cover the wear and tear on the engine.[3] Sellers with diesel pumps were just recovering their own costs under either type of contract.

In contrast, Saleth (1998) suggests that in some areas of India, monopoly rents may be extractive. He cites as evidence the variation in water charges compared with pumping costs in different areas. For example, water charges are 1.3 to 2 times higher than operating costs in the Indo-Gangetic region but 2.5 to 3.5 times higher in the water-scarce hard rock regions of southern India. The difference in rates, however, might be explained in part by the difference in water scarcity and in the value of water in those two regions.

The degree of monopoly power may also be related to the terms of the transaction or contract for water. Not surprisingly, some of the contracts for water are quite similar to contracts for land. Water contracts include crop sharing, crop and input sharing, and labor arrangements. If the payment is cash-based, buyers have more freedom to take their business to another well owner anytime during the season. When the transaction is a contract in kind, especially one based on crop sharing or on crop and input sharing, the buyer is tied to the seller for at least one season, if not longer. Similarly, if buyers contract to pay for the water with their labor, they may find it difficult to change suppliers until they have fulfilled the contract. Yet in the villages, informal markets do not appear to face extreme cases of monopoly rents. In fact, monopoly power that restrains trading in areas with serious problems of declining groundwater levels may help reduce overextraction. In contrast, when suppliers are taking advantage of their monopoly position and there are adequate groundwater supplies, the best strategy is to encourage (legalize) trading and increase competition through community and private well development (Palanisami and Easter 1991).

Thus informal water markets can improve water use and incomes in irrigated areas where water rights are not well defined or recorded. They also may be a good option if formal water markets are likely to produce third-party challenges and result in excessively high transaction costs. Finally, informal markets would work well in traditional irrigation systems where the farmers manage the irrigation system and would be able to maintain a relatively modest level of transaction costs.

Formal Markets

In situations where informal markets can work well, it may not be necessary to incur the extra expense of establishing formal water markets. Formal markets will be required, however, to provide the certainty necessary for permanent water transfers or transactions between different sectors and jurisdictions. Because the need for permanent trades and interjurisdictional water exchanges is likely to become more important as nonagricultural demands for water grow, formal water markets are likely to

become more common. The growing demand in water-scarce regions has been one of the driving forces behind the new interest in water markets. Several studies have illustrated the benefits that are possible from interjurisdictional trading in permanent water rights for short-term use.

In Texas 99 percent of the water traded has been transferred out of the agricultural sector in the Rio Grande Valley to nonagricultural users (Griffin 1998). Of the municipal water rights in the valley that existed in 1990, 45 percent had been purchased since 1970. Although water markets are not active in other areas in Texas, Griffin notes that the surface water law has evolved to the stage where trading will be more widespread in the future. In contrast, the groundwater law is just beginning to evolve.

ECONOMIC GAINS. In a study of the Guadalquivir Basin of southern Spain, Garrido (1998b) finds that the economic gains of trading within an individual water district or community may be relatively modest. In contrast, if permitted, trades among communities subject to different supply constraints and drought conditions could produce substantial gains. Garrido estimates the total welfare gain at no more than 10 percent over the current water allocation for four communities where trades were only intracommunity. Intercommunity trading, however, could produce estimated economic gains in one of the older irrigation communities of almost 50 percent. Garrido also shows that both types of trades are very sensitive to the level of transaction costs. If those costs exceed 8 to 12 percent of the market price, trading and the gains from trading would be too small to justify the expense of establishing formal markets. Yet Garrido may underestimate the potential gains because he considers only the crops traditionally grown in the region (cotton, wheat, corn, oilseed, and sugar beets) and excludes any transfers to nonirrigation uses. Evidence from Chile found significant changes in cropping as a result of water trading (Hearne and Easter 1997).

In contrast, Horbulyk and Lo (1998) found that most potential gains from introducing water markets in Canada's Alberta Province were likely to come from trades within a subbasin. They considered four subbasins and compared the current water allocation situation with the allocation under four separate markets (one in each subbasin), as well as with a market encompassing the total basin. The four separate market scenarios created 90 percent of the welfare gains that were obtained when unrestricted trading was allowed among the four subbasins. The urban sectors purchased most of the water, except on the South Saskatchewan River, where the agricultural sector purchased additional water when market trading was allowed among the subbasins.

TRADING PATTERNS AND TRANSACTION COSTS. In their analysis of selected water markets in Chile, Hearne and Easter (1997) found trading both within and between sectors. In the case of permanent transactions either within or between sectors, well-established water use rights that were recorded and recognized by the government

were critical in fostering trade. Several trades between farmers and the city of La Serena were not consummated because of uncertainty regarding ownership of the water rights. La Serena is a growing vacation destination located on the coast in a dry region some 400 kilometers north of Santiago. Rapid growth in demand has strained the city's water supply, particularly during the summer tourist season. The opening of water markets allowed the city to purchase water and delay development of new water sources. Starting in 1992, the city's water company purchased enough water to increase its water supply by 28 percent. Additional purchases were made by upstream households for domestic uses and by farmers.

