Cost-Benefit Analysis and Valuation Uncertainty

Empirical Contributions and Methodological Developments of a Study on Trade-offs between Hydropower and Wild Salmon

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Abstract

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This thesis addresses the economic trade-offs between hydropower and fish production, based on an empirical assessment of the costs and benefits of changing the water flow of the Ume/Vindel River in northern Sweden at a major hydropower plant in ways that would reduce its production of electricity but increase the number of wild salmon in the river.

A theoretical framework for dynamic cost benefit analysis (CBA) is presented and applied to the salmon passage-hydropower production conflict. The approach has wider applicability than suggested here, and should be useful in other, similar contexts.

To obtain estimates for the benefit of increasing the number of wild salmon the contingent valuation method (CVM) was applied. The CVM is a survey-based method developed for measuring values of non-market goods by using willingness to pay (WTP) questions.

A new open-ended valuation question, the "classic and interval open-ended" (CIOE) question, was introduced to accommodate the fact that many people have an inability to state their preferences accurately. Interpretation of the resulting valuation uncertainty is more straightforward with this type of question than with other types of valuation question. There are other advantages as well. In addition, methods are introduced for: finding a WTP point estimate for the CIOE question; estimating lower and upper boundaries for the WTP; and for estimating confidence intervals for the total present benefit.

An important element of the empirical analysis is that estimated changes in resource conditions are based on detailed river-specific data. The resource dynamic considerations were introduced into both the scenarios and the WTP questions, using an estimated salmon population model for the Vindel River as a base. A model predicting the effects of varying the water flows on the salmon's migration behaviour was used to estimate the costs of increasing the number of salmon.

A total of 1785 individuals received a questionnaire including the CIOE question; the response rate was 66%. Passive use (non-use) values are the major contributors to the benefit (96-517 MSEK) 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.

Keywords: classic and interval open-ended (CIOE) question, contingent valuation (CV), dynamic cost-benefit analysis (CBA), hydropower, salmon, valuation uncertainty, willingness to pay (WTP)

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To my Grandmother Nanna
who taught me to see the world from a different angle,
and my Grandmother Henny
who taught me to never give up.

Contents

Appendix

Papers I-III

The thesis consists of the following papers, which will be referred to by their Roman numerals:

I. Håkansson, C., Johansson, P-O. & Kriström, B. 2005. Salmon and hydropower: Dynamic cost-benefit analysis, in *The theory and practice of environmental and resource economics- Essays in honour of Karl-Gustaf Löfgren*, Eds. Aronsson, T., Axelsson, R. & Brännlund, R., Edwar Elgar, UK.

II. Håkansson, C. 2006. A new valuation question – Analysis of and insights from interval open-ended data in contingent valuation. Forthcoming in *Environmental and Resource Economics*.

III. Håkansson, C. Costs and benefits of improving wild salmon passage in a regulated river (Submitted).

Appendices

Questionnaire- used to elicit data for Paper I-III.

1 Introduction

Living in a world of scarce resources, it is essential to rigorously examine the consequences (costs and benefits) of potential developments for the affected communities in order to assess the relative merits of possible options. In the studies underlying this thesis cost benefit analysis (CBA) was used to investigate the economic merits of changing the water flow at a major hydropower plant on the Ume/Vindel River, northern Sweden, that would reduce its production of electricity but increase the number of wild salmon in the river. Several approaches that could be applied to similar problems, and to CBA more generally, were developed in these studies. Two novel contributions concern ideas to deal with two recognized challenges when conducting a CBA: incorporating interactions between ecological and economic systems in the analysis and accounting for the inability of many people to state their preferences accurately.

Various decision-aiding techniques are applied in CBA that numerically weigh the advantages and disadvantages of the considered projects. In a typical CBA, the consequences of two or more public decision alternatives are compared. The nature of these consequences may be highly diverse (*e.g.* economic costs, risks of disease and death, environmental improvement or damage *etc*.) but are assigned a common metric: monetary value. The option with the highest net benefit (benefits minus costs) is usually recommended, although this neglects distributional aspects (*i.e.* who wins or loses does not matter; the sum value is the decision criterion).

In contrast to a CBA, private or purely financial economic assessments very rarely consider all of the effects projects may have on the community, and thus do not provide solutions that are economically optimal, which is the key concern if the goal is to maximize welfare.[1] This is because such estimates only include market-related costs and benefits. For projects involving environmental issues this is problematic, since many goods are not market-priced, such as clean air, recreation and wildlife, the adverse consequences being undesirable effects on natural resources. By finding efficient solutions for the utilization of our resources, the use of CBA can in the long run lead to more sustainable development.

