

Chapter 2

Origins of CBA of Water Use Conflicts*

Although the conceptual underpinnings of CBA may be traced to the nineteenth-century French civil engineer and economist Jules Dupuit, extensive application of the method had to wait until the twentieth century.¹ The sharpening of CBA into a potentially useful decision-making tool also involved engineers, i.e. the U.S. Army Corps of Engineers (ACE). Propelled by a rising demand for electricity and substantial damage from several serious floods, the U.S. Congress passed two significant flood control acts (1936, 1944) (referred to here as the 1936 Act and the 1944 Act, respectively).² The 1936 Act called for “works of improvement” on more than 50 major rivers throughout the United States and made flood control a federal government activity. The necessary physical constructions had been the ACE’s expertise, and ACE became heavily involved in many construction projects, as it was given responsibility for analysis of rivers for flood control (whereas the U.S. Department of Agriculture was given responsibility for water flow on upstream watersheds.³)

Importantly, the Act introduced an approach to prioritizing between projects:

The federal government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds ...for flood-control if the benefits to whomsoever they may accrue are in excess of estimated costs (as quoted in [68])

* This chapter draws extensively on [105].

¹The Swedish water law of 1918 stipulates that no one is allowed to build a hydropower plant unless the revenues after deduction of the construction cost is at least twice the damage inflicted. It goes on to stipulate that construction is not permitted if a fishery is seriously affected. Nor is construction permitted if there are very serious ecological damages. In an abstract sense this law suggests that a hydropower plant must pass a cost-benefit test. Furthermore, the law stipulates compensation for damages, implying the Pareto criterion rather than Kaldor-Hicks (since compensations were actually paid); again, this is in the abstract, but compensations potentially had to be negotiated for each stakeholder in the vicinity of the proposed plant. The process that led to the construction of the Dönje plant provides an example.

²According to [112], the federal Reclamation Act of 1902 required economic analysis of projects.

³For further details on the problems created by this separation of tasks, see [153].

These ideas were later developed in several handbooks and manuals. The 1944 Act gave the Corps responsibility for multi-purpose dams, e.g. hydropower constructions.⁴ CBA subsequently conquered new worlds and new applications in the 1950s and onwards, as the tool was applied to various types of public projects in Europe and later on in the third world countries.

The classical contributions that can be said to have sprung out of the 1936 Act include [47, 82, 83, 120], and [131]. Of these, [131], a key output from the Harvard Water Program, stands out as the most comprehensive in terms of perspective, as it presses a system perspective and multiobjective planning. Thus, sophisticated computer modeling was used to generate insight into large sets of alternatives, using – somewhat controversially – a multiple objective framework. This work was further developed by [90] who demonstrated the use of simulation modeling within a detailed application of the methods to the Lehigh River system (and, in less detail, the Delaware river system). The simulation model is exceptionally detailed, including a hydrological projections module, descriptors of water supply and demand and a range of development measures. In spirit, this systems approach to water project is reminiscent of the EU Water Frame Directive, in that the Directive emphasizes a river basin perspective (a perspective that is also important in [120]).

Rather than providing a detailed review of the empirical literature that exists, we discuss a few high-quality contributions, mainly from the US. In addition, we will illustrate some recent ideas in the application of CBA to water projects, as they flow from our framework. While the problems are encountered world-wide, we will concentrate on U.S. and Europe. Thus, we begin with the U.S., then turn to review a study in Sect. 2.2 on applying CBA to the Water Framework Directive and one study applying a dynamic approach to cost-benefit analysis.

2.1 The United States

We target studies that more or less directly are related to energy from moving water.⁵ We begin with a capsule summary of the U.S. literature and then turn to the classical U.S. studies. This brief review goes some way in appreciating the difficulties encountered in the pioneering studies. Indeed, we have come quite a long way, especially regarding the measurement of benefits. It is possible that the attitude, in some cases, towards benefit measurement was affected by the paucity of such studies. We will give an example below, but let us now turn to the facts.

