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WATER POLICY AND ECONOMIC OPTIMIZING: SOME CONCEPTUAL PROBLEMS IN WATER RESEARCH1/

by

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1. Water Policy and Water-Resources Systems

For the purpose of today's discussion, I should like to view water policy from the standpoint of decision theory: water policy may be regarded as a set of decision rules in a multistage decision process. In this process, a sequence of decisions extends over time and space in an "open" system.

The first step in such a study of water policy3/ is to identify the system or systems in the control of which decision rules are sought. In other words, what are the characteristics of the water-resources system with which water policy is concerned? This seemingly simple issue of system identification is, I submit, at the root of some of the most serious conceptual problems in contemporary water research.

The large and still expanding literature on water economics during the last decade is mainly concerned with one particular class of a water-resources system,

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1/ Giannini Foundation Paper No. . Presented to the Joint Meeting, American Economic Association and American Farm Economic Association, San Francisco, December 27-28, 1966

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3/ In the terminology of decision theory, policy refers to the decision rules, that is, the criteria of decision making. But the study of policy includes the whole decision-making process and the implementation and the effects of decisions.

namely, the public multipurpose development of surface water through storage dams, canals, and other large engineering structures. The term public usually refers to the federal government, and economic analysis focuses on the efficiency of federal investment in water resources. This is the same class with which the earlier discussion of benefit-cost analysis was concerned--exemplified by the Green Book, the controversy about the TVA, and the various critiques of the Army Engineers and the Bureau of Reclamation. The Green Book used the term river-basin project for this class, but later the terms water-resources system and water development became synonymous with it.

Such terminology is not helpful for several reasons. First, this particular class is less significant in inputs and outputs than other classes. Second, this class is always closely related to others as a part of an integrated system; it is merely a subsystem. Third, the decision rules suggested in the literature for this subsystem under constraining assumptions are neither valid nor relevant for the integrated system as a whole. The last point will be elaborated presently (Section 2), but first let us ask what are the characteristics of an integrated water-resources system as understood here?

Such a system is a mixed groundwater-surface water system. Groundwater use is quantitatively at least as significant as surface-water use, and integration of the two uses raises some of the most important issues for water policy. The design of such a system does not necessarily involve large engineering structures. Appropriate institutional structures, on the other hand, are a necessary and frequently sufficient condition for its functioning. Such institutions relate to water law influencing water development, water allocation, and water quality; to water-district law controlling the establishment, organization, and operation of public water districts; and to state and federal administrative agencies affecting water development, allocation, and quality. For short, these structures will be called here "water institutions."

Groundwater is developed largely by private rather than by public investment. The public investment that is involved is by water districts rather than by federal and state governments. Private firms and water districts are also active in multipurpose, multiunit surface-water development. Some of the federal developments and the California State Water Plan outrank private and district developments in size of individual projects; but in the aggregate, water development by private firms and water districts exceeds that by federal and state governments.

We may say, then, that the water-resources system with which we are concerned consists of operating sectors which are private firms, public districts, and projects of federal and state governments.1/ In aggregate quantity of water developed, private firms--households, farms, industrial corporations, and public utilities--are the most significant group of operating sectors. In second place are public water districts such as irrigation districts, municipal water districts (and departments), and conservancy districts. Federal projects are in third place and state projects are last.2/

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1/ It should be noted that a differentiation is made here between projects of federal and state agencies and those agencies themselves. This is in accordance with procedures of economic optimizing. Thus, optimizing procedures are applied to projects of the Bureau of Reclamation and not to the Bureau itself or the laws regulating its establishment, organization, and operation. A parallel differentiation is made here between public water districts and the state water district laws controlling the establishment, organization, and operation of such districts.

2/ In recent decades, water districts have changed in part from water developers in their own right to retailers of water developed by federal and state projects. In some states--for example, California--federal and state projects are intertwined. Statistical separation of quantities of water developed by districts, federal projects, and state projects has become increasingly difficult. For a more detailed discussion of the relative significance of the various groups of operating sectors in the above sense, see S. V. Ciriacy-Wantrup, "Water Policy," Handbook of Applied Hydrology: A Compendium of Water-resources Technology, Editor-in-Chief, Ven Te Chow (New York: McGraw-Hill Book Company, 1964), Section 28, pp. 28-1 to 28-25.

2. Water Policy and the Hierarchy of Decision (Optimizing) Levels

In order to find decision rules for such an integrated water-resources system, I should like to differentiate three levels of decision making. These levels constitute a logical pyramid similar to the levels of conceptualization differentiated in formal logic.[1] For the present purpose, this pyramid will be called "the hierarchy of decision levels."

