ECONOMIC SCIENCE AND THE CENTRAL ARIZONA PROJECT: LESSONS LEARNED

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INTRODUCTION

Mobilizing economic science for water resource management decisions has a checkered past in the western United States. In many instances, economic analysis of varying degrees of rigor has been applied to water resource planning efforts as either an *ex post* validation or critique of a political decision. All too rarely do economists play a timely *ex ante* role equivalent to the roles played by politicians, engineers, hydrologists, and lawyers in water resource management planning and decision-making. Responsibility for being a non-player partially rests with economists themselves, as we are drawn away from difficult Western water issues towards safer discipline-based research. However, major responsibility rests with public policy makers and private water users who often view economic science as a threat to their political ideas, particularly their desire to appease special political interests by extracting economic rents from rate- and taxpayers.

The early history of the Central Arizona Project (CAP) is well documented by Johnson (1977), starting with the formation of the League of the Southwest in 1919 to project authorization by Congress in 1968. Along the way Arizona filed an interstate legal suit against California to adjudicate its rights to the use of Colorado River water. This suit ended in 1963 when the U.S. Supreme Court decreed that Arizona had a right to 2.8 million acre-feet of Colorado River water (*Arizona v. California, 373 U.S. 546*). The consistent authorization of federal funding for the CAP proved equally contentious for 25 years. One *quid pro quo* for continued CAP funding required by the Carter Administration was the hurried design, passage and implementation of the 1980 Groundwater Management Act by the State of Arizona. Construction on the Havasu Pumping Plant began in 1973 and households in Tucson, at the end of the 335-mile aqueduct, began drinking CAP water in November 1992.

The major controversy surrounding the CAP centered on its economic feasibility as an agricultural development project. Congressional authorization and appropriation required supporting documentation that the CAP was necessary for the economic viability of central Arizona agriculture. All parties recognized that in 30-50 years the CAP would evolve into a largely urban and Native American project due to increasing urbanization in central Arizona and successful adjudication of Indian water rights. However, the initial economic justification was based on the agricultural economy.

The key economic issue surrounding the CAP, at least for agriculture, is captured in Figure 1. First, total project cost would approach $5 billion and the aqueduct would be 335 miles long. Not only did a little less than half of this cost need to be repaid by water users, but also the distribution systems for irrigation districts had to be repaid by growers as well. Some of these systems cost grower-managed districts $100 million. Secondly, water had to be lifted over 2,000 feet from the Colorado River to Tucson. Combined with other operations, maintenance and repair (OM&R) costs, early projections for water costs were two to three times the current cost of pumping groundwater. The fundamental question surrounding the early discussion of the CAP was, "Can farmers afford this water?"

Early economic analyses, one prior to the signing of the Colorado River Basin Act in 1968, challenged the economic rationale for the CAP (Young and Martin, 1967; Kelso et al., 1973). CAP water, if priced at cost of delivery, would drive growers out of business if they were forced to substitute CAP water for groundwater. Kelso et al. (1973) argued that Arizona had sufficient water for economic growth; the real problem according to these analysts was the misallocation of existing water supplies. Barr and Pingry (1977a,b) released detailed reports analyzing the complex cost structure of the CAP, warning policy makers that municipal water users and taxpayers would pay the majority of the CAP costs. These early analyses created a firestorm of criticism against the scientific findings. Careers were threatened and financial support for research was withdrawn for a time. Bush and Martin (1986) concluded that most

