WATER PRICE RESPONSIVENESS AND ADMINISTRATIVE REGULATION—THE FLORIDA EXAMPLE

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Florida has an estimated 618 trillion gallons of fresh water in the aquifer system. In addition, there is a considerable amount of water in lakes, and annual runoff from streams (and underground aquifer seepage) has been estimated at 40 billion gallons [1, p. 9]. The annual runoff alone is seven times the withdrawal (about 14 percent) and 22 times the consumption (about 5 percent). A curious development has occurred in Florida, however, that would not have been expected by the reviewer of such aggregated figures. The general populace and, as a result, the legislators, became concerned enough with water management and use in the early 1970s to develop and implement sweeping water legislation. The nature of this legislation had not heretofore been observed in the southeast nor, for that matter, almost anywhere else in the eastern United States.[1] The Florida Water Act of 1972 [3] was enacted to deal with localized shortages that were developing in, and have been compounded since, the late 1960s. Florida's population was growing at a tremendous rate in the 1960s and early 1970s, reaching an increase (net) of over 7,000 people per week from July 1973 to July 1974 [16, p. 33]. In the four years after the 1970 Census, the growth rate was four times the national average [16, p. 32]. The result has been an unprecendented demand for Florida's water, especially in south Florida.

The Act has facilitated various actions toward alleviating shortages and resolving conflicts. As a result of the Act, an administrative water law system has been imposed on top of the riparian system [17, p. 2]. The administrative system is still evolving in Florida. It is evident, however, that the effect of the Act was to declare the water to be owned by the people; water is to be managed in the public interest [3, Part 1, Sect. 2(2)].

In effect, a system has been developed whereby the state has control of the development, allocation and management of the water resource. The technical staff of each water management district serves as a central planning group that recommends alternatives to an appointed governing board. In turn, the governing board of each district makes decisions regarding the allocation of water to "reasonable-beneficial" uses, in light of public interest.[2]

The objectives of the state, with respect to water management, are many and varied. Certainly there is a multiple objective function involved if the state is to "... promote the health, safety, and general welfare of this state" [3, p. 3] in addition to insuring that waters are "... conserved or fully controlled to realize their full beneficial use" [3, p. 3]. In fact, a state water use plan is to be formulated with "... due consideration given to (among others) ... the maximum economic development of the water resources consistent with other uses" [3, p. 3]. Some tradeoffs, obviously, will have to be made.[3]

While economic efficiency considerations are a concern in the Act, actual water allocation rules based on non-economic criteria have evolved. These rules will have significant impacts on efficiency and

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[1] There is one exception: A similar law was passed in Iowa in 1957.

[2] More detail is needed for a full understanding of the framework created with the Act. The reader is referred to Kiker and Lynne [6], Wadley [17] and Maloney [11].

[3] See [9] for the pitfalls involved in trade-off calculations between economic efficiency and other goals in water management and development, as well as a further discussion of multiple objective functions.

distribution of benefits and costs from water use. Technical-political based allocation rules are being used in the Florida system.[4] It is well known by economists, of course, that arbitrary (from an economic perspective) decision rules will yield economically efficient allocations only by accident. What is not generally known is the difference in elasticities of demand among competing uses and users, which influences the nature of impacts from such allocation rules. It is the primary purpose of this paper to provide insight regarding the relative magnitudes of these demand elasticities. A secondary purpose of the paper is to highlight expected impacts from such technical-political based allocation rules. It is argued that knowledge of relative elasticities is also important under such rules. The Florida experience will be useful to other humid states in the East and Southeast in the switch to administrative law.

ELASTICITY ESTIMATES

Demand elasticities were developed for competing uses in the Miami Standard Metropolitan Statistical Area (SMSA). This area, which is Dade County, draws water from the Biscayne aquifer, one of the most productive (and highly managed) aquifers in the world [2, p. 52].[5] Irrigated agriculture accounted for 16 percent and domestic-commercial use about 80 percent of all water withdrawals in the Miami SMSA in 1970 [14, p. 18]. Industrial use is minimal in the area; thus, elasticity estimates were not developed for this group.

