PROJECTIONS OF WATER REQUIREMENTS IN THE ECONOMICS OF WATER POLICY[1]

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1. *Objectives*

THE meaning of water demand in the professional language of the economist is rarely identical with that of water requirements as used commonly in the extensive literature on water development. My first objective is to clarify the relation between these two concepts and to draw conclusions about the significance of this relation for water policy.

The second objective is to review the logical validity of projecting water requirements into the more distant future—let us say for a decade or more. The intent is not to suggest that one might dispense with long-range economic projections in water policy. Rather, I should like to inquire into possible differences in the logical validity of different kinds of projections. If it can be shown that there are such differences, greater weight in decision making and greater statistical effort should be given to those kinds of projections, the logical validity of which appears greater.

The third objective is to appraise the relevance of projections of water requirements for purposes of water policy. Superiority of a projection in logical validity does not necessarily also mean superiority in usefulness for policy. This objective requires a sketch both of the goals and the tools of water policy. Economists usually refer to the goals as quantitative optima in water allocation and development. As to the tools, one gets the impression from the current rash of optimizing literature that quantitative methods and high-speed computers are the most important ones. Although it may not be popular, I should like to explore whether the study of systems other than the quantitative ones currently in vogue may not be necessary—and sometimes even sufficient—for identifying and implementing goals of water policy.

2. *Water Requirements in Relation to Water Demand*

It is elementary economics that the essence of demand and supply concepts consists of the functional relation—and its changes over time—between prices and physical quantities. In the numerous projections of water

[1] Giannini Foundation Paper No. 193. Presented before the Western Resources Conference held at the University of Colorado, Boulder, Colorado, August 22-26, 1960. The assignment for this paper was to develop, from the standpoint of water policy, certain ideas broached earlier in: S. V. Ciriacy-Wantrup, "Conceptual Problems in Projecting the Demand for Land and Water," *Modern Land Policy*, ed. Harold G. Halcrow (Urbana: Univ. of Illinois Press, 1960), Chap. 3, p. 449.

requirements, this functional relation is scarcely, if at all, considered.[2] On theoretical grounds, supported by somewhat meager evidence, we may assume that the price elasticity of the demand for water is small within the relevant range for each major water use such as domestic, industrial, agricultural, and recreational. In spite of this small price elasticity, there are several reasons why insufficient consideration of the price/quantity relation leads to an upward bias in projections of water requirements.

In the first place, the elasticity concept is a proportional one. There is little doubt that proportionally the upward changes of water prices that can be expected in most parts of this country and the world will be large. In the past, water has been used without or with only a nominal charge per unit. The economic, institutional, and technological factors responsible for this have recently been investigated.[3] Some of them will be touched upon later. Costs of water development have been covered through various forms of taxes, special assessments, and fees. While a portion of the water bill will continue to be met in this way, there is an upward trend in the portion covered by prices and some economic argument for continuation of this trend. In other words, the expected upward movement of water prices starts at low—sometimes zero—levels. Increases will be large proportionally. With such large proportional changes of prices, even small

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[2] U. S. President's Water Resources Policy Commission, *A Water Policy for the American People* (Washington, 1950), vol. 1.

U. S. President's Materials Policy Commission, *Resources for Freedom* (Washington, 1952), vol. 5, 154p. (Selected Reports to the Commission.)

U. S. Congress, Senate, Select Committee on National Water Resources, *Water Resources Activities in the United States: Land and Water Potentials and Future Requirements for Water,* Comm. Print No. 12, 86th Cong., 1st Sess., S. Res. 48, 1960, 73p.

U. S. Congress, Senate, Select Committee on National Water Resources, *Water Resources Activities in the United States: Estimated Water Requirements for Agricultural Purposes and Their Effects on Water Supplies,* Comm. Print No. 13, 86th Cong., 2d Sess. (i.e., 1st Sess.), S. Res. 48, 1906, 24p.

U. S. Congress, Senate, Select Committee on National Water Resources, *Water Resources Activities in the United States: Future Needs for Reclamation in the Western States,* Comm. Print No. 14, 86th Cong., 2d Sess., S. Res. 48, 1960, 45p.

State of California, Water Resources Board, *Water Utilization and Requirements of California,* State Water Res. Bd. Bull. No. 2 (Sacramento, June 1955), vol. 1, 227p., and vol. 2, 358p.

Edward A. Ackerman, "Water Resource Planning and Development in Agriculture," *J. Soil and Water Conservation,* vol. 14, no. 3, May, 1959, pp. 112-17.

John D. Black, "Resources Needed in American Agriculture," *J. Farm Econ.,* 39: 1074-86, Dec. 1957.

Colin Clark, "Afterthoughts on Paley," *Rev. Econ. and Stat.,* 36:267-73, Aug. 1954.

Edward S. Mason, "Afterthoughts on Paley: A Comment," *Rev. Econ. and Stat.,* 36: 273-78, Aug. 1954.