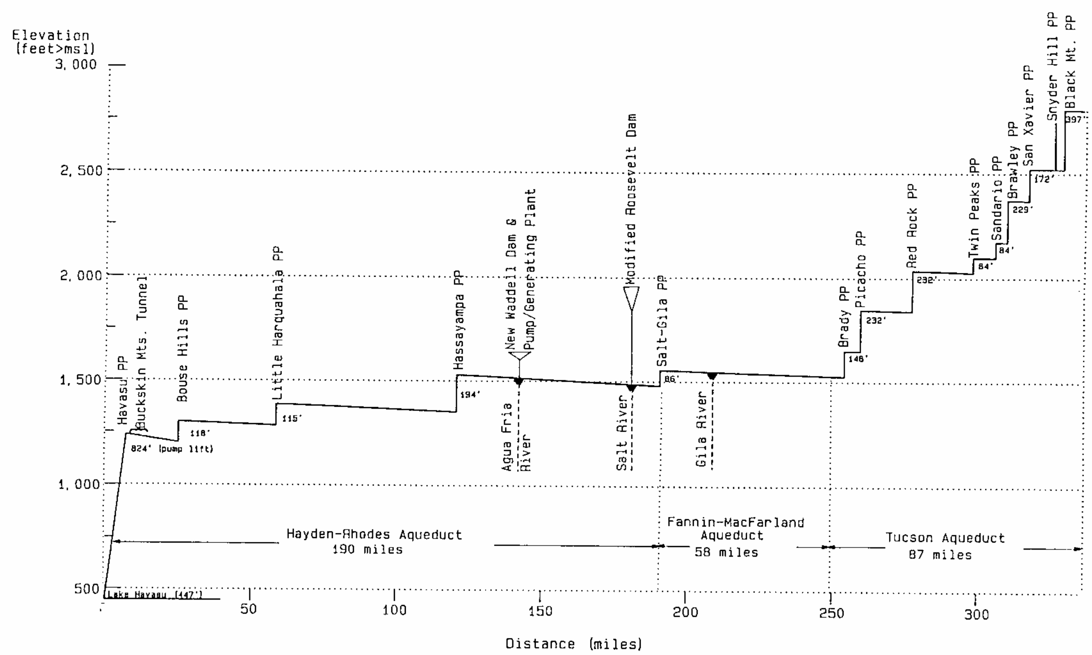


Figure 1. Elevation Changes in the CAP Main Canal

irrigation districts would be worse off with the CAP than without it. Not all grower-controlled irrigation districts heeded these warnings.

Nine of 23 potential irrigation districts or agricultural operations contracted for CAP water and built distribution systems. By the early 1990s the underutilization of CAP water by farmers became a serious public policy issue in the state (Wilson, 1992). Two irrigation districts declared bankruptcy, the first time in U.S. history that a federally supported irrigation district has failed economically (Baker, 1995). Irrigation districts surrendered their long-term CAP contracts for assurance of subsidized CAP water for at least 10 years. The CAP became a municipal and industrial (M&I) and Native American project 40 years earlier than anticipated by project planners. And finally, the State of Arizona initiated a massive effort to bank CAP water in the ground to increase the state's utilization of its Colorado River allocation. The implications of faulty CAP economics have cost taxpayers millions of dollars in attorney and consultant fees, countless hours of public officials' time, and lower returns on municipal bonds. However, the CAP aqueduct continues to be professionally managed and operated by the Central Arizona Water Conservation District.

The remainder of this paper is a brief, personal evaluation of the continuing lessons learned as economic science attempts to inform water resource policy decisions. The CAP is the case study. A more thorough analysis of the agricultural component of the CAP can be found in Wilson (1997).

ECONOMIC SCIENCE LESSONS

Economics, the science of decision-making under scarcity, presents the decision maker with a rich array of analytical models for understanding resource allocation issues. These conceptual frameworks produce important insights concerning the direction and magnitude of change in key variables when existing policies are modified or new policies are implemented. Economics also has a rich tradition of empirically validating economic theory through case study analysis, econometric data analysis, financial budgeting, laboratory experiments, mathematical programming and simulations. Significant efficiencies are gained for society by "getting the economics right" in the public policy process. These cost savings can be comparable to or exceed efficiencies realized from engineering, financing or legal expertise.

Key federal and state policy makers began to understand how "wrong" their economic understanding was as they participated in an interdisciplinary, interagency study in the state's largest CAP irrigation district in the early 1990s and with the subsequent publication of the team's detailed analysis (Dedrick et al., 1992). Within months it became clear that deals would have to be negotiated between all participating parties to avoid a significant financial burden on the state's rate- and taxpayers. These deals involved a combination of refinancing, contract cancellations, subsidized water for agriculture, electrical power generation swaps, increased property taxes and a plethora of new CAP water using programs (e.g. Water Bank, river rehabilitation projects). Adjustments to the institutional environment surrounding the CAP continue to this day. What should we learn from this interaction of economic science and water management?

Lesson #1: Cheaper is Better

Mainstream economic theory has produced a rich and powerful understanding of firm-level decisions using the assumption that business managers maximize profits. This scientific construct, while not a perfectly accurate view of actual decision-making within the firm, has generated a useful body of knowledge on the comparative statics of economic behavior. Within this profit-maximizing framework we know that businesses will use their cheapest or less expensive inputs first (assuming quality is equivalent) in the production of goods and services. The lower-cost producer will receive more net returns in the market relative to their higher cost counterparts.