⁴For a historical review of the development of CBA in the U.S. the reader is referred to [189], for Australia to [43], and for some UK studies to [75]. A fine book-length treatment of water planning in the U.S. that covers the developments in great detail is the volume by [157], see, especially, Table 3.1 in the chapter by [21] for a comprehensive overview of the developments.

⁵For a recent summary of valuation studies on water quality, see e.g. [15].

Reference [128] has collected 1,239 estimates on the value of 30 outdoor recreation activities, a subset of which is relevant for water projects. He concludes that hunting on public lands in the Pacific Northwest has an average value of \$35 per day, fishing averages \$42 per day, wildlife viewing \$35 per day, and hiking \$24 per day in the Pacific Northwest. He reports on about 20 studies of river recreation such as rafting, kayaking, and canoeing in the U.S., which yield about 80 separate valuation estimates. The average value of these recreation activities is \$101 per day, with a 95% confidence interval of \$82–\$120. The highest average values per day are for the Southeastern U.S. at \$127 per day. Values for unique sites are even higher, at \$300 per day. Reference [22] has performed a meta analysis on fishing recreation studies, suggesting that the value of an angler day is \$11.63 higher for fishing days taking place in rivers than in standing freshwater (e.g. reservoirs, ponds). For further details on additional studies (e.g. property value studies for dam removals and passive use values for preserving existing free flowing rivers), we refer to [129]. Finally [14], estimate the non-use values associated with increased instream flows for the purpose of protecting endangered fish species in the Southwestern U.S. Reference [164] is an extensive early study of the benefits of water quality.

A number of in-depth studies have examined the costs (e.g. foregone revenue) and benefits (use and non-use values) associated with maintaining minimum flows in regulated rivers. For example [41] estimated USD 325 million in costs (1994 present value dollars) associated with purchasing replacement peak power sources when hydroelectric facilities draw down reservoir levels slowly to assist fish migration. Reference [67] examine alternative “water banking” schemes that allow parties to purchase water for the purpose of assisting endangered species. Similarly [95], estimate the costs for policy makers to purchase water to ensure minimum flows for fish.

As indicated above, applied CBA arose from the efforts in the U.S. to shed light on the benefits and costs of water projects. In one of the classic studies, [120] looked at private- and public-sector activities in river basin development from an welfare economics point of view. They explained the role of welfare economics and the tools that can be used in practice to measure benefits and costs. In the same year, another classic study [47], was published. The book brought together the existing approaches towards benefit measurement through the lens of formal welfare economics. As summarized by [111] (p. 46),

A common feature of all of them [studies on “conventional” outputs of water projects] was that benefits could be satisfactorily evaluated by ingenious applications of information generated by markets. Eckstein’s *Water Resources Development* was an exposition and critique of these methods and an interpretation of them in terms of formal welfare economics.

However, the early studies largely ignored recreational values since methods to measure them were not yet available. For example [47] claims that “recreation must be judged on other criteria, for the use of benefit-cost analysis for them not only is invalid, but casts general doubt and suspicion on procedures which can effectively serve a high purpose where they are appropriate” (p. 41).

Reference [119] forwards an early critique of the view that environmental benefits lack an economical value. He was concerned with more or less unique natural environments that would be permanently destroyed if developed, so developing such environments or resources would cause irreversible effects or damages. One of Krutilla's arguments is that the willingness to pay for developing a resource is limited to the area under a demand curve for the resource's services (if we take a static perspective here, for simplicity). On the other hand, the minimum which would be necessary to compensate losers is not limited to such areas. Reference [119] concludes that it is impossible to determine whether the market solution is efficient or inefficient. At first glance it seems a bit surprising that he does not connect his discussion to property rights and the Coase theorem; see [34]. However, the explanation is that Krutilla was dealing with situations where no property rights could be established. Another of Krutilla's arguments draws on the concept of option value when demand is uncertain; see [180] for details. Even if a person does not currently consume a particular good he or she might value the option to consume it in the future. Thus retaining the pure possibility of future consumption has a value.