[3] M. F. Brewer, *Water Pricing and Allocation with Particular Reference to California Irrigation Districts,* Univ. of California, Giannini Foundation Mimeo. Rept. No. 235 (Berkeley, October 1960), 149 p.

elasticities of water demand—let us say around −0.10—lead to considerable absolute changes in quantities.

In the second place, given a sufficient period of time, price elasticity of demand for an aggregate of water uses may be considerable if quantitatively important uses are priced out of the market. For example, rising water prices may force a curtailment of irrigated agriculture in favor of domestic, industrial, or recreational uses. In agriculture, large quantities of water are used with relatively low average value productivities. At this point, I am not interested in the social welfare aspects of such price-induced shifts between major water uses. I am merely suggesting that projections of water requirements already imply policy decisions with respect to water pricing and water allocation among major uses. Since water requirement projections in most studies are to serve as a basis for policy decisions, this point is significant.

If projections are to serve as a basis for water policy, separation of the demand (ends) and the supply (means) aspects of water development becomes conceptually necessary and, in empirical investigations, variables pertaining to demand must be differentiated from those pertaining to supply. Water requirements, on the other hand, are usually identified with water use and are statistically determined by extrapolating past trends in per-capita consumption for domestic and industrial use and in irrigated acreage and water duty per acre for agricultural use. For these trends, changes in supply variables are no less significant than changes in demand variables. For example, the great increase of water use in the 17 western states since 1940 is largely based on ground water development for which changes in pumping technology and relative price decreases of important inputs—such as power—and a favorable water law—if based on the correlative rights doctrine—are responsible. Overdraft on ground water, on the other hand, has led to increased costs of pumping. Furthermore, in many basins, ground water development is identical with ground water mining. Extrapolating water requirements on the basis of past use appears especially hazardous for ground water.

I do not want to leave the impression that separation of demand and supply in water economics is a simple matter, conceptually or empirically. The example just mentioned is an illustration. Water in agriculture is an input and demand for water is derived demand. A meaningful demand function for one input requires reference to prices and quantities of complementary and competing inputs. Power is an input that is used for many purposes besides ground water pumping. Technology in water application is closely related to the technology of applying other inputs, for example, fertilizer. In such cases, changes of prices and quantities of other inputs affect both water supply and water demand at the same time.

The difficulties of separating water supply and demand are especially great if one considers aggregates. This is due to the structure and the functioning of the "water market." Clarification is needed here in view of some current misconceptions.

It is not sufficiently appreciated by most economists that the largest part of aggregate water use is self-supplied by individual water users. Decisions about production and use of water are internal. Such decisions are not expressed through the firm's behavior in a water market. Hence, market-oriented economic concepts have more limited analytical significance for explaining and evaluating the behavior of water-producing and water-consuming firms than is true for other fields of economic inquiry. This holds both for agricultural and nonagricultural uses of water.

According to the 1950 census, 47 per cent of the irrigated acreage in the United States (58 per cent in California) was supplied by single-farm irrigation enterprises.[4] Of the industrial use of water in the United States and in California, 97 per cent was supplied by individual company systems.[5]

The second largest part of aggregate water use was supplied by water users themselves, cooperatively through nonprofit water organizations such as mutual water companies and public districts. In the United States, 28 per cent (in California, 12 per cent) of irrigated acreage was supplied by mutual water companies.[6] The corresponding figure for public districts is 18 per cent (25 per cent in California).[7] Regarding domestic water use, 87 per cent of a population of 79,000,000 in communities of more than

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[4] Developed from data given by the U. S. Bureau of the Census, *U. S. Census of Agriculture: 1950, Irrigation of Agricultural Lands, The United States* (Washington, 1952), vol. III, Table 16, p. 58, and U. S. Bureau of the Census and U. S. Agricultural Research Service, *U. S. Census of Agriculture: 1954, Irrigation in Humid Areas, A Cooperative Report,* Spec. Rept. (Washington, 1956), vol. III, part 6, Table 14, p. 86.

[5] These data are developed from data given in U. S. Bureau of the Census, "Industrial Water Use," *U. S. Census of Manufacturers: 1954,* Bul. MC209 (Supp.) (Washington, 1955), Table 1, pp. 209-2 and 209-3; Table 2, pp. 209-4 and 209-5; Table 6, pp. 209-18 and 209-19; Table 7, pp. 209-20, 209-21, 209-26, and 209-27; Table 8, pp. 209-28 and 209-29; Table 9, pp. 209-30 and 209-31. Water supplied includes fresh, brackish, and mine water but excludes the quantity of water necessary if there were no recirculation. An insignificant proportion of this supply is provided by combination systems and sources not specified. Steam electric plants account for 80 per cent of the industrial water use in California and 67 per cent in the United States. Steam electric plants use 87 per cent of the total brackish water used in industry in California and 77 per cent in the United States. Brackish water in the above tables is not differentiated on the basis of supplying systems. In our computations, brackish water is counted as supplied by company systems. If steam electric plants are excluded from industrial water use, 85 per cent was supplied by company systems in California and 86 per cent in the United States. (See also footnote 19.)