Running throughout Bureau of Reclamation (BoR) and engineering firm planning documents was the assumption that groundwater would play a secondary role in Arizona agriculture once CAP water could be delivered to farms. For some hydrologic and economic reasons (unknown at least to this author), CAP water would soon be cheaper than groundwater. But the reality was that "cheaper is better," so farmers continued to pump lower cost groundwater, leaving CAP water in the Colorado River and causing a severe underutilization problem for the state's leaders. Some planners and elected officials demonstrated complete surprise when they finally understood how businesses make decisions. But one elected city official in 1994 still insisted, "Farmers should buy CAP water because that is the right thing to do."

Lesson #2: Willingness to Pay is Less Than Ability to Pay

A well-developed and empirically tested concept in economics is that people make decisions "on the margin." We evaluate the incremental (i.e. marginal) benefits and costs associated with decisions, going forward with the decision if the marginal benefits exceed the marginal costs. In irrigation decision-making the grower compares the cost of the last acre-foot of water with the anticipated revenue produced by that last acre-foot of water. Average values of benefits and costs are higher over the relevant decision space because high and low values over the entire range of production levels are averaged. Averages can be useful to establish overall profitability in an accounting sense but serve very little purpose in accurately determining the economic impact of an adjustment in the business. The ability to pay concept is economically flawed as a project evaluation criterion.

BoR- and district-funded feasibility studies failed to use *willingness to pay* methods and elevated *ability to pay* for the CAP. First, it was assumed that all the acreage in the CAP districts would be farmed every year for 50 years. Secondly, the studies assumed that relatively large acreages of a high value crop would be farmed every year, an assumption without historical precedence then or now. And finally, these studies failed to recognize that growers would use lower-cost groundwater resources first. These errors in economic judgment produced a false sense that farmers would buy CAP water. The growers' willingness to pay on the margin actually was one-half to one-third the CAP price in the early 1990s.

Lesson #3: You Can't Predict the Future

The economics of decision-making under uncertainty has been a core field in microeconomic theory for thirty years. Economists recognize that the future cannot be predicted with certainty. Therefore, economists and financial analysts have developed a wide range of models and analytical techniques to produce insights on decisions and projects when uncertainty characterizes key economic variables. Possibly the most elementary technique is sensitivity analysis, changing a key variable by 10 percent to evaluate the impact on a key performance measure (e.g. profits, net present value, internal rate of return, benefit-cost ratio).

There is no record of any sensitivity analysis being performed in the irrigation district feasibility studies. Point estimates were used on prices, yields, water prices, government programs, the acreage of high value crops, etc. A realistic 10 percent drop in gross revenues in the farm models used in these studies would have produced an "ability to pay" of approximately $20 per acre-foot—far below one estimate exceeding $100.

Lesson #4: Price Matters

One of the fundamental theoretical constructs of economics is the principle of diminishing marginal utility for buyers of goods and service. As we purchase goods and services, eventually we receive less satisfaction or fewer benefits from the last good or service purchased. Combined with price, this empirically validated principle produces the downward sloping demand curves so familiar in economics textbooks and used in sophisticated models for public policy analysis. Price must be lowered, *ceteris paribus,* to increase sales. Higher prices reduce the quantity sold.

I vividly recall informally teaching this economic principle in the early 1990s during a board meeting of the Central Arizona Water Conservation District (CAWCD), the autonomous administrative entity responsible for the CAP. A majority of the board wanted to survey CAP water users to discover their intended water usage so the CAWCD could establish the water price. This is backward economic logic and doomed to failure. Eventually, the board agreed to survey water users using a price schedule, asking them how much water they would buy at different prices. The CAWCD's revised process developed a demand curve, or willingness to pay curve, for water. With this information the CAWCD established a more realistic water price and correlated price assumptions to their projected financial position. With many elected public officials, and even technical personnel in some public agencies, the economic lesson that buyers respond to price requires constant instruction if a sound understanding is to be reached.

Lesson #5: I Can Outbid You

The equal marginal value principle in economics implies that a resource will be allocated to its highest value use until either the quantity constraint of the resource is met or the marginal values of all the alternative uses are equal. Operationally, this principle produces maximum profit in the case of the firm, maximum utility in the case of a consumer, and maximum economic welfare in the case of society. Value is determined by the willingness to pay for the product or service. So water in a market environment will be allocated to its highest value use first (e.g. drinking water), then other potable uses in the household (e.g. cooking), then . . . and eventually to the production of low-value, non-food agricultural crops. In practice this optimal allocation process is constrained by laws, regulations and property rights that discourage a market for water.

