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WATER ALLOCATION: THE ROLES OF VALUE AND PRICES

CURT L. ANDERSON
JERROLD M. PETERSON

University of Minnesota—Duluth

ABSTRACT

Fresh water may no longer be considered as a free resource by society. The demands for water with reasonable quality characteristics have surpassed available supplies in many regions of the United States. This will likely lead to major changes in state and national water policy as the need to more effectively allocate the available water supplies becomes necessary. This article discusses some of the basic economic principles which may serve as guidelines for this allocation. In particular, the distinction between the value of water and the appropriate price of water are discussed as well as their roles in efficient water allocation.

Fresh water has long been considered to be a free resource. By definition fresh water is a free resource if it is so abundant that all users can have as much as they desire without depleting the resource or impinging on the use of others. In this case there is no economic problem and the implied price of water is zero. Fresh water, however, has long passed the point where all demands can be satisfied at a zero price in many southern and western states. Even in the supposedly water-rich states such as Minnesota demands are beginning to put pressures on existing supplies. For example, Minnesota currently receives between 1.1 and 2.0 trillion gallons of new water annually. By 1980 the Minnesota Department of Natural Resources had already issued permits for the withdrawal of 1.125 trillion gallons of this water.

In the near future the scarcity of fresh water in several states and the nation as a whole will likely lead to drastic changes in past state and national water

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policy as the need to more effectively allocate the available water supplies becomes clear. This article discusses some of the basic economic principles which may serve as guidelines for this allocation. In particular the distinction between the value of water and the appropriate price of water will be discussed as well as their roles in efficient water allocation.

To illustrate how the value of water may be determined and then used in deciding its allocation, suppose there are two major water users in some river basin, corn farmers and food-processing firms. The river provides the main source of water for these users. The food processers (who are assumed to be upstream from the farmers) use the water in the production of a particular food product while the corn farmers use it to irrigate their corn fields.

Water is clearly a vital input to both of these users. The more water that is available for crop irrigation, the greater the yield per acre the corn farmers can expect while the more water that is available to the food processers, the more food products they will be able to produce. Let the relationship between the amount of water used and these outputs be as shown in Table 1, Columns 1 and 2. As suggested above, larger amounts of water lead to higher levels of production in both industries. However, the numbers in Table 1 also reflect the well-established economic principle of diminishing returns; that is, as more of a single input (in this case, water) is added production tends to rise but less than proportionately. For example, the first units of water significantly improve corn yields as without them the crop could not survive at all. But additional units of water beyond these while helpful in terms of additional growth do not dramatically increase the yield as much (in fact, it is possible to use so much water that the yield may even fall). Column 3 illustrates how much additional food products and corn yield respectively each additional unit of water enables the production of. The numbers in this column decrease to reflect diminishing returns.

If we suppose each unit of the food product sells for a market-determined price of $2 while each unit of corn sells for $1, the value of the added output as additional units of water are used may easily be calculated as shown in Column 5 (Column 5 = Column 3 X Column 4). So, for example, adding the fifth unit of water to the corn fields increases corn production by ten units ("bushels") each of which may be sold for $1. Thus, this unit of water adds $10 to the revenues of the corn farmers.

The figures in Column 5 are important for two reasons. First, both the corn farmers and food processers will use these to determine the amount of water they desire to use. In particular, they will want to take any unit of water which adds more to their revenues than it costs to obtain that unit since this leads to maximum profits. Second, these figures are a measure of the value of the water as *they measure the value of the output produced for society by the water.*

If water is abundant so that all users may have as much water as they desire without depleting the resource, then there is no economic problem. In this case,

Table 1. Water Amount and Output

	(1)	(2)		(3)	(4)	(5)
	Acre Feet of Water	Number of Food Products Produced		Change in Amount of Food Products Produced	Price of Food Products	Value of Added Food Products (Additional Revenues Earned by the Food Processers)
	0	0	>	10	$2	$20
	1	10	>	8	2	16
	2	18	>	6	2	12
Food Processers	3	24	>	4	2	8
	4	28	>	2	2	4
	5	30	>	1	2	2
	6	31	>	0	2	0
	7	31				
	Acre Feet of Water	Corn Yield (in "Bushels")		Change in Corn Yield	Price of Corn	Value of Added Corn Production (Additional Revenues Earned by the Corn Farmers)
	0	0	>	24	$1	$24
	1	24	>	20	1	20
	2	44	>	16	1	16
Corn Farmers	3	60	>	12	1	12
	4	72	>	10	1	10
	5	82	>	8	1	8
	6	90	>	6	1	6
	7	96				

both the corn farmers and the food processers will take units of water as long as the additional revenues earned are positive (i.e., six units for the food processers and somewhere beyond seven for the corn farmers). But now let us consider the more important case of a scarcity of water. In particular, suppose there are but five units of water available for use and the water is still treated by society as a "free" (first come, first served) resource.