[6] U. S. Bureau of the Census, *U. S. Census of Agriculture: 1950 . . . ,* and U. S. Bureau of the Census and U. S. Agricultural Research Service, *U. S. Census of Agriculture: 1954. . . .*

[7] *Ibid.*

25,000, covered by a survey of the U. S. Public Health Service in 1957, was supplied by water systems owned by municipalities or municipal water districts.[8] A comparable figure for California is 89 per cent.[9] All of these water organizations have in common that, in their formation, operation, and growth, water consumers have a direct and significant influence that is outside the demand-supply mechanism of a market. In many respects, the factors affecting decision making in these organizations are similar to those affecting self-supplying firms.

Only a small part of the aggregate water supply is produced for sale by profit-seeking firms. Most of these in turn are regulated by state public utility commissions. In the United States, only 3 per cent of the irrigated acreage is supplied by such firms. In California, the corresponding figure is 4 per cent. Of industrial water use, only 5 per cent is supplied by such firms in the United States and 3 per cent in California. Of municipal water use, the data in the above-mentioned survey indicate that only 13 per cent of the population surveyed is supplied by privately owned systems in the United States and 11 per cent in California.

Seasonal and permanent transfers of water between individual firms and between water organizations occur. In special cases, for example, if water consumers are owners of mutual water companies, seasonal water transfers show market characteristics.[10] Permanent transfer is generally in terms of water rights and is governed by water law. Water exchanges (differentiated by time and location) are not uncommon. They are individual transactions and usually do not involve pecuniary considerations. But they are potentially important for increasing efficiency of water allocation with respect to time, location, and uses. More research is needed on the social performance of these transfer mechanisms. But it is already fairly clear that there is little meaning in speaking of aggregate water demand and supply in the sense of a market in which water-supplying and water-demanding industries meet.

This situation raises a question with respect to the analytical contribution of the term "water industry" that has become popular recently. The problems of water economics, I submit, are more those of the organization and management of self-supplying firms and of governments at all levels than those of an industry as the term is used in economic theory.

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[8] John R. Thoman and Kenneth H. Jenkins, "Inventory of 1956 Water Supply Facilities in Communities of 25,000 and Over," *J. American Water Works Assoc.*, vol. 50, August 1958, Table 3, p. 1078.

[9] Data summarized from U. S. Department of Health, Education and Welfare, Public Health Service, Division of Sanitary Engineering Services, *Municipal Water Facilities Communities of 25,000 Population and Over, Continental United States and Territorial Possessions, as of January 1, 1958,* Public Health Serv. Publ. No. 661 (Washington, 1959), pp. 10-15.

[10] Raymond L. Anderson, "Operation of the Irrigation Water Rental Market in the South Platte Basin," *J. Farm Econ.*, 42:1501-02, Dec. 1960.

Must we conclude, then, that the conceptual and empirical difficulties in dealing with aggregate water demand and supply are so great that we are forced back, after all, to rely on water requirement projections? Before this question can be answered, one must inquire into the validity of economic projections in terms of the logic of inductive inference and into their relevance for water policy.

3. *Validity of Water Requirement Projections*

Projection over time is a special problem of inductive inference. In such projections, all undetermined cases of a hypothesis or of a system of hypotheses—a theory—are future cases. A projection is then called "prediction."

Predictions differ with respect to the degree of articulation in the formulation of hypotheses and with respect to the degree of quantification. On the basis of these differences, "projection" is sometimes differentiated from "forecast" and "estimate." Without endorsing such differentiation, it may be noted here that projections, forecasts, and estimates must be classed as predictions as far as the criteria for their logical validity are concerned. On the other hand, a prediction is not a prophecy. The only criterion that can be applied to a prophecy is the eventual outcome. In contrast, the eventual outcome of an individual case is not, in itself, a sufficient criterion of validity for a prediction. A prediction, in order to be valid, requires tested theories in the sense of "lawlike" generalizations.

Criteria to determine whether a generalization deserves or does not deserve the designation "lawlike" and, therefore, can be used for prediction, have occupied formal logic for a long time. In a small book, little known among economists, Nelson Goodman has suggested a criterion which has attracted some attention in the philosophy of science.[11]

It follows from the Goodman criterion that a high degree of quantification is not a requirement. On the contrary, most lawlike generalizations are phrased on a rather low quantitative level. For example, lawlike generalizations regarding the relations between variables refer to less quantified characteristics—such as general direction of change (increase, decrease), ordinal characteristics of change (greater, smaller, equal, proportional), temporal distribution of change (earlier, later, simultaneous), and tendencies toward correction (equilibrium), or cumulation (disequilibrium)

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[11] Nelson Goodman, *Fact, Fiction, and Forecast* (Cambridge: Harvard Univ. Press, 1955), espec. pp. 63-120.

R. Carnap, "On the Application of Inductive Logic," *Philosophy and Phenomenological Research*, 8:133-47, Sept. 1947.

For the classical views, see: John Stewart Mill, *A System of Logic* (London: Longmans, 1843; reprinted, 1947), espec. Book 3, Chap. 3.

