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The Economics of Groundwater Resource Management

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Abstract Many economists have recently discovered that the problem of groundwater resource management is an important and interesting area for the application of the tools of economic theory and econometrics. At the same time, many water specialists from other disciplines have discovered that the language and tools of economics are helpful in furthering the understanding of water management problems. In this article, we present the conceptual framework within which economists examine the elements interacting in the management of ground-water resources, indicate why the role of the market is limited with respect to the price of this very complex resource, and point to the mechanisms that can pull competitive water price and quality- graded quantity of groundwater in line with their equilibrium levels.

Keywords Groundwater Management, Economic Tools, Market Role, Water Price

The issue of groundwater management remains a practical concern in many regions throughout the world, while water managers continue to grapple with the question of how to manage this resource. Groundwater constitutes about 89% of the freshwater on our planet (discounting that in the polar ice caps); hence, given the well-documented world water scarcity, it is one of the most important natural resources that we are challenged to manage. Many economists have relatively recently discovered that the problem of groundwater resource management is an important and interesting area for the application of the tools of economic theory and econometrics. At the same time, many water specialists from other disciplines have discovered that the language and tools of economics are helpful in furthering the understanding of water management problems. For these reasons, this branch of economics has developed rapidly in recent decades and is likely to continue to do so. The absence of intervention, groundwater is misallocated. Here we discuss the inefficiency of groundwater pumping in the absence of central(optimal) control and emphasizes that the estimates of the welfare loss under the common property regime depend on the particular model of firm behavior enlisted in the analysis. This allows us to conclude in favor of an existing potential and pressing need for the development and implementation of management policies for groundwater resources. When groundwater withdrawals exceed recharge, the resource will be mined overtime until either supplies are exhausted or the marginal cost of pumping additional water becomes prohibitive. The first implication of this is that a marginal user cost is associated with mining groundwater, reflecting the opportunity cost associated with the unavailability in the future of any unit of water used in the present. An efficient allocation considers this user cost, which effectively signals the in situ scarcity of the resource and is called the resource's scarcity rents. Hence, efficient pricing of are source that exhibits natural supply constraints incorporates both marginal cost of extraction and scarcity rents. Scarcity rents must be imposed on current users.

Given the difficulty of establishing clear groundwater ownership rights, scarcity rents frequently go unrecognized and are difficult to estimate. Ignoring scarcity rents means that the price of groundwater is too low and extraction is above the socially optimal level. In the absence of optimal dynamic management of common-pool groundwater resources, or, alternatively, in the presence of acompetitive extraction regime, Ignoring scarcity rents results in inefficient pricing and misallocation of the resource.

Economics deals with the allocation and use of scarce resources. As long as a resource is abundant, there is little need to take such decisions. As the resource becomes more scarce (due to quantity or quality constraints) questions about how to utilize and protect it (preferably for the best of society) arise. Economic considerations can help the decision-making process and promote more efficient resource use.

Groundwater tends to be undervalued, especially where its exploitation is uncontrolled. In this situation the exploiter of the resource (in effect) receives all the benefits of groundwater use but pays only part of the costs usually the recurrent cost of pumping (providing the energy input is not subsidized) and the capital cost of well construction, but rarely the external and opportunity costs. This undervaluation often leads to economically inefficient resource use.

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1. Costs of Ground Water Use

Costs of Groundwater Abstraction are of mainly two types- 1) costs paid by users and 2) full economic costs. The costs paid by users consist of two types of costs i.e. Capital cost and Operational & Maintenance cost. On the other hand full economic cost may be divided into three categories such as 1) Water supply cost 2) Social opportunity costs and 3) External cost. Water supply cost may be of three types i.e. a) Capital cost b) Operational & Maintenance cost c) Resource Admin cost. Social opportunity costs may be the Foregone value of Alternative users (present & future) and External cost is the In-Situ value (i.e. cost of saline intrusion, land subsidies, drought buffer etc).

The economic value of a resource depends on what one can do with it and on its relative scarcity compared to alternative resources. Thus the economic value of groundwater in a specific aquifer is derived from the use it can be put to, and from its local availability and quality compared to surface water. For instance, an aquifer in a region with abundant unpolluted surface water will generally have lower economic value than one in a region with polluted surface water or one in an arid region without alternative resources. The economic value of groundwater originates from the benefits that it generates the services that it provides. In many areas of the world, the economic value of groundwater is increasing, due to population growth and economic development (and thus increased water demand), due to pollution of surface water basins and, increasingly, due to climatic variability and the necessity of having a drought-secure resource.

2. Values of Groundwater

The economic value of a given groundwater resource is determined by its prospective use. In the absence of a market price for groundwater, economists often measure its value through user's ***willingness to pay*** for a given quantity and quality of supply. For instance, an industry that needs water as an input for car production will be willing to pay more per unit volume than a fruit farmer. The economic value of groundwater in the area concerned is thus determined by the willingness of industry to pay—up to the point that their demand is met. The economic value of the next volume used by the fruit farmer will be lower, but still higher than what a subsistence farmer would be willing to pay.

When 'willingness to pay' is not known (usually the case because groundwater markets revealing true price rarely exist), the ***residual value method*** can be used to value groundwater. This method values all inputs for the good produced at market price, except for the groundwater itself. The residual value of the good, after all other inputs are accounted for, is attributed to the water input.

Groundwater quantity and quality may affect the productivity of land as an input in agricultural production. Where this is so, the structure of land rents and prices will reflect these environmentally determined productivity differentials. Hence, by using data on land rent or land value for different properties, one can in principle identify the contribution which the attribute in question makes to the value of (willingness to pay for) the traded good, land. This identifies an implicit or shadow price for quality (or even quantity) attributes of groundwater. The method commonly used to implement this approach is the ***hedonic technique***.