Because the cost of using the water is still essentially zero, the food processers, taking advantage of their upstream position, will take units of water as long as, again, the additional revenues earned from these units is positive. Since only five units are available and the additional revenues added by even the fifth unit is positive ($4), this means they will take all five units and no water will be available for use by the corn producers. Is this the best allocation or use of this water? To answer this we need to know what is meant by the "best."

Given the illustrated situation, the benefits to society are most easily measured by the total value of the output produced. So, the "best" allocation of the water would be that one which maximizes the value of the food products and corn produced with the scarce water. The point here is that the food processer's use of water will involve opportunity losses to society in the form of lowered corn yields. Only when the benefits of using a unit of water in food processing are greater than those when used in corn production should the unit be allocated to the processing firms. When the food processers take all the five units they produce thirty units of output which have a value of 30 X \$2 = \$60. To find the maximum value of the output flow that could be generated with this water, each unit of water should be allocated to its most valued use as measured by the value of the output produced. Thus, the first unit should go to corn production since it would generate corn valued at \$24 while only \$20 would be generated in food processing. The second unit of water can go to either user since \$20 worth of increased output (benefit to society) is generated by both. Continuing this procedure, the "best" allocation is two units to the food processers and three to the corn farmers which generates a total output flow valued at (18 X \$2) + (60 X \$1) = \$96. Clearly, this allocation is superior to the former since society gains \$36 (\$96 - \$60) additional benefits.

There are basically two approaches to bring about this desired allocation: 1) quotas or appropriation rights and 2) establishment of a price for water. Under the former approach each firm is given a mandate as to the maximum number of units it may remove from the water source (for example, two for the food processers and three for corn farmers). This mandate should be based on the value of the resource to each user as illustrated above. Under the latter approach a price for water is established which would induce the users to use the appropriate quantities. For example, consider a water price of \$15/unit. As before each user will desire additional units of water as long as the additional revenue generated by the units exceeds their cost (which is now \$15 instead of \$0). Thus, each user will buy water units at \$15/unit as long as additional revenue generated is greater than \$15. Note that this results in the same amount of water taken by each firm as in the quota system (also note that any price, p, such that $12 < p < 16$, would yield the same result). If more (less) water is available, the price may simply be adjusted downward (upward).

The principal advantage of using a water price to ration the limited water is that the value of the water in the alternative uses need not be known by the policymakers as under a quota system. Water will automatically be allocated to its most valued uses since those uses wherein the return from using the water is not sufficient to cover its price will not be willing to take the water. Thus, policymakers must simply adjust the price until the total quantity of water demanded by all users equals the quantity available. A disadvantage of using the price mechanism to allocate the water is that it may result in a competitive disadvantage for the users in their respective markets since an input (water) which was once free will now be costly to them. The quota approach avoids this problem.

The roles of value and prices in water allocation thus are clearly delineated. The *value* of the water resource in a particular use is equal to the benefit flow to society in terms of the output generated by the water. The "best" allocation is thus that allocation which maximizes the value of this output flow (each unit of water going to its most valued use). The proper *price* of water, on the other hand, is simply any price which brings this allocation about. In the above example when there are but five units of water, an allocation of two units of water to the food processers and three units to the corn farmers yields the maximum value of $96. A price of $15/unit would bring about this allocation although no price is needed if another rationing mechanism is used.

Note that in the original case of abundant water that while the implied *price* of water would be zero, the *value* of the water would be even larger than $96, since the food processers would produce thirty-one units (valued at $2/unit) while corn farmers would produce in excess of ninety-six units (valued at $1/unit). Thus, a zero price does not imply a zero value, but merely that no scarcity of the water exists.

When use of the resource is of a nonconsumptive nature, opportunity costs of its use may still not be zero due to possible changes in water quality and/or the fact that while the water is withdrawn it is unavailable for other uses at that time. Thus, much of the foregoing analysis may also be applied to nonconsumptive uses of the water resource.

Whatever rationing mechanism society chooses to allocate water, it is clear that the value of water in alternative uses is the key element in deciding upon the most desirable allocation. The determination of these values is in its early stages of development but empirical studies yielding relationships not unlike those illustrasted here have been undertaken. Moore and Hedges have estimated the net returns to additional acre-feet of water in irrigating fields in Tulare County, California [1]. Industrial demands for water (in terms of marginal valuation) have not been extensively studied but the work of Callaway, Thompson, and Schwartz provides an example of water demand for an ammonia plant [2]. Residential water demands have been considered by Linaweaver, *et al.* [3] and Hanke [4] both indicating quite a response to metered versus non-metered water use. Other water values such as the value of water in recreational uses such as water skiing, boating, and fishing are just now being considered as part of studies on the value of recreational benefits in general (Freeman [5], Chapter 8 provides a useful summary).

While the determination of water values is not an easy task, it is an important one in water policy, especially in those cases (such as recreational uses of water) where a price rationing scheme may not be possible or appropriate.

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Direct reprint requests to:

Curt L. Anderson
Department of Economics
165 School of Business and Economics Building
University of Minnesota, Duluth
Duluth, MN 55812