The Goodman criterion was discussed at some length in the publication previously mentioned: S. V. Ciriacy-Wantrup, "Conceptual Problems in Projecting. . . ."

—rather than to cardinal characterization of parameters.[12] On the basis of the Goodman criterion, we may conclude that predictive power of a theory and degree of quantification are not correlated positively. Demand theory may serve as an illustration.

If by demand theory one means the broad generalizations in the Marshall-Henderson-Hicks formulation, they will pass Goodman's predictivity test.[13] By the authors themselves and by most economists, these generalizations are referred to as "the" demand laws. Yet their language is couched in terms that refer only to direction of change, that is, increase or decrease of prices and quantities. Elasticities, if mentioned at all, are stated in terms of ordinal characteristics.

On the other hand, there is little possibility of passing the Goodman predictivity test if by demand theory one means a demand function with a quantitative characterization of parameters that would allow demand projections comparable in numerical precision to existing projections of water requirements.

Existing projections of water requirements may be regarded as a species of economic model. Even the best of this particular species is incomplete in the sense that the most significant dynamic variables, namely, changes of technology, preferences, and institutions, are not included or only to a small extent.

Models are not substitutes for theories. Models are designed for better understanding of individual cases—past or future—and may be used for testing theories in the process of validation. Models, however, carry no predictive power. This holds for economic models generally but especially for existing projections of water requirements.

Against this lack of predictive power of models must be weighed the fact that for the individual case for which a model is designed it gives a more precise and frequently a "better"—in terms of outcome—projection than a prediction based on lawlike generalizations. This superiority of

[12] There is, of course, no implication here that measurement is not necessary in science in order to ascertain "reasonable agreement" between theory and observation. Measurement, however, is commonly thought of as significant not merely for testing but also for the formulation of theories. There is some doubt whether in the formulation of theories—that is, in the creative act of innovation—quantitative data are so superior to qualitative ones as is generally supposed in contemporary literature. Support for this doubt has recently come from a historian of modern physical science: Thomas S. Kuhn, "The Function of Measurement in Modern Physical Science," paper presented at the conference on the History of Quantification in the Sciences, New York, Nov. 20-21, 1959, sponsored by the Joint Committee on the History of Science, National Research Council and Social Science Research Council, 23 p., processed.

[13] Alfred Marshall, *Principles of Economics* (8th ed.; London: Macmillan and Co., 1930), 871 p., espec. Book 5.

H. D. Henderson, *Supply and Demand* (New York: Harcourt, Brace, and Co., 1922), Chapter 2, 181 p.

J. R. Hicks, *A Revision of Demand Theory* (Oxford: Clarendon Press, 1956), 196 p.

models, however, depends on their completeness. In this respect, as just noted, existing projections of water requirements are especially deficient. One may add that a prophecy also may happen to be a better projection than a prediction based on lawlike generalizations.

4. *Relevance of Water Requirement Projections for Water Policy*

To question the validity of water requirement projections in terms of criteria for predictability implicitly raises a question of relevance. Projections based on lawlike generalizations—for example, on the demand laws—would be on a quantification level far lower than that of existing water requirement projections (Section 3). We may ask, therefore, what quantitative level is relevant for the purposes for which the projections are made.

One may postulate that the main purpose of projections in water economics is to serve as a basis for public water policy. This is a far more comprehensive field of study than that of public water projects. The economics of water projects—such as benefit-cost analysis, other quantitative techniques of evaluating such projects, and the whole problem of efficiency in government investment—comprise only a segment, and sometimes only a small segment, of water policy.

Reasons for this proposition are not far to seek. As noted (Section 2), in this country—and this is true also for most countries of western society—water is largely allocated and developed through decentralized decision making of self-supplying firms and nonprofit water organizations. These agents are the subsectors in operating the water economy. Individual federal and state projects may be regarded as subsectors in this sense, subject to "rules of the game" not greatly different from those applying to other subsectors. These rules become operational through water institutions—such as water law proper and the laws and regulations under which nonprofit water organizations are established and managed. These rules of the game and their modification are the domain of water policy.

At first glance, the rules of the game with which water policy is concerned could be taken one by one or set by set, introduced as alternative institutional constraints into economic analysis and the paraphernalia of optimizing applied. This is the procedure in most of the many current studies on optimum water resource development. In this procedure, institutional constraints are treated in the same way as the technological ones. Only too often, investigators are not aware of the severe limitations which this procedure imposes on the relevance of quantitative optimizing if the results are to serve as a basis for decision making in public policy. To me, at least, the implications seem so important that several of them need to be explored in the present context.

First, when social institutions are used as constraints, they become conceptually indistinguishable from social objectives. In this respect, they are different from technological constraints. As explained elsewhere,[14] in natural resource policy, changes of social institutions are among the most significant controllable variables and relations. In natural resource policy, as a field of scientific inquiry, the attitude towards social institutions is pragmatic.[15] In other words, institutions must frequently be regarded as means (tools) rather than ends (objectives) of policy. Hence, the distinction in econometrics between the part of the model that constitutes the "objective function" to be maximized or minimized and the part that constitutes the constraints describing the structure of the operation and the relations between variables becomes misleading if the conceptual difference between technological and institutional constraints is not sufficiently recognized.