On the first level, the lowest, the decision-making process relates directly to the control of inputs, outputs, and other quantitative characteristics of the water-resources system. These characteristics may be deterministic or stochastic; they may be in physical or in value terms. Decision making on the next higher level, the second, controls the institutional framework of the decision-making process on the first level. On the third level, the framework of the decision-making process on the second level is the subject of decisions.

Decision levels may also be conceived as optimizing levels. This term will not be used here because it requires interpretation of optimizing as a fictional construct or scientific fiction.[2] On each level, decision rules are sought for making the best decision on that level. Although decision-making processes differ from level to level, they are interrelated because the effects of each decision can be traced through all lower levels. From the observation of these effects on the water-resources system, decision makers can learn how to make improvements in decision-making processes on all levels. Such learning--or in

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1/ For an application of levels of conceptualization to the concept "resources," see Ciriacy-Wantrup, Resource Conservation: Economics and Policies (2d ed. rev.; Berkeley: Division of Agricultural Sciences, University of California, 1963), Chap. 3. It scarcely needs to be mentioned that the logical pyramid referred to here carries no connotation of social or ethical ranking.

2/ For a discussion of this interpretation, see Ciriacy-Wantrup, "Policy Considerations in Farm Management Research in the Decade Ahead," Journal of Farm Economics, Vol. XXXVIII, No. 5 (December, 1956), pp. 1301-1311.

computer jargon "feedback"--is the essence of a multistage decision process. The decision-making process on each level can be studied in its structure, its functioning, and its performance.

We can now proceed to the application of these general concepts. As we know, an integrated water-resources system is composed of private and public operating sectors (Section 1). The decision making on the level of these operating sectors constitutes the first level of our hierarchy. Decision rules for this level are familiar to economists because they are identical with "the" rule generally suggested for decision making in economic literature. This rule was originally postulated for a calculative economic man and for the private profit-seeking firm. It was later modified for public decision making in order to take account of problems involved in aggregating individual utilities and in dealing with externalities. The recent revival of the concept of social time preference may be regarded as a special case of these two problems. The public maximizing agent striving to obtain such Pareto optima in water-resources development by internalizing externalities has been dubbed the "river basin firm."1/

The common decision rule for private and public operating sectors specifies maximization of an objective (profit or welfare) function under constraints regarding institutions, technology, and resource availability. In terms of formal criteria, maximization is accomplished through fulfilling the necessary and sufficient conditions and other qualifications given by the first and second derivatives of the objective function and, for maximization over time, by the calculus of variations.

Little needs to be said here about this decision rule itself. The conceptual and operational limitations of quantitative optimizing in private and in

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1/ Allen V. Kneese, The Economics of Regional Water Quality Management (Baltimore: The Johns Hopkins Press, 1964), 215p.

public decision making have been discussed elsewhere.[1] There is, however, one aspect of these limitations that is of interest here because it points to the next higher decision level. This aspect is the treatment of institutions as constraints in quantitative optimizing. Such treatment does not create conceptual problems in private decision making. In social decision making, however, institutions correspond conceptually more to independent or dependent variables than to constraints.

The latter treatment of institutions has received critical review in welfare economics through "the theory of second best."[2] This critique has cast serious doubts on the validity of Pareto optimizing under institutional constraints. Whether or not one agrees with the entire reasoning of this critique, the main result can well be accepted: institutional conditions are conceptually different from technological conditions and resource availability. To look at the former as constraints views their appearance only on the first decision level. On the second level, they appear as the operational parts in the decision-making process.

The purpose of decision making on the second level is not to control directly inputs, outputs, and other quantitative characteristics of the water-resources system nor to obtain a path of quantitative welfare optima at various points in time under projected conditions for these points. Rather, the purpose

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1/ Ciriacy-Wantrup, "Philosophy and Objectives of Watershed Policy," Economics of Watershed Planning, ed. G. S. Tolley and F. E. Riggs (Ames: Iowa State University Press, 1961), pp. 1-12; and "Conservation and Resource Programming," Land Economics, Vol. XXXVII, No. 2 (May, 1961), pp. 105-111.