Reference [119] did also consider natural environments as endowments for certain groups. His argument opened up for the possibility that resource stocks are included as arguments in individuals' utility functions (as in the framework above). Then stocks as well as harvests are modeled in utility maximization problems, although from an individual's point of view a stock's path over time might be exogenous. The "conventional" (instantaneous) utility function $u[c(t)]$, where $c(t)$ is consumption at time t is replaced by a function $U[c(t), s(t)]$, where $s(t)$ denotes the stock of a natural resource at time t with $s(0) = \bar{s}$ denoting the initial and given endowment of the resource. In the simplest case the path of the stock evolves according to the equation $\dot{s}(t) = f[s(t)] - h(t)$, $f[s(t)]$ is the natural growth of the resource (if any), and $h(t)$ refers to the harvest of the resource. This way of modeling the problem, which is only sketched here, opened up for analysis of the welfare significance of national product in a dynamic economy as is indicated by the title of the classical article by [181]. Early contributions with a focus on how to augment the conventional net national product measure so as to become a better welfare indicator in the presence of natural resources are [37, 80], and [132].⁶

The following quotation neatly summarizes Krutilla's are views of the state of the art of cost-benefit analysis in the 1960s:

Accordingly, our problem is akin to the dynamic programming problem which requires a present action (which may violate conventional benefit-cost criteria) to be compatible with the attainment of future states of affairs. But we know little about the value that the instrumental variables may take. We have virtually no knowledge about the possible magnitude of option demand. And we still have much to learn about the determinants of the growth in demand for outdoor recreation and the qualitative significance of the asymmetry in the implications of technological advances for producing industrial goods on the one hand

⁶For reviews and extensions, see [4] and [84].

and natural environments on the other. Obviously, a great deal of research in these areas is necessary before we can hope to apply formal decision criteria comparable to current benefit-cost criteria (p. 785).

Fewer than 10 years later [121] published another major contribution, “The Economics of Natural Environments”.⁷ This book addresses several important issues. In contrast to [119, 121] discuss the Coase theorem. They also model an intertemporal decision problem involving an irreversible investment constraint. We do believe this is one of the earliest applications of optimal control theory in environmental and resource economics. They also discuss the concept of quasi-option value, a concept attributed to [5, 56], and [85]. Finally [121] discuss how to empirically measure the benefits of preserving a natural environment,⁸ acknowledging that they do not fully understand how to estimate such benefits. Nevertheless they suggest an approach which can be useful whenever we lack detailed and robust benefits estimates.⁹

The Coase theorem states that in a competitive economy with complete information and zero transaction costs the allocation of a resource will be efficient independently of the initial allocation of property rights. For example, the optimal level of pollution of a river will be the same regardless of whether polluters, say farmers, or fishermen are assigned property rights. These rights determine the direction in which compensation is made if rights are violated. However the invariance part of the theorem holds only if preference relations are quasi-linear so that payments cause no income effects. This is also noted by [121]. A simple way of stating this is by noting that the willingness-to-pay (the compensating variation) for access to a resource differs from the willingness-to-accept compensation (the equivalent variation) in exchange for access unless the considered individual’s preference relation is quasi-linear. In addition the informational requirement is strong as is the assumption of zero transaction costs, in particular when a large number of individuals are involved.

To handle investment decisions under an irreversibility constraint they use optimal control theory. They maximize the discounted net benefits:

$$\int_0^{\infty} e^{-rt} [b^d(s(t), t) + b^p(s(t), t) - C(I(t))] dt \quad (2.1)$$

subject to $ds/dt = I$, $I \geq 0$, and $s(0) = \bar{s}(0)$. In Eq. 2.1 $b^d(\cdot)$ refers to the *net* benefits at time t of developing a resource (and the interest rate at which items are discounted is denoted r). These are a function of the scale of development or the size of the project $s(t)$ and might also change over time as indicated by the time argument t . There is an opportunity cost of development covered by $b^p(\cdot)$.