Secondly, when social institutions are used as constraints in a quantitative optimizing calculus, a new optimum must be calculated for each combination of constraints that is considered. The optima calculated for different sets of constraints are then compared. Recently, a whole literature has grown up around this approach known as "the theory of second best."[16] This term merely indicates that there is at least one constraint additional to the ones existing in the "Pareto optimum."[17]

The exponents of this theory claim that the major contribution is a negative one: If a deviation from one of the Pareto optimum conditions prevails, the best course of action is not an attempt to attack this deviation and keep all others intact. On the contrary, a second-best solution is usually obtained only by departing from all other Pareto conditions. To apply only a part of the Pareto optimum conditions would move the economy away from rather than toward a second-best position. In consequence, the exponents of this theory direct their criticism against what they call "piecemeal welfare economics."

If this criticism is valid—I believe it has some merit—does it not point to a basic weakness in the logic of quantitative optimizing itself? If one tries to avoid the futility of piecemeal welfare economics and strives for bold changes in the combination of constraints, can one be sure that quantitative optima are comparable in a meaningful way? Is it not unavoidable

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[14] S. V. Ciriacy-Wantrup, *Resource Conservation Economics and Policies* (Berkeley: Univ. of California Press, 1952), espec. Chap. 16-21.

[15] For a recent statement on the schism between "orthodox" and "pragmatic" attitudes toward social institutions, see: F. O. Sargent, "A Methodological Schism in Agricultural Economics," *Canadian J. of Agr. Econ.*, 8:45-52, 1960.

[16] R. G. Lipsey and R. K. Lancaster, "The General Theory of Second Best," *Rev. of Econ. Studies*, vol. XXIV (1), no. 63, 1956-1957, pp. 11-32. The earlier literature is cited in this article.

[17] Vilfredo Pareto, *Cours d'Economique Politique* (Lausanne: F Route, Libraire-Editeur, 1897).

An excellent bibliography of welfare economics is appended to: E. J. Mishan, "A Survey of Welfare Economics, 1939-1959," *The Economic Journal*, 70:197-265, June 1960.

that such bold changes affect the "givens" of the optimizing calculus—among them especially preferences, technology, and the motivation of human agents in their various functions in the economy? Are we not confronted with a problem of identification, in the econometric sense, on a grand scale?

In view of these questions, a somewhat different approach may be explored. I should like to submit that the rules of the game with which policy is concerned should not be used one by one or set by set and introduced into economic analysis as constraints. Rather, these rules constitute structured systems that function as wholes, each with particular patterns of change over time. These systems can be studied in structure, functioning, performance, and change over time. They are created by men and can be modified through the legislative, the judiciary, and the executive branches of government, each with a different range over which such modification can be accomplished.

The purpose of these systems is not to obtain quantitative optima of welfare at given points in time under given conditions projected for these points. Rather, their purpose is to maintain and increase welfare continuously under constantly changing conditions that at any point in time can be projected only vaguely and are always uncertain with respect to actual occurrence. Responsiveness of these systems to economic change is more relevant than their effectiveness in optimizing welfare under a particular set of actual or projected conditions.

It follows that to appraise the performance of these systems by introducing arbitrary temporal cross sections of them—either actual or hypothetical—as alternative combinations of constraints in a quantitative optimizing calculus is inadequate. Performance can be appraised only by criteria applied to a whole system as it functions over time. Such criteria need not be pecuniary. For the system that is of special interest for this paper, namely, water law, it has been shown elsewhere that nonpecuniary criteria, such as security against legal, physical, and tenure uncertainties and flexibility in its various legal and economic categories, can effectively be employed.[18] Such an appraisal is an integral part of economics that includes econometrics but is not restricted to it.

5. *Water Allocation Policy*

For analyzing further what kind of projections are relevant for water policy, I should like to deal first with water allocation and then with water development. In political reality, decisions in these two spheres are closely related. In economic analysis, it is useful to separate them.

[18] S. V. Ciriacy-Wantrup, "Concepts Used as Economic Criteria for a System of Water Rights," *Land Economics,* 32:295-312, Nov. 1956. Also published in: *The Law of Water Allocation in the Eastern United States,* ed. David Haber and Stephen W. Bergen (New York: The Ronald Press Co., 1958), pp. 531-52.

In the arid and semiarid regions in this country and elsewhere, water allocation among uses and users has always been a policy problem under greatly changing conditions affecting the aggregate quantity of water used and the quantitative relations between uses. In the beginning of water development—for example, in the "gold rush" days in the Mother Lode country of California—water allocation was such a problem when all uses, including agricultural, were small but when industrial use, namely, hydraulic mining, was the dominant one. In present day California, water allocation is such a problem, even though other uses are a fraction of a quantitatively dominant agricultural use. [19] Since water allocation is always vital for societies in arid and semiarid regions, numerous institutional arrangements have been developed which govern it.