2/ R. G. Lipsey and R. K. Lancaster, "The General Theory of Second Best," Review of Economic Studies, Vol. XXIV(1), No. 63 (1956-1957), pp. 11-32; John V. Krutilla, "Welfare Aspects of Benefit-Cost Analysis," Economics and Public Policy in Water Resource Development, ed. Stephen C. Smith and Emery N. Castle (Ames: Iowa State University Press, 1964), pp. 22-33; and O. A. Davis and A. B. Whinston, "Welfare Economics and the Theory of Second Best," Review of Economic Studies, Vol. XXXII(1), No. 89 (January, 1965), pp. 1-14.

is to maintain and to increase welfare by continuously influencing decision making on the lower level under constantly changing conditions that for any point in time cannot be projected--or only vaguely--and that are always uncertain with respect to actual occurrence.

In order to fulfill such a purpose, each water institution may be regarded as a decision-making system that functions as a whole with a particular pattern of change. Under the constitutional organization of the United States and other Western democracies, the system is modified through actions by the three branches of government--the legislative, judicial, and executive--each with a different range over which modification can be accomplished. Modification takes place on the federal, the state, and the local levels; generally the state level is the most important for water institutions.

Performance of such a decision-making system can be appraised only by viewing the system as it functions over time under various economic conditions. It is conceptually inadequate to appraise performance by studying temporal cross-sections of the system for particular conditions and points in time. Criteria for performance must be sought on the system's own level. They need not be the same as those on the lower level discussed previously. Neither need the criteria on the lower level be those that economists suggest they should be. What we seek for the second level are criteria that could serve as conceptually and operationally meaningful proxies for the fictional construct of optimizing welfare. They may be called intervening criteria in analogy with intervening variables. The search for such criteria will be undertaken in the following section (Section 3).

While the second decision level is the most significant one for the study of water policy, it does not complete our hierarchy. A third decision level was implied by the reference to the constitutional organization of the United States, which sets the basic framework for water policy as for all other policies. Water institutions, however, are not confined to modern Western democracies. Highly developed water institutions existed in ancient feudal societies and city states in the Old and in the New World. They exist in primitive tribal communities in Africa no less than in modern authoritarian states. Time does not permit sketching the differences between water institutions in different societies: Although the causal connection is controversial, the basic organization of a society is always closely interrelated with water institutions. Accordingly, this organization may be regarded conceptually as a social decision-making process on the next higher, the third, level of our hierarchy. Discussion of this level would lead away from water policy and need not be undertaken here.

3. Criteria for the Performance of Water Institutions

Decision-making processes on the second and third levels are a part of the political process. When economics was understood as political economy, it encompassed the political process in the study of decision making. Later, emphasis shifted toward the quantitative optimizing model almost to the exclusion of other decision-making processes. However, there are some nonconformists. For example, Lindblom and his coauthors in several books, especially in the last one, argue that the political process is the only valid and relevant general model of decision making.[1/] He applies his central theme of "mutual accommodation of

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1/ Robert A. Dahl and Charles E. Lindblom, Politics, Economics, and Welfare: Planning and Politico-Economic Systems Resolved into Basic Social Processes (New York: Harper & Brothers, 1953), 557p.

David Braybrooke and Charles E. Lindblom, A Strategy of Decision: Policy Evaluation as a Social Process (London: The Free Press of Glencoe, Collier-Macmillan Limited, 1963), 268p.

Charles E. Lindblom, The Intelligence of Democracy: Decision Making Through Mutual Adjustment (New York: The Free Press, 1965), 352p.

partisans" to private as well as to public decision making. Others have suggested that the political process should merely supplement quantitative optimizing in the solution of specific technical difficulties, for example, to determine trade-off values between different objectives of public investment.1/ Multidimensionality of the objective function has long been a major conceptual and operational difficulty in quantitative optimizing.

These and similar suggestions are a refreshing change from reiterating over and over the goal of quantitative optimizing--often with little regard for the operational possibility of fulfilling the necessary and sufficient conditions and other qualifications. There are, however, two provisos which I should like to make: First, one must recognize the differences between decision-making processes on different levels: the political process must be brought in at the second level; it cannot be relied upon to solve ad hoc the many technical difficulties of quantitative optimizing. Second, conceptually satisfactory criteria must be provided to differentiate a "good" from a "bad" decision.

By the authors mentioned and by others, agreement based on mutual accommodation of partisans is specified as the main criterion. Such a criterion has strong appeal in a Western democracy. But its application involves several conceptual difficulties. The criterion requires a careful definition of the meaning of political agreement and a specification of the means of bringing it about. While the criterion is operational in the sense that "feasible" decisions are always selected, it does not enable one to make a selection between alternative decisions for all of which agreement is attainable. Agreement may fluctuate over relatively short periods of time for substantially identical decisions; this would not make the criterion inoperative at any point in time, but differentiation

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1/ Arthur Maass, "Benefit-Cost Analysis: Its Relevance to Public Investment Decisions," Quarterly Journal of Economics, Vol. LXXX, No. 2 (1966), pp. 208-226.

between good and bad decisions would have little meaning under these conditions. Finally, and most importantly, the agreement criterion is not useful in appraising performance for the purpose of scientific analysis.