⁷A revised edition of the book was published in 1985 where, in particular, the option value issue was further developed.

⁸At the time, some economists argued that CBA did not apply if there were irreversible effects. See the discussion (and defense of CBA in such cases, referring to [121]) by [163].

⁹For application of their framework, see e.g. [74, 158] and [185].

For example, if development means building a dam recreation is possibly damaged. The scale of the project might be the number of dams constructed. Thus $b^d(.)$ is increasing in the scale of the project while $b^p(.)$ is decreasing in $S(t)$. Finally the flow capital cost of the project is denoted $C(I(t))$. The constraints are the dynamic constraint on development, the restriction on reversibility, and the initial condition indicating that the planner starts with an exogenously given project scale $\bar{S}(0)$ at time zero. This so-called *Krutilla-Fisher model* has attracted much interest in the literature, and we will return to it in our own cost-benefit analysis.

Reference [121] focus on likely time patterns of $b^d(.)$ and $b^p(.)$. They find it likely that the benefits of development of a natural resource are decreasing over time. One reason being technological change over time. The benefits of preservation, on the other hand, are likely to increase over time. One reason being that technological change can hardly produce close substitutes to environmental resources while increasing incomes tend to increase the willingness-to-pay for environmental resources (if they are normal, as is typically assumed). Reference [162] develops these ideas in detail.

Reference [121] also discuss the concept of option value (although the concept dates back at least to [119], or even Stanley Jevons, as argued in [117]). There are several definitions available, but the two most common in environmental and resource economics are the real option value associated with Dixit and Pindyck, see, for example, [42], and the quasi-option value associated with Arrow-Fisher-Henry-Hanemann. The relationship between these two concepts has been analyzed (in a simple two-period model) by [137]. The Dixit-Pindyck real option value of postponing an investment, here denoted OV^{DP} , can be decomposed as follows:

$$OV^{DP} = OV^{AFHH} + PPV, \quad (2.2)$$

where OV^{AFHH} is the quasi-option value (≥ 0) reflecting the value of information (the difference between closed-loop and open-loop solutions), and PPV is the pure postponement value, i.e. the value of having the option of postponing the investment. This last value, which is also present in a deterministic setting, might be positive or negative (≥ 0). For example, if net flow benefits of a project are negative today but will become positive at some future time, it is profitable to delay the project until that point in time. Unfortunately, and as acknowledged by [121], estimating option values is difficult. Still the concept might be useful in circumstances where the known benefits of development are of roughly the same size as the benefits of preservation and development causes irreversible damage to preservation interests.

Let us add that another concept of option value was developed from Krutilla's early paper. This concept was ultimately recognized as a measure of risk aversion in a framework that characterized choice with state dependent preferences and with discrete characterization of uncertainty. Reference [65] is the paper that clarifies this literature.

Reference [121] undertake several empirical cost-benefit analysis, devoting two chapters to an impressive analysis of a hydro power development in the Hells

Canyon¹⁰ where they estimate a slightly simplified version of Eq. 2.1. A lot of space is devoted to discussions how b^d and b^p might change over time. However, to today's reader it is obvious that they lack the instruments for estimating the willingness to pay for having the canyon preserved. In those days (the Hells Canyon study was undertaken in 1969) there was at least a travel cost study [31] and a study [39] using a survey technique that today is known as the Contingent Valuation method. Reference [121] refer to both but did not use these instruments in the Hells Canyon study. Travel cost methods can be used to estimate use values, or the willingness to pay of visitors or users of a resource. Passive use values relate to the value of the continued existence of a natural environments and their living organisms as well as bequest motives, such as a desire to also allow future generations to "consume" these resources. Passive use values cannot be measured in markets but require other methods such as surveys where respondents are asked about their willingness-to-pay for the preservation of a particular resource, i.e. a natural environment.