If one wants to undertake an economic appraisal of the allocative functions of this system, one cannot be content with appraising quantitative allocation prevailing at a particular point of time. What needs to be appraised is the direction and speed of reallocation in response to economic change. Improvements in these respects are the main policy objectives. The first step toward such improvements is an understanding of the existing system and of the process of its change. Each state is a laboratory in which this system has developed and is still developing. When individual provisions are modified, such changes must be fitted into the whole system. If the system as a whole is judged inadequate, a better substitute must be offered. Only too often, criticism of water allocation at a particular point of time is voiced by economists without regard to the nature of the decision problems that water allocation poses for policy. Optimizing as a fictional construct is confused with an actual policy objective.[20]

As an illustration, let us focus on four facts already alluded to : (1) that water law in the West has developed with and around the growth of agriculture; (2) that agricultural water use is now quantitatively dominant;

[19] For comparing different uses quantitatively, two factors are frequently not sufficiently considered: (1) whether conveyance losses are included or excluded for agricultural use and (2) whether water use by steam electric plants—the quantitatively most significant one among industrial uses—is included or excluded for industrial use. In California, for example, agricultural use is 87 per cent; industrial use, 5 per cent; and domestic use, 8 per cent of total use if conveyance losses are included and steam electric plants excluded. Agricultural use is 67 per cent; industrial use, 25 per cent; and domestic use, 8 per cent if conveyance losses are excluded and steam electric plants are included. In terms of water consumption, the former is a more appropriate comparison, provided that double counting is avoided. Some conveyance losses are used via ground water and counted then. On the other hand, there is considerable interfirm reuse of water both in agricultural and industrial use. The quantitative extent of such reuse is not known. Steam electric plants use, largely, cooling water that is not usable for other purposes and, in any event, is not consumed. Potentially, of course, most domestic use can be made nonconsumptive. (See also footnote 5.)

[20] The usefulness of optimizing as a fictional construct is discussed in: S. V. Ciriacy-Wantrup, "Policy Considerations in Farm Management Research in the Decade Ahead," *J. Farm Econ.*, 38:1301-11, Dec. 1956.

(3) that nonagricultural water uses are increasing at a rate greater than agricultural use; and (4) that water is used in agriculture with relatively low average value productivity. Do these four facts indicate that western water law misallocates water to the advantage of agriculture as is commonly alleged? I believe the answer must be negative or, in more guarded terms, "not necessarily."

As to the past, only a fraction of present water development would exist if agricultural use had not become dominant. In other words, no large quantities of developed water would be available now for reallocation. As to the present, the relevant criterion, as we know, is not whether misallocation exists at the moment, but whether continuous reallocation is too slow. As to relative value productivities of water in different uses, it is the marginal and not the average value productivity that is the proper basis for continuous reallocation. The figures that are presented in the literature refer to average values frequently aggregating over highly dissimilar situations. If one wanted to be facetious, one could say that the average value productivity of water in nonagricultural uses would be negative if the whole or a large portion of agricultural water were to be reallocated to nonagricultural uses. Moreover, care must be exercised that marginal productivities are taken at comparable stages of water distribution and refinement. Agriculture uses water wholesale and largely unrefined. Domestic use, on the other extreme, is retail and frequently refined. Costs of water distribution and refinement are by far the largest items in the retail water bill.

The indictment of misallocation then boils down to an allegation that the rate of water reallocation from agricultural to nonagricultural uses is too slow. Invariably, this allegation is based on two structural elements of western water law: (1) preference of agricultural over industrial use in most states and (2) priority in time of agricultural use that becomes relevant in those states operating under water laws based on the appropriation doctrine.

It is true that the statutory preference given to agricultural over industrial use is obsolete. I have gone on record to that effect on previous occasions.[21] I suggested then to eliminate statutory preference altogether and to leave to the courts or special water rights boards the determination of which is the higher use in each situation of conflict. On the other hand, the economic significance of agricultural preference and priority is already limited by other provisions in western water law. There are no less than seven of these that are relevant.

First, municipal use has preference over agricultural use. A large part of municipal water use is for commercial and industrial purposes, although it is difficult to differentiate this part statistically from domestic use.

[21] S. V. Ciriacy-Wantrup, "Some Economic Issues in Water Right," *J. Farm Econ.*, 27:875-85, Dec. 1955.

Second, under several state laws, municipal water use enjoys the right of water reservation. This means that municipalities can hold water rights for future rather than present need without being subject to the due diligence clause that is such an important part of the appropriation doctrine.

Third, municipalities can acquire agricultural water rights through eminent domain proceedings. Frequently, the mere threat of such proceedings is sufficient. The Owens Valley in California is an example.

Fourth, in most states, many industrial self-suppliers rely on riparian and correlative ground water rights rather than appropriative rights. They are, therefore, not affected by the preference and priority clauses of appropriation law.

Fifth, water organizations such as irrigation districts and the Bureau of Reclamation that originally developed water under agricultural preferences and priorities now deliver water and hydroelectric power on a large scale for industrial and municipal purposes. Irrigation district laws have been adapted to permit such deliveries. Often, industrial and municipal uses take place on the same acreage where irrigation agriculture has been replaced by urban development. Per-acre requirements of irrigation agriculture are more than sufficient to cover those of "higher" uses. This is an example of what was suggested above: namely that water development historically undertaken mainly for agriculture is now of direct benefit for other uses.