Interest in environmental issues has intensified in recent decades and there have been accompanying increases in demands for suitable assessment tools to evaluate environmental goals, and for new environmental policies and policy instruments. The Amsterdam treaty of 1999 provides examples of such demands. The treaty stipulates that within the measures of potential benefits and costs shall be considered when the European Union's environmental policy is prepared

[1]Economic welfare theory is built on the assumption that every person wants to maximize his/her own utility/satisfaction/pleasure/welfare. The utility a person generates from a good depends on the person's preferences. Utility is unit-less and cannot therefore be bound to a specific scale. Since different actions require valuations of very different effects, use of standard units (and thus scales) facilitates comparisons of different alternatives. It is convenient to convert utility to monetary terms since most people can refer to such units.

(Frykblom & Helgeson, 2002). Another example is the Swedish Environmental Objectives Proposition (2004/05:150), which specifically states that the use of economic models for analysing consequences of environmental measures, and methods for the economic valuation of environmental values, should be further developed (pp.188).

Two of the Swedish environmental objectives[2] are to ensure that the Swedish environment has "Flourishing Lakes and Streams" ("Levande sjöar och vattendrag") and "A Rich Diversity of Plant and Animal Life" ("Ett rikt växt- och djurliv"), while the EU Water Framework Directive (WFD) from 2000 states EU-wide objectives for improving the status/potential of ecological systems.[3] Those objectives illustrate the importance that is being attached to the restoration of river ecosystems in Sweden and the rest of the EU WFD (2007).

The construction of hydropower plants is one of the human activities that has had major effects on river ecosystems. The flow-controlled areas in regulated rivers hinder the passage of fish. In Sweden, fish passage problems arise in rivers where fish, notably salmon, spawn in upriver areas while critical migration passages such as bypass channels and fish ladders are situated in the downriver areas. Many Baltic rivers have lost their native salmonid populations; the numbers of rivers hosting wild salmon have fallen from *ca.* 100 a century ago to only 44 today (ICES, 1997). Besides migration problems due to hydroelectric plants, the salmon in the countries adjoining the Baltic Sea have been affected by over-fishing, pollution, timber floating and reductions in lake levels. The Vindel River, northern Sweden, is one river that still has a wild salmon stock, but fish ecologists suggest that the conditions in the river may be unsustainable for its population of wild salmon in the long run. Several fish recovery plans have been presented (see Section 2.3).

Numerous valuation studies on fish recovery/management have focused solely on the fishes' value for sport-fishers (see Paulrud, 2004, for a review). It should be noted that since both users and non-users may have passive-use (non-use)[4] values for a fish stock, and there are many more nonusers than users, the aggregated passive use value may constitute a major part of the fishes' total economic value (*e.g.* Navrud, 2001). Hence, excluding non-uses from a study may lead to the actual benefits of an increase in fish stocks being underestimated by an unknown magnitude.

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[2] The government's overall environmental goal is to hand over a country to the next generation in which the major environmental problems have been solved. The 15 environmental objectives have been formulated on the basis of what "the environment can handle" and define the state of the Swedish environment that we should aim at (prop. 2004/05:150, pp 1).

[3] The increasing demands by citizens and environmental organizations (in all 27 EU states) for cleaner rivers and lakes, groundwater and coastal beaches has been evident for a "considerable time" WFD (2007).

[4] Passive use values consist of three components: the value based on the welfare the good may give other people; the value based on the welfare the good may give future generations; and the value based on knowing that the ecosystem exists.

A number of different techniques have been developed for measuring values of non-market goods. A person's valuation of a good may be reflected in his/her willingness to pay (WTP) for receiving the good, *i.e.* the WTP reflects the person's subjectively experienced welfare for receiving the good.

Valuation techniques can be roughly divided into two types: revealed preference and stated preference methods. The major strength of the revealed preference methods is that they are based on real market actions. Accordingly, one of their weaknesses is that they cannot catch changes that are not reflected in market prices, *i.e.* losses of passive use values. Conversely, a major disadvantage of the stated preference methods is that they are based on hypothetical, rather than actual, behaviour, while their strength is that they can provide estimates of both use and passive use values.