To find a more satisfactory criterion is not easy. But since the social sciences may be regarded as an extension of human ecology, performance criteria used in our sister sciences may offer a suggestion.

Geneticists, studying genotypes, populations, and species, differentiate between favorable and unfavorable gene variants, mutations, traits, and other characteristics.1/ Students of animal behavior differentiate between favorable and unfavorable instincts and other habit patterns of behavior with various degrees of openness to learning.2/ These and similar appraisals of characteristics--from molecular to social--are based on a common criterion, namely, survival under the pressure of selection. One might explore the possibility of applying a similar criterion to characteristics of economic behavior, in our case to the performance of water institutions. Here, survival must be interpreted in economic terms, that is, not in physical growth and numbers but in economic growth and welfare.

The first step in such an exploration is to note some relevant conceptual implications of survival value as a criterion of performance. Survival value indicates only direction, even though highly quantitative methods may be used in determining it; it cannot be employed, therefore, for obtaining optima. It

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1/ Curt Stern, "The Genetic Resources of Man," Natural Resources: Quality and Quantity, ed. S. V. Ciriacy-Wantrup and James J. Parsons (Berkeley: University of California Press, 1967). (In press.)

Ernst Mayr, Animal Species and Evolution (Cambridge: Harvard University Press, 1963), 797p.

2/ Konrad Lorenz, On Aggression (New York: Harcourt Brace and World, Inc., 1963), 320p.

N. Tinbergen, The Study of Instinct (Oxford: Clarendon Press, 1951), 228p.

has no normative connotation: it is useful for scientific analysis; but for political decision making, its usefulness is indirect and uncertain. Knowledge of structure and functioning of a system is required before performance of its individual characteristics can be appraised. Appraisal is valid only for a specified environment or sequence of environments.

None of these implications render the criterion unsuited for our purpose. It will be recalled that quantitative precision and optimizing are not involved on the second level of decision making. Further, a criterion is desired that is useful for scientific analysis. For political decision making, such a criterion can only be a supplementary one, its significance depending on the influence of scientific understanding on political agreement.

Survival value can be applied in various ways. Sometimes it is the performance of water institutions as it affects the viability of operating sectors (in the sense of Section 1) that is of interest; for example, how water-district law affects the viability of water districts during economic depressions or their growth in underdeveloped regions. Sometimes it is the water-resources system itself that is of interest; for example, to what extent are water institutions responsible for the growth, stagnation, and decay of irrigation systems in many parts of the world? Usually, however, scientific interest is focused on how water institutions--especially water law--are related to the welfare of a whole region in various periods of its development.

4. Illustrations and Conclusions

In order to bring the conceptual analysis (Sections 1-3) closer to applied water research, some of these examples may be spelled out further.

Among the most difficult problems of water policy is the allocation of costs of water development among beneficiaries for the purpose of repayment.

For water districts, solution of this problem is crucial for viability because they cannot rely on the resources of the federal and state treasuries. Water research can use two approaches: First, through various computational techniques of benefit-cost analysis one can project benefits accruing to different groups of beneficiaries and allocate costs and repayment more or less in proportion. The second approach focuses on alternative characteristics of water-district law. The objective of this approach is to appraise the historic performance of these characteristics and to select those with survival value in terms of viability of districts.

Since the Wright Act of 1887, California has had a great deal of experience in employing district taxation and water prices in various combinations. With some modification in 1907, the original taxation provisions of the Wright Act have stood up well under the test of cyclical and structural economic change. Conversely, the difficulties of water districts in other states, in Canada, and elsewhere are largely due to the absence of similar provisions in water-district law. The details are of great interest for institutional analysis, but time does not permit discussing them here.[1] In summary, one may suggest that as a basis for repayment to water districts, computation of indirect benefits and of optimum cost allocation have yet to demonstrate their superiority over the results of institutional characteristics tested over some 80 years. In other words, a decision-making process on the second level, by controlling decision making on the first level, has performed in a way that is conceptually and operationally more acceptable than "ad hoc" sophisticated computations. One might call the taxation provisions of the Wright Act an institutional characteristic with survival value.

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1/ For details, see Michael F. Brewer, Water Pricing and Allocation With Particular Reference to California Irrigation Districts, University of California, Giannini Foundation Mimeographed Report No. 235 (Berkeley, 1960), 149p.