The above are a selection of methods used by economists to determine the value of public goods such as groundwater, and while none are perfect they do provide guidance to decision makers on the valuation of groundwater resources and on possible courses of action. An important consideration in this regard is the distinction between short- and long-term benefits expected from groundwater use. Depending on the discount rate used to estimate the benefit stream from the use of groundwater, it may appear advisable to use the resource more rapidly or more slowly. Thus, the choice of a realistic discount rate is very important and needs careful evaluation.

3. Economic Instruments for Managing Groundwater

That relevant costs and benefits can be measured, but we discuss the pros and cons of the major economic instruments suggested and used for managing both groundwater extraction and pollution. In doing so, we should keep in mind that an economic approach to groundwater depletion and pollution assumes that relevant costs and benefits can be measured, but we discuss the pros and cons of the major economic instruments suggested and used for managing both groundwater extraction and pollution. In doing so, we should keep in mind that an economic approach to groundwater depletion and pollution assumes this is not easy. Moreover, it is not always clear who must comply with particular policy instruments, how their compliance, or performance, will be measured, and how to induce changes in behavior.

4. Instruments for Managing Groundwater Extraction

Theoretically, a tax can be used to restrain farmers from lowering the groundwater level below a certain standard. The effectiveness of a tax depends on the right estimation of the marginal tax level and on how risk averse farmers are with respect to damage from reduced water availability (both in quality and in quantity terms). A differentiated tax level has to be created, because of local differences in both the monetary value of reserves and vulnerability of the environment to changes in the groundwater level. An advantage of a tax is that it improves both economic and technical efficiency. Administrative costs are high, since a differentiated tax is not easy to control and monitor. The financial impact on affected parties depends on the restitution of revenues, which affects tax acceptability. Finally, there are practical implementation problems. It is hard to define a good basis for a tax. A volumetric tax on extraction is complicated, since it involves high monitoring costs. A tax on a change in the groundwater level is also complicated, because external and stochastic factors affect the level of groundwater, which is not uniform across any given aquifer. Charging water boards for lowering surface water levels will not influence an individual farmer's behavior, but it will affect strategy of groups of farmers represented in the governing body of water boards.

A subsidy is a reward for meeting a certain groundwater level, which is higher than the desired standard. Subsidies are not economically efficient; they create distortions and do not provide incentives for the adoption of modern technologies.

Acceptability, however, is not an issue, since participation in subsidy schemes is voluntary and has positive financial implications. Implementation problems are similar to those of a tax. Another prescription economists offer in the face of demand–supply imbalances is the introduction of water markets. Such institutions have the capacity to rationalize water scarcity, both qualitatively and quantitatively. Tradable rights improve economic and technical efficiency, since the market determines the price of the right in a dynamic way. The high demand for administrative institutions is a major disadvantage. The financial impact on affected parties and related acceptability depends on the initial allocation of rights. The use of tradable rights for groundwater seems to be complicated in practice, since the impact of changes in the groundwater level on agricultural production and nature depends on location-specific circumstances. To avoid transferring rights among areas with heterogeneous characteristics, trading has to be restricted. That is, on the one hand, the market approach is embraced, but on the other hand, we need a trade institution for guided trading. A legal groundwater standard or quota can also be introduced. It will be effective if farmers face substantial monetary penalties for lowering the groundwater level below this standard or not adhering to the quota. Standards and quotas do not improve economic efficiency and do not introduce incentives to innovate. The financial impact is not always equitably distributed among affected parties, since there are differences in the vulnerability of areas to changes induced by these instruments. Differentiated standards and quotas, however, will pose a large burden on the administrative capacity. Usually, serious resistance is raised against the introduction of these policy instruments.

The approach to environmental protection has been evolving from a regulation driven, adversarial 'government-push' approach to a more proactive approach involving voluntary and often 'business led' initiatives to self-regulate their environmental performance'. In this spirit, another policy option for controlling groundwater use is voluntary agreements between farmers and government organizations. Participation in such control programs is encouraged by means of positive incentives (a restitution of taxes). Such programs try to convince farmers (through education) of the advantages of fine-tuned groundwater control. Voluntary agreements on controlling groundwater use are efficient, since they rely on specialized knowledge of participants about local conditions. When costs and benefits are not equitably distributed among affected parties, both parties can bargain about compensation payments.

The allocation of such payments depends on the assignment of rights. Acceptability is not an issue, since it is a voluntary regime. Because of these advantages, participation of farmers in planning and decision-making at the local level is becoming more common. The principle of allowing the individual members of agricultural organization and water boards to make decisions on issues that affect them rather than leaving those decisions to be made by the whole group, the so-called principle of subsidiary, is widely accepted.

An indirect economic instrument for groundwater management derives from agricultural and food trade policies. Since most groundwater is consumed by irrigation, agricultural policies have a major impact.

For instance, subsidies encouraging highly water-intensive farming in semi-arid areas (e.g. rice or wheat cultivation) will provide an economic incentive to use groundwater. From an economic perspective, however, the allocation of groundwater to this type of consumptive use is not very efficient, and agricultural policy should better reflect the scarcity of groundwater resources. Moreover, international trade policy can have an indirect impact on groundwater use—for instance by creating barriers to the export of high-value agricultural products thereby confining production to local, often low-value, uses.

The introduction of economic instruments will depend on current hydrologic, economic, social and political conditions. The **feasibility analysis** should include an assessment of costs and benefits of each instrument and possible combinations. It should also take into account long-term recurrent costs and institutional capacity (for administration, monitoring, enforcement) and the transaction costs involved to set up systems. The expected costs and benefits would also influence the trade-off between the use of economic instruments and other groundwater management tools.

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