Sixth, water development itself tends to reduce the economic significance of the superiority of a senior over a junior right under appropriation. This superiority is based mainly on greater security against "physical uncertainty"—as distinct from "tenure uncertainty"—that is, against variability over time of the quantity of water usable under the right due to seasonal or annual variability of natural runoff and ground water recharge. Storage above and below ground is the major technical possibility of reducing physical uncertainty. After storage capacity has been provided and is managed with a view to reducing physical uncertainty, the relative economic status among senior and junior rights changes without changes in their relative legal status.

This situation is related to my seventh and last point. Water rights are increasingly vested in nonprofit water organizations such as districts, federal bureaus, and state water departments. Contracts between water users and these organizations rather than private water rights become the operationally important aspect of water allocation. These organizations do not serve agriculture alone and can reallocate water over time under the terms of the contracts by following appropriate statutory procedures.[22]

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[22] Stephen C. Smith, "Legal and Institutional Controls in Water Allocation," *J. Farm Econ.*, 42:1345-58, Dec. 1960.
Stephen C. Smith, "Resource Policies and the Changing West," *Land Economics*, 36:22-34, Feb. 1960.

Space does not permit more than a sketch of these seven points. Enough has been said to illustrate the proposition that economists should carefully study the actual functioning and performance of water law before far-reaching conclusions with respect to failure to optimize water allocation are drawn from two structural elements.

This does not imply, of course, that a given temporal cross section of water law in a given place (state) is perfect or even that, over time, water law is adapting to economic change at an adequate rate. Economists should be continually alert for possible improvements in water law. While economics cannot define quantitative optima of water allocation which the law—as "social engineering"—should aim to realize, economics can determine whether and explain why the reallocative performance of water law is too slow. This area of water policy is a promising field for cooperative research between the economist and the student of law.

Much can be learned from observing historically the allocative performance of water institutions in relation to changes of demand for different uses. The results of this comparison can be used for institutional change. Changes in the allocative system can also be made in anticipation of the above general characteristics of demand changes that can be projected. On the other hand, precise quantitative projections of water requirements for different uses are not relevant for water allocation policy. Such projections merely beg the question.

6. *Water Development Policy*

Water development policy was differentiated from water development projects (Section 4). This paper is concerned with the former. The economics of public investment in water projects has been discussed elsewhere.[23]

Water development policy, like water allocation policy, becomes operative mainly through water institutions. But different aspects of institutions are involved. Among these, several may be mentioned. First, there is the blend in state water laws between riparian and appropriation doctrines; this blend is significant because the riparian doctrine is relatively less favorable to water development—with one important exception to be discussed presently. There are, second, the laws concerning water reservations for future development by particular uses and regions; municipal reservations and the area of origin legislation in California are examples. Third, there are the antipollution laws that affect the broad field of water quality management; this field becomes increasingly significant as water development is intensified and natural purification processes are over-

[23] S. V. Ciriacy-Wantrup, "Cost Allocation in Relation to Western Water Policies," *J. Farm Econ.*, 36:108-29, Feb. 1954.

S. V. Ciriacy-Wantrup, "Benefit-Cost Analysis and Public Resource Development," *J. Farm Econ.*, 37:676-89, Nov. 1955.

loaded. Fourth, there are the laws establishing and regulating water organizations; the problems of coordinating these organizations through "superdistricts" has become especially acute for water development. These problems are related to a fifth aspect which may be selected here for more detailed discussion because of its implications for water requirement projections (Section 2). This aspect is ground water law and the need for integrating ground water development with that of surface water.

The recent economic literature on water development focuses on the efficiency of public investment in water projects. When this focus becomes dominant, it must be diagnosed as a myopia that overlooks the significance of ground water development. Ground water is developed largely by private investment. The quantitative significance of ground water development may be illustrated with a few figures.

Ground water development was responsible for 67 per cent of total public and private irrigation development in the 17 western states since 1940. If federal water development is excluded, this figure rises to 89 per cent. The share of ground water development by decades is also interesting. Before 1900, ground water was responsible for only 1 per cent of total public and private irrigation development in the 17 western states. Between 1900 and 1909, this percentage was 8 per cent; from 1910 to 1919, 27 per cent; from 1920 to 1929, 52 per cent; from 1930 to 1939, 42 per cent; from 1940 to 1949, 63 per cent; from 1950 to 1958, 69 per cent.[24]

Ground water development is a major reason for the significance of self-supply in the water supply picture of agriculture mentioned previously. Ground water development, being based on private investment, decreased absolutely and even more so relatively during the depression decade in agriculture, 1930-1939. During this decade, federal water development, which consists largely of storage of surface runoff, showed a strong increase. We may also note that for industrial water use surface water development is more important than ground water development. For industry, the locational attraction to surface water is explained largely through the adequacy of "free" brackish and sea water for steam electric plants,[25] through the effects of navigable waters on costs of transportation, and through facilities offered by large bodies of water for waste disposal. Availability of water for consumption is incidental to these other water uses.