RESIDENTIAL DEMAND

A residential water demand study was accomplished for the area in 1974, the details of which are outlined elsewhere [4]. The price elasticity of demand from that study is given by:

$$E_r = -1.8511P_w$$

At the average price of \$0.28 per thousand gallons [4], elasticity is −0.52. Residential water demand becomes price elastic at P_w = \$0.54 per thousand gallons. The demand equation presented in Gibbs and Andrew [4] was developed from recognition of the major properties of a consumer demand model; residential water demand was a function of price, income, seasonal effects, household technology and size of the household. These variables are suggested from consumer demand theory. The aggregate demand for the Miami area was developed in Lynne and Gibbs [8] and is illustrated in Figure 1, based on population (census) statistics for 1970.

COMMERCIAL DEMAND

Commercial water demand elasticities for the Miami SMSA were estimated by Luppold [7] and this author. The theory of derived demand provided the framework for that study. It was reasoned that each commercial establishment has a "production function", with water one of the inputs into the provision of the goods and/or services from such businesses. It was hypothesized that water use would be responsive to price. An extensive literature search failed to reveal any commercial water demand studies where this hypothesis had been tested. The possible impact of water price, while discussed, was not quantified in one study [10]. Other studies simply did not mention price considerations [5, 12, 13, 19]. Conclusions of the Luppold study lend support to a contention that water price is a significant variable, and could be used in affecting quantities purchased [7].

Models were developed for department stores, grocery stores, eating and drinking establishments, and hotels and motels.[6] A total of 308 observations were collected from businesses in the Miami SMSA with a mail questionnaire and 93 observations from secondary sources.[7] The water use and prices were collected directly from 15 water companies. The resulting models are presented in Table 1. The aggregate commercial demand is illustrated in Figure 2 based on 1970 population statistics. Price of water (P_w) was a "highly" significant variable in all but the equation for eating and drinking establishments; P_w was significant at the 0.30 probability level for that case (standard errors in parentheses below coefficients). Area of the store (or subsections thereof) was also found to be significant at fairly high levels in all cases.

Elasticity estimates (Table 2) ranged from −0.12 for the hotel-motel group to −1.33 for the department store group, at the mean prices (and quantity in the case of eating-drinking establishments). These are

[4] See Kiker and Lynn [6] for more discussion of current rules.

[5] Water is a "flow" resource (as opposed to a "stock") in this aquifer. The level of the aquifer is regulated by water releases from Lake Okeechobee in the southern portion of the state. The aquifer is very porous, making it an easily filled, large underground storage reservoir.

[6] A model was also developed for "other" commercial establishments, which included several other types in one model. The results were erratic, with sign reversals and insignificant variables.

[7] A few observations were also collected from the Keys area of Florida which pumps water from the same aquifer, in order to obtain a wider range in price. The price was \$3.00 per thousand gallons in that area, giving a range of \$0.30 to \$3.00.

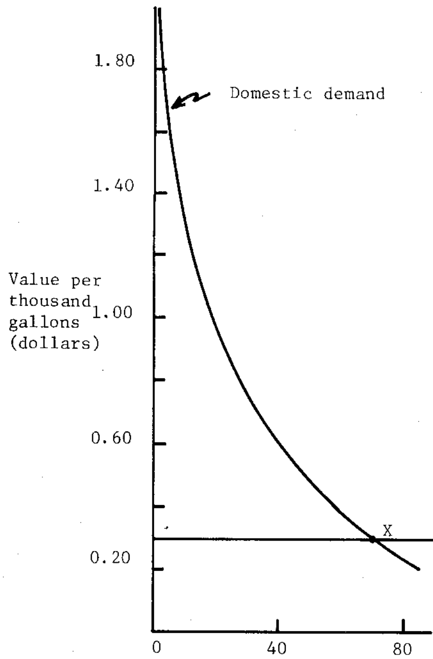

FIGURE 1. RESIDENTIAL WATER DEMAND, MIAMI SMSA (DADE COUNTY)

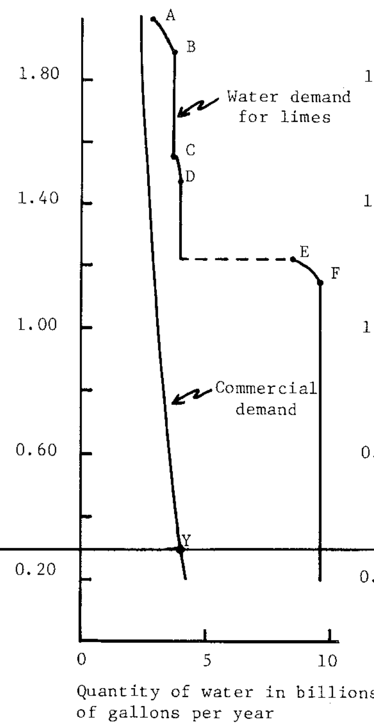

FIGURE 2. COMMERCIAL AND AGRICULTURAL WATER DEMAND, (DADE COUNTY)