Elsewhere in Chile, significant trading occurs in the Limari Valley for agricultural purposes (the urban sector has adequate water). A survey of 37 farmers selling water and 19 farmers buying it reported transfers of rights to 9.2 million cubic meters. The gains from trade (measured as the difference between the value of water to the seller before the sale and the value to the buyer after the sale) were, on average, $2.47 a cubic meter ($3,045 an acre-foot), with a transaction cost of $0.069 a cubic meter ($86 an acre-foot).[4] This sample was neither random nor complete, but the numbers surveyed were large enough to show that the water market was very active and had created significant gains from trade. The largest gains accrued to three grape producers who purchased 5.8 million cubic meters of water (63 percent of the total amount traded in the sample). In these active water markets, transaction costs were low and did not seem to constrain trading. In other areas, such as the upper section of the Maipo River that supplies the southwestern Santiago area and irrigates 100,000 hectares, the transaction costs are high, and trading is quite limited. The Maipo River is divided into three sections for management and water trading. As a result, water rights are uncertain, and the lack of adjustable control structures raises transaction costs and therefore limits trading (Hearne 1998b).

Similarly, Archibald and Renwick (1998) found that high transaction costs in California limited a large number of potentially profitable trades. Two types of transaction costs were identified: administrative-induced costs, which are explicit and included in the price of water sold through the California Water Bank, and policy-induced transaction costs, which stem from existing legal requirements designed to avoid injuring owners of water rights, damaging fish and wildlife, and creating negative third-party effects in exporting areas. Administrative-induced transaction costs, including the costs of locating buyers and sellers and negotiating quantities, timing, and other terms of transfer, were $0.041 a cubic meter ($50 an acre-foot) in 1991 and $0.014 a cubic meter ($17.50 an acre-foot) in 1992 and 1994. Policy-induced transaction costs in the West range from $0.152 a cubic meter ($187 an acre-foot) in Colorado to $0.044 a cubic meter ($54 an acre-foot) in New Mexico, all states with less stringent state and federal transfer requirements than California. Policy-induced transaction costs in this range would be as much as or more than the potential gains from trading in the California Water Bank (Archibald and Renwick 1998).

Because of high transaction costs in Colorado, Howe (1998) recommends shifting the administrative responsibility for water transfers from the water courts to the State Engineer's Office. He also recommends reserving or acquiring water for "public good" uses such as recreation, as well as making other changes to allow water to be marketed as freely in Colorado as it is in the neighboring states.

Colby (1998) suggests that the claims of Native Americans have the effect of imposing high transaction costs on water trading in many western rivers. She argues that even though markets do not work well with high transaction costs, when those costs are compared with the costs of litigated solutions, water markets look like a much better alternative.

Howitt (1998) reports that spot and options markets performed well during California's droughts in the 1990s. Even though these markets are a fairly recent phenomenon, he thinks they are a promising option for stabilizing available water supplies in California and other similar areas. Permanent shifts in demand, however, require a much more active formal market for water rights.

Conclusions

Contrary to the claims of many critics, water markets have worked and are likely to be a better mechanism for reallocating water than the alternative methods. There are both formal and informal water markets at work today. In addition, there are spot market sales, sales of permanent water rights, and leasing arrangements that are similar to those used for land, including crop sharing and cash rents (Saleth 1998).

Where water is scarce and large amounts of the available water supplies were committed to particular uses a long time ago, the economic benefits from water markets are likely to be large. In contrast, if the allocation was made fairly recently, based on the most highly valued uses of water, and new opportunities are not available, then the gains will be much more modest, as is shown in the Spanish example developed by Garrido (1998b).

For markets to be effective, transaction costs must be kept low. To keep these costs low, the appropriate institutional and organizational arrangements need to be in place, as well as flexible infrastructure and management. As pointed out earlier, the critical first step is to establish tradable water rights or water use rights separate from land, as well as the mechanisms to deal with third-party effects.

If it is difficult to establish legally enforceable, permanent water rights, a "thick" spot market may provide almost the same security as ownership of permanent water rights. In other words, the ability to buy the water needed at a reasonable price may provide enough security so that firms are willing to invest in enterprises that are dependent on this purchased water. A contingent water market can provide additional security so that firms can be assured of a given volume of water at a set price.

With only a spot market and no contingent markets, firms may be subject to wide fluctuations in prices.

For those users needing certain supplies, spot water markets are probably cheaper alternatives than having to buy enough senior water rights so that one is guaranteed adequate supplies even in the worst drought. (Owners of senior water rights have the right to whatever water is available, before the more junior water rights owners.) In Pakistan, for example, the markets for groundwater have greatly improved the security of water supply, particularly in government irrigation projects. This security has allowed increased investment and increased production. It will be important to see if spot and contingent markets have similar effects on the productivity of water.

Finally, the evidence indicates that appropriately designed water markets, supported by sound institutions, are an effective mechanism for reallocating scarce water among sectors. Carefully designed water markets make it possible to meet the growing urban and industrial water demands without derailing growth in crop production. Market transfers among sectors may make it possible to significantly scale back investments in new water supply projects. Government inaction, ineffective institutions for water management, and high transaction costs, however, are likely to prevent water markets from reaching their full potential for reallocating scarce water resources.

Notes

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1. "Public goods" are goods that consumers cannot be excluded from using and that are not consumed during use but continue to provide the same benefits to other consumers (World Bank 1993).
2. Scarcity value is the opportunity cost of water. It is the present value of the sacrifices imposed on the future by using the resource today. Buffer stock value is the value of groundwater in stabilizing water supplies when the supply of surface water is uncertain (Tsur 1990).
3. The 1995 exchange rate of 24.5:1 was used to convert Pakistani rupees to U.S. dollars.
4. An acre-foot equals 1,233 cubic meters.

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