To the best of our knowledge, the first study of water use conflicts incorporating use values as well as passive use values is [173], which investigated alternative strategies to no action at the The Glen Canyon Dam, the second largest dam on the Colorado River. The dam's main purposes include generating electrical power, storing water for the arid southwestern United States, and providing water recreation opportunities. Construction of the dam began in 1956 and it was able to begin blocking the flow of the river in 1963. Due to the stability of the dam, there has not been the periodic flooding that would wash away and renew sand banks along the portion of the Colorado River that transits the Grand Canyon. Because of the stability of the sand banks, several non-native species of plants became established, adversely affecting the native wildlife (http://en.wikipedia.org/wiki/Glen_Canyon_Dam). The silt that once flowed and settled along the Colorado River streambeds are now contained to Lake Powell reservoir. The reduction of silt in the water has been of great importance socio-culturally for the people and the animals that have had to learn to live with the consequences. Another cost of the Glen Canyon Dam is evaporation that takes place in Lake Powell (<http://www2.kenyon.edu/projects/Dams/glen.html>).

This environmental impact statement was completed in 1995; see [173]. It uses conditions as of 1990 as the baseline and evaluates eight alternative strategies to taking no action. The study aims at estimating use values as well as non-use values of the various alternatives. For both types of values the Contingent Valuation method is used. Reference [16] undertook a study of river-based recreation in the area. The study found that the value of angling and white-water boating was related to flow and that there were significant differences between the effects of flow on commercial

¹⁰The lower Snake River, forming the boundary between the northeastern border of Oregon and the west central portion of the Idaho border, passes through about 200 miles of a geologic formation known as Hells Canyon. The Snake River in this reach is one of the most scenic streams to be found anywhere according to [121].

white-water boaters and private white water boaters. However, the study was unable to find a correlation between the value of day use rafting and flow.¹¹

Reference [173] attempted to cover non-use values using the Contingent Valuation method. A focus group in New Mexico and two subsequent focus groups in Arizona explored whether individuals held any value beyond a use value for the hydropower resource. No non-use value for the hydropower resource per se was evident. However, participants in these focus groups clearly empathized with particular populations, such as small farmers and rural residents, whose lifestyles might be affected by the price impacts associated with the loss of peaking capability at Glen Canyon Dam. Therefore, descriptions of residential price impacts and impacts on farmers were developed and included in the pilot test survey instruments.

A pilot study was mailed to a national sample and a sample of households living in the affected area. The results are reported in [183]. Pilot-test sample sizes were too small to allow for statistically reliable estimation of non-use value for each of the alternatives. Non-users were most concerned about impacts to vegetation and associated wildlife, native fish, Native Americans, and archeological sites. Therefore alternatives that benefit these resources are likely to have higher non-use value. Pilot-test results indicated that estimates of non-use value obtained in the full-scale study may range from tens to hundreds of millions of dollars annually. The results of the full-scale study were not available to the authors of [173]. However, a study by [184] contains a massive account of all steps towards the full scale survey of 8,000 households in the United States.

In any case we do believe that this highly impressive study (covering 320 pages excluding bibliography and appendices) is the first to estimate use values as well as non-use values of a major water use conflict.¹²

2.2 Europe

We next discuss a study on how CBA has been used to shed light on how the Water Framework Directive might affect the usage of water resources in Europe and turn then to a Swedish study that is used to illustrate certain analytical points in our framework. Note that none of our European studies apply the Krutilla-Fisher approach to discounting, i.e. assuming the benefits can be discounted differently from costs. It can be argued that the environmental resources in these particular

¹¹Reference [173] also estimates what looks like a *Keynesian* spending multiplier. That is, every dollar spent in the considered region will generate further incomes that in part are spent, generating further incomes, and so on.