By far the most significant of water institutions are the systems of water rights that function in great variety in the 50 states and in most organized communities all over the world. Here also, California offers interesting material for appraising performance under a sequence of different economic environments.

Starting in the 1850's, when industrial use of water--for placer mining--was more important than agricultural use in a pastoral, nonurban region, water rights have controlled water development, allocated water, and influenced water quality up to the present day, when agricultural use of water is dominant in one of the most highly industrialized states of the union.1/ This adaptability of water law in responding to and influencing a rapidly changing economic environment can be explained largely by the functioning side by side of two legal systems, one based on riparian, the other on appropriative rights. Over time, they have come to a workable blend. For groundwater, this blend can be regarded as a specific system, that of correlative rights.2/

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1/ 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 percent; industrial use, 5 percent; and domestic use, 8 percent of total use, if conveyance losses are included and steam-electric plants are excluded. Agricultural use is 67 percent; industrial use, 25 percent; and domestic, 8 percent, 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 groundwater and counted then. There is considerable interfirm reuse of water both in agricultural and in 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.

2/ Ciriacy-Wantrup, "Some Economic Issues in Water Rights," Journal of Farm Economics, Vol. XXXVII, No. 5 (December, 1955), pp. 875-885.

To the superficial observer, the California "mix" of water-right systems appears as utter confusion. It is often criticized by economists who have made it responsible for retardation of water development, misallocation of water, cross-hauling of water, and other inefficiencies. Instances of this kind exist, although other factors are frequently more responsible for them than water law. Even if water law were solely responsible, economic inefficiencies under particular conditions at particular points in time are not sufficient for an indictment of the whole institution. As we have seen (Section 2), the function of water institutions is not to maximize economic efficiency for particular conditions and points in time but to structure decision making on the lower level under various and constantly changing conditions.

In studying the performance of water-right systems in fulfilling this function, a dichotomy of criteria has been developed.1/ They are <u>security</u> against legal, physical, and tenure uncertainties and <u>flexibility</u> in various legal and economic categories. Applying these criteria to California water law gives a farily good "fit." California water law has performed relatively well--as compared with other water-law systems--in stimulating water development, allocating water, and protecting water quality over more than a century of profound changes in the economic environment. To be sure, some structural characteristics, such as the system of preferences, have lost survival value and are largely neutralized by others.

The purpose of such a general evaluation is not to defend California water law but to suggest that in the perpetual process of legal adaptation, economists

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1/ Ciriacy-Wantrup, "Concepts Used as Economic Criteria for a System of Water Rights," <u>Economics and Public Policy in Water Resource Development</u>, ed. Stephen C. Smith and Emery N. Castle (Ames: Iowa State University Press, 1964), pp. 251-271; and "Water Economics: Relations to Law and Policy," <u>Waters and Water Law in the United States</u>, ed. Robert Emmet Clark (Chicago: Allen Smith and Co., 1967). (In press.)

could be more helpful by making careful institutional analyses of the performance of water law than by reiterating the criticism that water law has failed to optimize water development and allocation for particular conditions and points in time. Such criticism is neither valid nor relevant because its criteria are not applicable to a system operating on the second decision level.

If I may draw a conclusion for water research, it is that comparative analysis of water institutions is a promising field for economists. Like all institutional analysis, it is closely related to the political preferences, the emotions, and the social conditioning of the investigator--witness what some investigators have called the "rape" of Owens Valley. This challenge to scientific attitude must be faced. Even though some material is slanted and some merely descriptive, much is available in economic history, political science, law and engineering that is valuable for an analytical treatment of the structure, the functioning, and the performance of water institutions. In this treatment, theoretical constructs and their testing are no less needed than in the analysis of the marketplace. The hierarchy of decision levels is the most important of such constructs. From it follows the basic difference between decision rules (criteria) on the first and second levels.

As to criteria for decisions on the second level, the approach suggested here focuses on what we called intervening criteria as proxies for optimizing welfare, namely, on institutional characteristics that have demonstrated favorable or unfavorable effects on welfare. Examples were given for two of the most important water institutions. Other institutions would lend themselves to the same approach.

This approach is greatly interested in economic history and in relating one time period to another but not necessarily through increasing the number of variables and equations in mathematical models. It relies heavily on theoretical constructs but less on the maximization principle. Emphasis is on determining conditions for economic growth rather then on locating peaks, on avoiding dead-end streets rather than on computing the shortest distance, and on adaptability rather than optimum adjustment. This approach does not pretend to establish criteria for economic optimizing, but it offers a basis for water policy at successive stages of decision making.