A large amount of research effort has been expended over the years on attempts to increase the validity of results from valuation studies, and there have been substantial improvements. However, further research is needed in a number of important areas, one of which is the widely acknowledged problem of valuation uncertainty, *i.e.* the uncertainty many respondents reveal when they state their preferences for a project.

At present there is a lack of knowledge about the underlying causes of this uncertainty. The so-called contingent valuation method (CVM) is a stated preference method and the literature on CVM describes a number of types of valuation/WTP questions designed to capture valuation uncertainty, and approaches for interpreting the uncertainty and for estimating WTP distributions (*e.g.* Alberini, Boyle & Welsh, 2003). However, as stated by Alberini, Boyle & Welsh (2003), more consideration needs to be given to the framing of questions, and to response formats that allow for uncertainty (see Section 3.3).

Further development is also needed to improve and extend the treatment of natural resources in non-market valuations and CBA in general. There are two main reasons why the economic analysis of natural resources is very limited at present. First, renewable resources and the associated ecosystems have complex and only partly understood dynamics. Second, more knowledge about economic and ecological interactions is needed in order to increase the reliability of non-market valuation/CBA in situations where there are conflicts over natural resources. The lack of information gives rise to uncertainties, and thus undermines the usefulness of the methods (*e.g.* Hamilton & Clemens, 1999; Hey, Neugebauer & Sandrieh, 2002) (see Sections 2.2 and 3.3).

There were two main aims for the work underlying this thesis.

Empirical contribution

The first aim was to fill part of the gap in the CBA literature on trade-offs between environmental changes and hydropower production. A CBA was conducted to find out if the benefit for the Swedish society of increasing the amount of wild salmon

in the Vindel River, northern Sweden, would exceed the opportunity cost of lost electricity production.[5]

A major element facilitating this research was that a significant body of data on the wild salmon in the Vindel River was available, and access to the models and insights developed by fish ecologists who have studied them over many years. Such information, which has rarely been available in previous, relevant studies, provides crucial inputs for estimating both benefits and costs. The resource dynamics were implicitly integrated when designing the scenario for the WTP question, which in turn was generated from the theoretical framework for the CBA.

Methodology development
The second aim was to develop methods to increase the validity of non-market valuation and thus the validity of CBA. Towards this end I developed and presented a new WTP question mode to capture valuation uncertainty, which has several advantages compared to traditionally used modes. It is argued that it allows more straightforward interpretation of revealed valuation uncertainty and provides more information about people's preferences. The question mode also has advantages when a survey is carried out in more than one country.

Since there is a lack of information concerning the causes of valuation uncertainty it is argued that a WTP should not be presented solely as a point estimate, but should be complemented with lower and upper boundaries. I have presented methods for acquiring such estimates, and a technique for obtaining lower and upper limits for the total present benefit obtained from the point estimate. The new WTP question and the methods for acquiring WTP estimates were applied to capture and estimate both use and passive use values of increasing the wild salmon stock in the Vindel River.

The thesis is structured as follows. Section two briefly describes the history of CBA and reviews the theory and methodology issues that should be acknowledged before evaluating a CBA. It also presents a short review of economic studies concerning salmon recovery and background information regarding the case study under consideration. Section three discusses real world applications of valuation methods and provides an introduction to different valuation approaches. It also introduces some recognized concerns regarding the validity of stated preference methods, and issues of primary relevance to the thesis and underlying studies are considered in more depth. Section four summarizes the three papers on which this thesis is based, and discusses the results and contributions in relation to the overall aims of the work. This section also includes suggestions for future research. The full versions of Papers I, II and III are attached as appendices.

[5] Johansson & Löfgren (1980) investigated the net benefits of transporting timber on trucks versus timber floating. One of the major costs of timber floating is loss of hydropower production by the hydropower plant considered in Paper I-III.

2 CBA

The practical use of CBA can be traced back to American legislation from the 1930s. An investigation that recommended social accounting led to the Flood Control Act of 1936, which gave the American army's engineer troops the responsibility for flood control and a mandate to carry out projects to provide flood protection if "the benefits to whomsoever they may accrue are in excess of the estimated costs…". This was seen as a requirement to estimate all possible values a project could generate, *i.e.* not only values from a business economic perspective. In the 1950s the so-called "Green Book" was published, which can be seen as the first CBA manual. During the same period the first methods for valuing goods that are not market-priced were suggested.