It was explained why the increasing significance of ground water development over the last half century makes hazardous any projections of water requirements through extrapolating past trends of water use (Section 2). However, overdraft on ground water may be used for a somewhat different kind of projection: for projecting the requirements for surface

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[24] Computed from data given in: U. S. Congress, Senate, Select Committee on National Water Resources, *Water Resources Activities in the United States: Future Needs for Reclamation in the Western States, op. cit.*

[25] See footnotes 5 and 19.

water development in order to put economic development based on ground water overdraft on a firm foundation with respect to the water economy.

The economist cannot accept the necessity of such stabilization as a foregone conclusion. But there are economic reasons for expecting that the benefits of surface water development undertaken mainly for stabilizing ground water development are relatively high. Surface water development for "new" uses can then be regarded as a joint product of firming up "old" ground water uses and can be treated in benefit-cost analysis accordingly. Some features of the California State Water Plan are of this kind.

Use of overdraft for quantitative water requirement projections is, however, not as significant for the integrated development of ground with surface water as appropriate institutional arrangements. Ground water law, where based on riparian ideology such as the correlative rights doctrine developed mainly in California, has been an important factor in permitting overdevelopment (in the physical sense of overdraft). This is the exception to the rule that the riparian doctrine is less favorable to water development than the appropriation doctrine. On the other hand, after adjudication of a ground water basin, correlative rights acquire the economic characteristics of appropriation rights. They become quantitatively defined, transferable, and secure against tenure uncertainty.

At first glance, ground water rights could be transferred without adjudication to the water organization that imports the surface water. This water organization would then allocate quantities of ground or surface water or combinations of the two to individual users. If pumping is done by individual users, they would be appropriately compensated since overdraft during extended periods of time is an essential part of integrated development of ground water with surface water. The most important resource of a ground water basin—namely, its storage capacity—could then be utilized to counteract seasonal and cyclical variability of precipitation without a complex system of price and other inducements that would become necessary if all rights to ground and surface water were not held by the same water organization.

There is some question whether private ground water rights will be surrendered voluntarily in this way without prior adjudication. Ground water rights are valuable private property rights because local ground water is generally much cheaper than imported surface water. Owners, therefore, will not be willing to surrender these rights without quantative definition and adequate compensation. Such definition and compensation also become necessary if private ground water rights are taken by the water organization through eminent domain proceedings.

The problem of private ground water rights is only one aspect of a water development policy aimed at integration of ground and surface water.

Another aspect is the establishment, regulation, and supervision of the type of water organization that actually does the integrating. It is fairly clear that water organizations of sufficient size are needed to cover the ground water basin that is to be managed and to import and distribute adequate quantities of surface water. If present water organizations are not of sufficient size, the question arises whether they should amalgamate or whether they should federate and form a superdistrict within which each organization would still maintain a degree of independence. The trend, I believe, is toward superdistricts. The most outstanding example in terms of size is the Metropolitan Water District of Southern California, in which the municipal water organization of Los Angeles is the most important member. There are others of this kind in California and elsewhere.

What is the implication of such superdistricts for the state that establishes, regulates, and supervises them? Some students feel that water development in the West is an undertaking too big for even the largest superdistricts and that it should be undertaken by the state. Others feel that superdistricts have become so big financially and politically that the state should step into direct water development through planning, constructing, and operating projects in order to preserve balance in the rate of water development between the various regions of the state. Still others feel that statewide water development should be left to the interaction of water organizations including superdistricts, that the state should stay out of direct water development, and that in such a less involved position it could more effectively play its important role as the locus of water development policy in the sense in which the word is used in this paper.

These and other views on appropriate institutional arrangements for integrated ground and surface water development are in conflict. This conflict is acute in California. It is mentioned not in order to take sides but to suggest that some of the crucial issues of water development are in this area. With water development policy, as with water allocation policy, the functioning, performance, and change over time of an institutional system is involved rather than quantitative optimizing at given points in time under projected conditions.

Research in this area need not return to the descriptive approach to water institutions. There is now considerable historical evidence on water institutions that can be approached analytically by the social sciences. An analysis of the structure, functioning, performance, and change over time of superdistricts is an example. Such studies can be extended to other countries where interesting material is available. Last year, I had occasion to study the Metropolitan Water District of the Ruhr comprising Germany's industrial heartland. This district has been in successful operation since 1913. Some of the same problems now faced in this country, such as the relation between superdistricts and state, have been solved there.

On the other hand, how helpful in this area of water development are any or all of the many water requirement projections for the year 2000 or the quantitative programming of optimum water development for which arbitrary sets of these institutional arrangements have been employed as constraints? For some narrower problems of water development, especially in the economics of individual public projects, such studies have a place. But it would be unfortunate if the current concentration of effort in this direction should lead to the neglect of the crucial issues of water development policy. For dealing with these issues, an analytically oriented institutional economics is by no means obsolete.