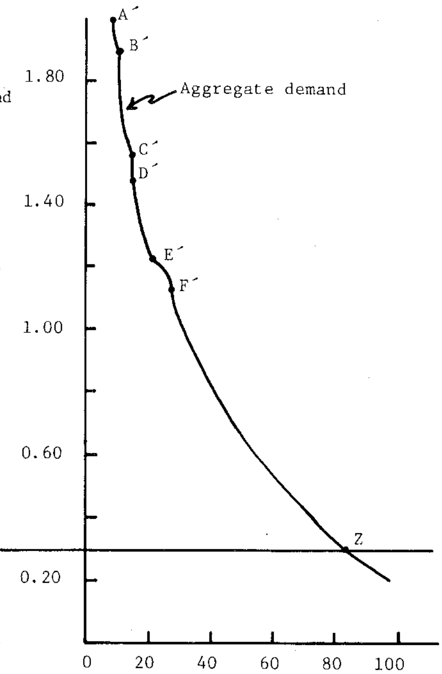

FIGURE 3. AGGREGATE WATER DEMAND, MIAMI SMSA (DADE COUNTY)

TABLE 1. COMMERCIAL WATER DEMAND MODELS, MIAMI SMSA, 1975-76

$$\ln W_1 = \underset{(1.017)}{1.3960} + \underset{(0.158)}{0.6489} \ln A_s + \underset{(0.0002)}{0.0004} A_r - \underset{(0.231)}{1.0704} P_w$$

$\bar{R}^2$ (adjusted)[a] = 0:78   n = 20

$$\ln W_2 = \underset{(0.2350)}{2.8876} + \underset{(0.001)}{0.0036} A + \underset{(0.257)}{0.9837} B - \underset{(0.143)}{0.7191} P_w$$

$\bar{R}^2$ = 0.73[a]   n = 19

$$W_3 = \underset{(32.701)}{-20.1555} + \underset{(3.323)}{10.8750} \ln(HA_e) + \underset{(3.160)}{7.9186} \ln(HA_d) + \underset{(0.124)}{0.0334} V - \underset{(16.822)}{14.2643} P_w$$

$\bar{R}^2$ = 0.25[a]   n = 24

$$\ln W_4 = [\underset{(0.282)}{3.2500} + \underset{(0.005)}{0.0242} R + \underset{(0.014)}{0.0228} P_r - \underset{(0.052)}{0.1140} P_w]$$

$\bar{R}^2$ = (model was adjusted for heteroscedasticity)[b]   n = 93

Variables defined as:

- W_i = thousands of gallons purchased per month; i=1, department stores; i=2, grocery; i=3, eating and drinking establishments; i=4, hotels and motels area;
- A_i = area; A_s = area of store in hundreds of square feet, A_r = area of restaurant in square feet, A_e = area of eating space in tens of square feet, A_d = area of drinking space in tens of square feet
- B = 0-1 dummy; 1 if bakery present in store
- H = hours open per week
- V = value of residence in census block where establishment is located
- R = number of rooms
- P_i = price of item i; P_r = price of room; P_w = price of water (measured at the margin)

[a]Adjusted for sample size and number of variables. Standard errors are in parenthesis.
[b]R^2 is no longer valid.

TABLE 2. AVERAGE PRICES, QUANTITIES AND ESTIMATED ELASTICITIES BY MAJOR TYPES OF COMMERCIAL BUSINESSES, MIAMI SMSA, 1975-76

Type Business	Elasticity Equations	Averages[a] Price	Quantity per Month	Estimated Elasticity at Mean Value of Variables
		Dollars per thousand	Thousands of gallons	
Department Stores	$-1.0704\ P_w$	1.24	179.0	-1.33
Grocery Stores	$-0.719\ P_w$	1.06	41.7	-0.76
Eating and Drinking Establishments	$-14.2643\ (\frac{P_w}{W})$	0.66	53.4	-0.18
Hotels and Motels	$-0.114\ P_w$	1.02	297.0	-0.12

[a]Averages for the sampled firms in each group.

long-run elasticities because cross section data was used. It is apparent the differences in elasticities among business establishments are significant enough to warrent their consideration in price policy formation. More will be said on this later.