The CAP received Congressional funding based on the need to develop and support central Arizona agriculture. Planners did recognize that in 30-50 years the CAP would be a largely urban and Native American project. But not surprisingly, with the formal completion of the project in 1993, the CAP immediately became a municipal, industrial and Native American project. These interests had and have today a higher willingness to pay for water. This higher value in alternative uses bids water away from lower-value uses. Unfortunately, most of these exchanges are made through high cost administrative decisions rather than a market tool (Colby, 1993).

OTHER LESSONS LEARNED

Lessons 1-5 draw upon elementary economic principles that have a long and distinguished history in economic science. Economists become frustrated while working in the public policy process when decision-makers chose to ignore basic economic science. Water resource management policy has a long history of ignoring economic reality (Rucker and Fishback, 1983). The study of public choices under constraints has developed into two increasingly popular fields in economic science: public choice theory and neo-institutional economics. Both fields study how special interests use the political process to obtain privileged treatment or rents. Special emphasis is given in both fields to the measurement of gains and losses for both the winners and losers. The final three lessons learned from the CAP reflect lessons learned in the political economy of water resource management.

Lesson #6: Politics Trumps Economics, But Only Temporarily

The "need" for the CAP was obvious to anyone visiting central Arizona—it is a desert. By definition this area had a shortage of water. Therefore, to protect it citizens from drought and the lack of economic opportunity, the CAP became the Holy Grail for every public official and civic leader. Fear trumps economic science. With the successful completion of the project the current questions are who will pay for the available water and how will it be allocated? Basic economic principles remain so the pricing and allocation rules must be changed to reflect the new economic reality of underutilized CAP water.

Lesson #7: Law Trumps Economics, But Only Temporarily

Figure 2 illustrates a theory of economic development popularized by Nobel Prize-winning neo-institutional economist Douglas North (1990). Countries face

resource, technological, and market constraints over which they have limited control. With a science-based knowledge of these constraints, an institutional framework should be designed, according to North (1990), to create optimal opportunity sets for profit and non-profit organizations in the country. The key to economic development is developing appropriate rules for managing scarcity. Organizations can change their opportunity sets by modifying the constraint set (e.g. technological change) and/or creating different institutions (e.g. lobbying Congress for new rules). When politics dominate the economics of water resource management, institutions are changed, frequently to modify the opportunity sets available to special interests—municipalities (industry including agriculture), Native Americans, environmentalists, and recreationists. Why? The economic framework for socially optimal water allocation is not in place. Conflicts arise between these interests, creating an ongoing battleground for lawyers specializing in water law. New law will change economic incentives (e.g. opportunity sets) for some, but not others. This "improvement" is only temporary because technological change, urbanization, population growth, global markets, etc. change the constraint set. Any "improvement" also may be temporary when parties not served by the new law seek to change it.

Lesson #8: You Have the Deep Pockets

During the early 1980s it became even clearer to some analysts that agriculture would not be able to afford CAP water (Martin et al., 1982; Martin, 1988). The rational strategy of growers in CAP irrigation districts, according to these social scientists, was to play the water development game for as long as possible. Once it became clear that they could not afford this water, society, via government agencies, would adjust the rules and prices in favor of the farmers who were still in business. Growers were well aware that there was legal precedent to support this strategy (Smith, 1986).

Who pays when we do not get the economics right? You and I do. The favorite fiscal strategy of publicly funded projects like the CAP is to spread the costs "lightly" across millions of households and concentrate the benefits for a relatively select few beneficiaries. Urban taxpayers and ratepayers have the proverbial deep pockets.