¹²However, since the results of the full-scale survey reported in [184] were unavailable, non-use values were not included in the cost-benefit analysis of the alternatives to the baseline scenario (no action).

cases are not unique and hence the same type of irreversibility argument does not apply. Again, we abstain from a detailed literature review.¹³

2.2.1 The Water Framework Directive and CBA

The Water Framework Directive entered into European law on 22 December 2000 and covers EU water bodies, including rivers, lakes, reservoirs, wetlands, groundwaters, estuaries and coastal waters. The Directive's objective is to maintain environmental quality and to achieve "good status" in ecological and chemical terms by 2015. Implementation is based on river basin management planning, a mechanism for integrated catchment management. Plans are implemented over a 6-year cycle, which includes characterization, identification of pressures and impacts, and the setting of environmental objectives and programmes of measures to allow them to be met. Good ecological status is the default ecological target for all waters, but a kind of exemption is allowed via the so-called Heavily Modified Water Bodies (HMWB) (Article 4). A number of criteria must be fulfilled in order for a water body to qualify as a HMWB, including the key idea in Article 4(3)(b)) of being "disproportionately costly". Thus, if it is considered "too costly" to reach the goals, the water body can be given a HMWB status and hence an exemption. This exemption rule has led to a significant demand for CBA, as well as controversy, as the HMWB is considered a "loophole" in some circles and "a logical necessity" in yet others.

Reference [73] provide an illustration of how CBA has been used under the WFD. The study focused two cases, including the river Tummel in Central Highlands, Scotland. This river basin was selected to shed light on damages caused by hydro-electric development. All water bodies in the Tummel system were identified as candidate Heavily Modified Water Bodies (HMWB). Reference [73] asked if improving the ecological status of the Tummel system implies costs that are "disproportionately" greater than benefits. Because removing all hydropower related structures in the Tummel basin was considered an infeasible option, [73] looked at alternative scenarios that allowed continued hydropower, while promoting ecological quality towards good ecological status. Compensatory flows released to the rivers immediately downstream of hydro control structures and an upgrading of fish passes to enhance their effectiveness were principal measures suggested. These measures were considered to be practicable for the Rivers Garry and Errochty which form part of the east of the Tummel catchment. The essential part of the cost was found to be the value of lost electricity production. Estimated benefits

¹³The interested reader is referred to www.evri.ca for an inventory, and [142] and [143] for detailed surveys of the European literature on valuation. Reference [148] has a summary of the literature on the value of recreational fishing, including a survey of Nordic studies. Similar to the U.S. studies mentioned above, he also reports significant variation of valuations across type of fish, conditions at the site, income and so on.

included valuing the return of migratory salmonids to the Rivers Garry and Errochty, because this would increase rental values (and hence revenues) on the River Tummel downstream of the study area. The authors acknowledge that there are several categories of benefits that have not been included. Yet, their conclusion is that the proposed options for reaching a Good Ecological Status are “disproportionately costly” and therefore that these water bodies should be designated HMWB. A key factor in arriving at this conclusion is also the additional fact that alternative ways of generating peak-demand electricity are more detrimental to the environment.

2.2.2 A Salmon-Hydropower Conflict: Dynamic Model

In a recent study [72] analyzed a salmon-hydropower conflict. Society is assumed to value both its consumption of a numéraire good, produced via hydropower, and its consumption of salmon. In addition, the society attributes a value to the stock of salmon. The good is produced in a hydropower plant that creates the trade-off we are interested in here: more electricity generation means less salmon and vice versa. We sketch this trade-off in the following manner (ignoring initial and terminal conditions):

$$\text{Max} \int_0^\infty u(c(t), c_L(t), s_L(t)) e^{-rt} dt \quad (2.3)$$

subject to

$$c(t) = f(\dot{s}_w(t)) \quad (2.4)$$

$$\dot{s}_w(t) = k(t) - A(t), \quad (2.5)$$

where $c(t)$ denotes consumption of the numéraire good at time t , $c_L(t)$ denotes consumption of salmon at time t , $s_L(t)$ denotes the stock of salmon at time t , and r is a discount rate, for simplicity assumed to be constant across time. The amount of electricity is a function of the flow of water $\dot{s}_w(t)$ through the power station, which is determined by natural conditions (precipitation, etc.), denoted $k(t)$, and the amount of water diverted from electricity production, denoted $A(t)$, to the salmon (i.e. diverted into the old riverbed) to help salmon pass the station.