Agricultural Demand

Agricultural water demand equations for Dade County were developed by Williams [18] and this author. Data were collected with farm surveys (personal interviews) during 1975-76. Limes, avocados and tomatoes accounted for 33 percent of crop acreage during this period. The tomato crop represented about a third of the state production; all the commercial lime and avocado orchards in Florida are in the county. A great variety of other vegetables are also produced there. This area is the prime winter vegetable region in Florida. Also, nearly all crops in the county are irrigated. Supplemental water is necessary for a viable agricultural industry.

There is no "market" for agricultural water, of course. Therefore, it was necessary to estimate production functions and "derive" the demand curves for water. Production functions were estimated for tomatoes, limes and avocados. Statistical and data related problems developed in the case of tomatoes and avocados [18]; thus, only the water demand for limes is presented here, so as to facilitate some comparisons of the elasticities among major types of uses (commercial, agricultural, residential).

The primary concern in the estimation process for the lime production function was to isolate the effects of the water variable on output. It was hypothesized that firm size and drip irrigation shifters would be significant, as well as (non-irrigation) variable costs (VC), in removing variation not directly related to the water variable. The resulting standard error on the water variable was of such magnitude as to make the regression coefficient significant at the 0.10 probability level. Some of the variables were significant at much lower levels; they were still retained because it is expected these variables are relevant in lime production [18]. The regression coefficient on variable cost (VC) was significant at only the 0.50 probability level.

The production function form shown in Table 3 was selected from several others. It was hypothesized only that the marginal product of water was positive and declining over some region. The reciprocal function (with respect to water) was chosen from several tried. It is a most reasonable choice for the study area, because of the highly permeable Rockdale (crushed rock) soils. Additional quantities of water added beyond those giving a maximum yield would not reduce yield appreciably. The resulting marginal value product in relation for water has both increasing and decreasing regions.

The aggregate demand curve represented in Figure 2 for limes grown in the area (about 4700 acres) was developed using the marginal value product relation in Table 3. Average (of the total) variable costs incurred per firm were used. Thus, the "typical" or average firm was used in the aggregation process. Data on number of firms in each size category were obtained from county extension personnel. The demand curve is considered in "long run" relation.[8]

Elasticity estimates were found to vary over the extent of the demand curve (depicted in Figure 2). The demand curve was perfectly inelastic for all prices[9] less than $1.15 per thousand gallons (Table 4). Demand was perfectly inelastic again for all prices between $1.22 and $1.46; however, from a price of $1.15 to $1.22, demand was found highly elastic. For values above $1.46, demand was first very inelastic, becoming elastic again at a value of about $1.88 per thousand (Table 4). The resulting water demand curve for limes in "kinked" in several locations

TABLE 3. AGRICULTURAL WATER DEMAND FOR LIME PRODUCTION, MIAMI SMSA (DADE COUNTY), 1975

$$\ln q = \underset{(0.954)}{6.9569} + \underset{(0.153)}{0.2515} \ln DM - \underset{(0.989)}{0.2346} \ln DL + \underset{(0.545)}{0.1051} \ln D1 + \underset{(0.140)}{0.1296} \ln VC - \underset{(57.575)}{116.886} \frac{1}{W}$$

$\bar{R}^2 = 0.42^a$ $\quad n = 16$

$$MVP_w = 1{,}060{,}125.3\ (DM)^{0.2515}\ (DL)^{-0.2346}\ W^{-2} \exp(-116.886 W^{-1})$$

Variables defined as:

q = boxes of limes per acre

DM = 1-e "dummy", value of e = 2.71... for medium size firms

DL = 1-e "dummy", value of e = 2.71... for large firms

D1 = 1-e "dummy", value of e = 2.71... for drip irrigation systems

VC = all non-irrigation variable costs per acre

W = total water received from rainfall plus water pumped in acre inches (per acre)

MVP_w = marginal value product of water at D1 = 1, average VC = $1,046, and lime price of $3.50 per box. The MVP_w divided by 27.15 gives MVP_w per thousand gallons.

[a]Adjusted for sample size and number of variables. Standard errors are in parentheses.

[8]The "long run" is defined in the agricultural water demand function for a typical firm. Stated somewhat differently, the demand curve for water was derived from the estimated production function given the variable cost levels typical, or average, in the area. The production function is long run in nature due to cross section data used in the estimation process. Thus, the agricultural water demand is directly comparable with the others.