BUILDING WELL-TRAVELED BRIDGES BETWEEN ECONOMIC SCIENCE AND WATER POLICY

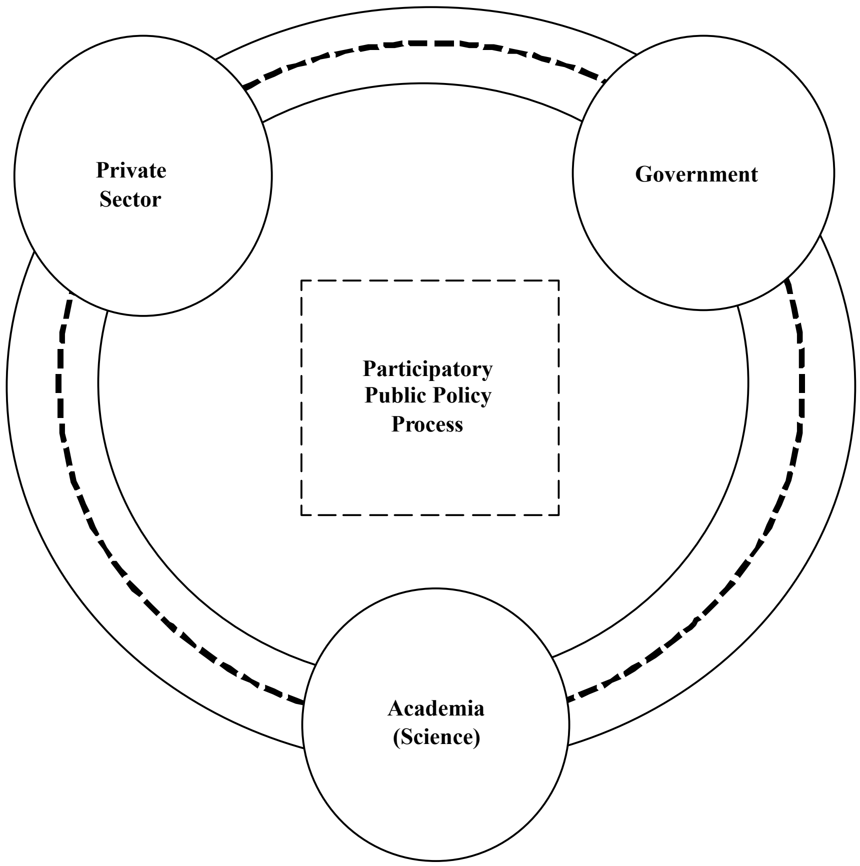
Effective and efficient decision systems for resource management require timely and useful information as well as the active participation of all impacted parties. Water management policy, given its vital role in the sustainability of life, demands the best science available. During my twenty years of working professionally in agricultural water policy, I have observed that good science is often an afterthought in the public policy process. Public policy makers require the best, science-based information available, but useful science will only be available if there are well-traveled information bridges between public agencies, the private sector, and the scientists (Figure 3). Currently, these three bridges receive highly variable traffic while at other times they fall into disuse. In some states, these bridges may have even fallen into disrepair and represent a hazard for the traveler.

Effective and efficient informational bridges cost money to construct and maintain. Optimal two-way information flows take time and effort to manage. There must be incentives to use them as well. For academics, the disincentives to travel these bridges are daunting. Policy decisions often have technical analysis deadlines that teaching faculty find impossible to meet. All academic incentives give priority to disciplinary research rather than interdisciplinary research and outreach education. Water policy decisions require a system-wide analysis where all sciences, combined with law and politics, produce a sustainable strategy. But this is a messy, time consuming process. Most academic scientists are not trained to think holistically, understand competing interests, or have the patience to work in multi-disciplinary teams. The National Science Foundation's sponsored science and technology centers are one model for building these needed bridges and maintaining two-way traffic between scientists and decision-makers.

A CONCLUDING REMARK

A fundamental challenge in water resource management is getting the economics right—right for this generation as well as future generations. Understanding the physical and biological science behind water scarcity is a necessary but not a sufficient condition for effective water policy. Appropriate emphasis as well should be placed on the social science of water management decision-making at all levels of society. Social science information, to be useful, must travel in a timely and effective manner in two directions on established information bridges between interested parties. A recent revelation associated with the CAP is that social science concerns associated with water management, more than hydrology and engineering, now drive the sustainability of the project. As Kelso, Martin and Mack (1973: 244) prophetically noted nearly thirty years ago, "Water scarcity, even growing scarcity, is far less costly to the

Figure 3: Bridging For Improved Water Resource Management



Arizona economy than is popularly supposed; whatever costliness the scarcity does impose, amelioration is far more a matter of reforming man-made institutional inefficiencies in water administration and management than in reforming its nature-made physical scarcities."

AUTHOR

A professor of agricultural and resource economics at the University of Arizona, **Paul Wilson's** teaching, research and outreach education interests are in the areas of the economics of agribusiness organization and management, irrigation technologies and management, finance, and environmental management. Currently Professor Wilson is working on an economic analysis of the privatization of Mexico's irrigation districts and an interdisciplinary project-evaluating alternative farming technologies necessary to reduce dust pollution in central Arizona. He has published over 90 professional papers and has been recognized at the University of Arizona for outstanding teaching and student advising. Professor Wilson earned his Ph.D. in agricultural and applied economics at the University of Minnesota.

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