The change of the stock of salmon is determined as follows:

$$\dot{s}_L(t) = g(s_L(t), A(t)) - c_L(t), \quad (2.6)$$

where $g(\cdot)$ is a generic growth function. Thus the natural growth of the stock of salmon is a function of $A(t)$ and the size of the stock of salmon at time t and Eq. 2.6 shows that the change of the salmon stock at time t is equal to the natural growth of the stock at time t less the catch of salmon at time t . For simplicity, it is assumed that the catch of salmon at time t is equal to consumption of salmon at time t .

A cost-benefit rule is arrived at by considering $A(t)$ as a parameter and proceeding in the way detailed in, for example, [4]. The resulting dynamic cost-benefit rule

was used in structuring a Contingent Valuation study. Data comes from a project regarding a potential salmon passage-hydropower conflict in the northern Swedish Ume River and its largest salmon producing tributary, the Vindel River, see [72] for details about this study. Daily water flow data is combined with daily data on the number of salmon (1974–2000) that pass the hydropower plant Stornorrfor. Detailed ecological studies were used to build a Contingent Valuation scenario and to study the opportunity costs of releasing more water versus the potential benefit of salmon upstream migrants. Two ecological models were developed, one predicted upstream migration success of salmon in the bypass channel at added bypass flows, another predicted the number of salmon passing the fish ladder after improved upstream migration. The ecologists used results from 1995 to 2005 of tracking radio-tagged upstream migration salmon in the Ume River, and 30 years of information from the fish ladder. The scenario entails reducing production of electricity, which would increase the number of wild salmon in the river, as more water would be allocated to salmon passage areas. The mail survey was carried out in the autumn of 2004, using a random sample of 3,200 Swedes above the age of 18. The response rate was 66%.

On average, approximately 3,000 wild salmon per year that reached the Vindel River's spawning grounds between 1995 and 2004. This figure was used as a baseline in the scenario. The forecast on future number of salmon was built on the ecological models, and given the uncertainty about how the salmon stock responds to a perturbation of the water regime, a number of different forecasts were used in different versions of the survey. The results suggested strongly that valuations are independent of the number of salmon in the interval 4,000–9,000 per year, implying an existence value. It appears that respondents would like to pay for increasing the stock, i.e. securing the salmon, a kind of existence value.

The key idea was to base the valuation question on the general equilibrium cost-benefit rule hinted at above. Therefore, a proper valuation-question should, according to the cost-benefit rule, give information about both the direct effects of the salmon stock due to a change of water flow diverted to salmon and the impact on growth of salmon due to an increase of water flow. It was assumed that the method used to increase the amount of salmon does not influence people's valuations, as long as it is considered a natural method (and the increase of salmon is the same regardless of the method). The study scrutinized preferences across different methods, in this case improving the fish ladder or increasing the water flow in the bypass channel.

In her analysis of the benefits and costs, [72] concludes that passive use (non-use) values are the major contributors to the benefit (SEK 96–517 m¹⁴) of increasing the wild salmon stock in the Vindel River. The sensitivity analysis suggests that the opportunity costs in terms of lost electricity are typically higher than the estimated benefits.

¹⁴In our own cost-benefit analysis a Swedish Krona (SEK) is assumed to correspond to 0.1 Euro (EUR).

The Economics of Evaluating Water Projects

Hydroelectricity Versus Other Uses

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