[9]It was suggested by an anonymous reviewer of this paper that it was inappropriate to consider "prices" in the case of agricultural demand because there are no markets for the water. While this is true, I have chosen to retain the "price" terminology in lieu of using the cumbersome "marginal value productivity of water" phraseology. The agricultural demand curve in Figure 2 reflects the marginal willingness (at least capability) to pay for water, or "value" of water.

TABLE 4. ELASTICITY ESTIMATES, WATER DEMAND IN LIME PRODUCTION, DADE COUNTY, FLORIDA, 1975

Price or value $/1,000 gallons	Water per acre acre inches	Total Water Used Acre feet	Million gallons	Elasticity Estimate
1.15	75	29,375	9,572	
				-1.13
1.19	70	28,220	9,195	
				-2.44
1.21	65	27,064	8,819	
				-5.17
1.22	60	25,909	8,442	
1.46	75	12,044	3,924	
				-0.24
1.50	70	11,965	3,899	
				-0.32
1.53	65	11,888	3,873	
				-0.51
1.55	60	11,809	3,848	
1.88	75	10,869	3,542	
				-2.51
1.93	70	10,144	3,306	
				-3.45
1.97	65	9,420	3,069	
				-7.58
1.99	60	8,695	2,833	

(Figure 2).[10]

The demand elasticity was higher than is generally expected of agricultural crops. The finding that water demand in lime production is elastic over some ranges has significance to water managers who generally assume agriculture has fixed "needs" of water per acre. Of course, the demand curve is perfectly inelastic at water levels of 2.8, 3.8 and 8.4 billion gallons. These are points where the evapotranspiration (ET) "needs" are satisfied.[11]

ELASTICITY COMPARISONS AND IMPLICATIONS FOR POLICY

The current administrative system in Florida relies on quantity allocation procedures. Under requirements of the 1972 Act, permits are given under a "reasonable-beneficial" use criterion. In practice, for agriculture, long-term permits are given for the evapotranspiration requirement for crops if this amount does not exceed runoff from the area. The permit assignment and allocation rules for such long-term commitments to other types of uses and users are similarly devoid of economic considerations. It is the contention of this author that elasticity estimates are crucial data to this type of system, even if markets are not involved.

Assume, for example, the system was in "equilibrium" at such quantities as to give an implicit price of $0.30 per thousand, as illustrated by points X, Y and Z in Figures 1, 2 and 3. An "across-the-board" reduction (for example, 15%, which was recently required in one of the Florida water management districts [14]) would obviously have substantial efficiency[12] (and distributive) impacts on agriculture and commercial users. The "implicit" or "shadow price" will rise substantially for agriculture (lime production) and commercial uses as compared to the impact on domestic use. This, of course, is due to differences in elasticities. The system would be placed out of equilibrium by such a quantity change. It is also obvious the impact on economic rents and consumers surplus (distributive impacts) will be considerably different among the groups, for any change in quantity allocations, dependent upon the relative elasticities. One, of course, could calculate the dollar impacts of various allocation strategies given knowledge of the demand curves and the elasticities. This would be valuable information to the central decision-making body of the water regulatory agency.

In the world of water regulation and management, it may not be feasible to estimate the demand curves for very different type of water use in a region.[13] Thus, while necessary to proper quantity allocation under administrative law regulation systems (assuming economic efficiency important), it may not be realistic to expect that central decision-making bodies be aware of relative elasticities.

A similar problem arises if the central decision-

[10] This was due to the nature of the aggregation process and the function estimated. Different farm size categories were found to have different demand curves, regions AB for medium size, CD for small, and EF for large. Sample statistics supported an assumption that small, medium and large producers had control of 4, 37 and 59 percent, respectively, of the 4700 acres. The discontinuities in the aggregate demand curve, then, reflect these assumptions. Movement from point D to point E, for example, entails irrigation water being used by the largest operators (who had the lowest MVP_W), in addition to water being used by the medium size operators (region AB) and by the small operators (region CD).

[11] It was also found the marginal factor cost of water (MFC_W) was near zero at water levels near the ET rate, suggesting the lime growers using ET levels of water were quite "rational." The MFC_W was estimated from the first derivative of a total water cost regression equation where water applied was the independent variable, along with "dummy" shifters for the type of irrigation system [18]. The MFC_W was highest for "big gun" sprinklers, followed by permanent sprinkler systems, and drip irrigation systems.

[12] One could debate whether economic efficiency is in fact a goal of water management personnel charged with implementing the 1972 Florida Water Act. Research should be initiated to discover their goals, as well as that of the society (in Florida) at large. Be that as it may, it is my contention that economic efficiency impacts should at least be considered in the decision calculus. A decision-making body (of water managers) should highlight the economic efficiency impacts of their decisions. This appears to be the intent of the 1972 Act: "economic development," "efficiency" and "optimum water management" pervades the text of the Act.

[13] One would have to estimate the production functions for all agricultural crops in the area, for example.

making body was able to set price, rather than quantity, faced by particular groups. Elasticities must also be known under this type of management scheme. To illustrate, assume all three user groups were competing in a market for water, with the current price at $1.20 per thousand gallons. Elasticity at this price is −0.27 in commercial demand, −2.44 in agriculture (lime production), and −2.22 in domestic use. If the price were increased by the central decision-making body, the impact would be greatest on quantity demanded for agriculture, followed by domestic use and commercial use. At a lower price, such as $0.30 per thousand, elasticity is about −0.06 for commercial use, zero (perfectly inelastic) for agriculture, and −0.56 for domestic use, suggesting a price increase would affect the greatest percentage quantity reduction in domestic use with no changes in quantity by agriculture. The resulting levels of purchases would be efficient (after price change), but the distributive impacts would be considerably different, dependent on the starting point, because of elasticity differences. Thus, the central decision-making body must also know elasticities if a "price fixing" strategy were followed.

If, indeed, costs of developing such elasticities and knowing the demand relations over all time and space are too high relative to possible benefits, what can be done to introduce some efficiency into an inefficient regulatory allocation system? One answer has already been presented and discussed in this *Journal* [6]. It was argued a market could be established for water in Florida (and in other humid eastern states). The central decision-making body could be an active participant in this market, with purchases and sales to facilitate changes in resource allocation and distribution. Responsiveness of the various user groups to price changes would, thus, be revealed over time as the market operated. The central decision-making body would eventually learn how much water would have to be purchased or sold to realize different efficiency and distributive goals (or other non-monetary goals), simply by active participation in the market place. While knowledge of the actual demand curves for all possible uses would be useful under this system as well, such knowledge would not be as crucial as it is under quantity allocation or price fixing strategies for allocation of the resource. Also, elasticity estimates would be easier to obtain if there was an active market for the water.[14]

SUMMARY AND RECOMMENDATIONS

Florida's administrative water system, created with the 1972 Florida Water Act, is evolving. Demand pressures on the water resource have revealed a felt need to allocate and manage water in the public interest. Technical-political based allocation rules are being developed and used. Obviously, such rules will lead to economically efficient allocations only by chance. Also, goals regarding distribution may not be met unless elasticity considerations are included. It is the contention of this author that knowledge of demand elasticities is crucial even if markets are not in operation. Some insights into the relative magnitudes of the elasticities of demand among commercial, agricultural and domestic uses were provided for the Miami Standard Metropolitan Statistical Area (SMSA), coincident with Dade County, Florida. It was shown that commercial establishments are responsive to price (in an inelastic manner) and that irrigation water demand elasticity, at least for some agricultural crops, may be greater than generally expected. Price responsiveness was shown to vary greatly over the extent of the demand curve for water in lime production.

It was argued further that it may not be realistic to expect that demand curves (and elasticities) be estimated for all types of uses in a hydrologic region. It may be especially expensive, for example, to determine all the production functions for all agricultural crops grown in an area. Such demand elasticities must be known, however, whether quantity allocation or price setting strategies are used to allocate water. Thus, there is a dilemma. One alternative that should be seriously considered in administrative allocation systems is to incorporate some elements of a market such as discussed elsewhere [6]. While demand estimates and knowledge of elasticities would also be useful in such a system, the decision-making bodies do not have to know *a priori* the relative magnitudes. Rather the central decision-making body can learn, over time, the impacts of their decision to buy or sell water merely by observation. Short of availability of a market, the administrative law based water regulatory agency and its appointed decision-making body are doomed to either incorporating a great deal of inefficiency into the allocation process or to expending a great deal of money to accurately estimate the relative elasticities and demand curves for all competing uses and users.

[14] In the case of agriculture, for example, one is forced to estimate the production functions (because of no market data on water "demand"), which is very costly.

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