During the 1960s CBA became increasingly common in the US and in 1965 the former president Lyndon Johnson ordered all federal authorities to use Program Planning and Budgeting (PBB), which was essentially CBA. Academic research on methods for valuing goods that are not market-priced intensified during this period. Since 1981, Executive Order 12291, which states that all federal authorities have to carry out a CBA for all larger measures, has strongly promoted the use of CBA in the US. The requirements to use CBA have also increased in Europe (*e.g.* the Amsterdam Treaty). However, only a few of the member states use CBA on a regular basis. Great Britain is the most frequent user of CBA (Frykblom & Helgeson, 2002).

In Sweden the so-called Verksförordningen (1995:1322) (which regulates the public authorities' consequence investigations, *i.e.* CBA and cost-efficiency analyses) demands that the financial consequences *etc*. of any publicly financed project should be assessed, although it does not stipulate in detail how this should be done (Samakovlis & Johansson, 2005). However, despite this and other regulations, relatively few Swedish public authorities use CBA (Frykblom & Helgeson, 2002), based on data from 1997-2002, and only three use it on a regular basis: the Swedish Road Administration (Vägverket), the National Rail Administration (Banverket), and the Swedish Institute for Transport and Communications Analysis (Statens Institut för Kommunikationsanalys, SIKA).

2.1 Theory and method[6]

From an economic perspective a policy/project should be undertaken if it improves the welfare of the society concerned. The strict Pareto criterion classifies a policy as socially desirable if, as a result, everyone is better off, or if at least one person is better off, while no one else is worse off. This criterion is rather restrictive, so other criteria have also been used. According to the Kaldor/Hicks criterion a change is classified as desirable if the winners are (potentially) able to compensate

[6] See Sugden and Williams (1978), *inter alia*, for a comprehensive introduction to CBA theory and methodology.

the losers such that everyone could be better off after the change has occurred (Kaldor criterion), or if the losers could not compensate the winners sufficiently before the change to ensure that neither group would prefer the change to be made (Hicks criterion). Note that actual compensation is not required according to these principles. The compensation criteria, in particular the Kaldor criterion, are frequently used in CBA (van den Bergh, 1999).

It can be shown that as long as the marginal benefits are greater than or equal to the marginal costs an action is worth considering, and when the marginal benefit equals the marginal cost of an action, the welfare for the society is optimized (*e.g.* Perman *et al.*, 1999). It is often implicitly assumed that the income distribution is socially optimal, so the Kaldor/Hicks criteria can be used directly.

When a CBA is carried out it must be recognized that some costs and benefits arise at different times. Discounting is used to estimate present values for future benefits and costs. The relevant decision rule in a CBA is therefore that the present value of the benefits should be larger than or equal to the present value of the costs.

Concerning the choice of discount rate, economic welfare theory does not give definitive guidance. Some authorities argue that the predicted growth rate should be used as a discount rate, while others argue that distributional issues should be considered when choosing the discount rate (see, for instance, Dasgupta, 2003). For instance, present value discounting can be seen as a tool to distribute the weights of costs and benefits between/within generations in the sense that values and costs that arise in the future will be given different relative weightings depending on whether positive, negative or zero discount rates are applied. However, CBA generally considers efficiency rather than distribution, *i.e.* who wins and who loses (people in the cities/the countryside, women/men *etc*.) is not usually considered.

Costs and benefits can only be defined relative to a specific baseline. A CBA therefore usually begins by stating a "business-as-usual" scenario, or outlining likely developments in the absence of the intervention under consideration.

Next, a CBA includes various types of constraints, which reflect both ecological and economic concerns. For example, a hydropower plant will affect a number of species, but due to factors such as time and financial limitations, most environmental impacts are not considered in CBAs.

Having constructed a baseline and identified the constraints, the process of detailing the costs and benefits can begin. The obtained cost-benefit rule clarifies what should be counted as costs and benefits, and how they should be measured. For example, the benefit of a measure that changes flow paths or rates in a river may be that it reduces migration problems for salmon, while the cost is that less hydropower is produced. Valuing these changes is not a trivial task.

When conducting the analysis it is often found that some of the project's effects can be difficult to estimate in either physical or monetary terms. Further, several

assumptions must be made, such as the choice of discount rate and the choice of project length (i.e. the number of years for which the project's costs and benefits will be included in the CBA), that influence the outcome of a CBA. Hence, a sensitivity analysis should always be carried out to identify variables that may have substantial effects on the final result.

2.2 Economic studies on salmon recovery

A number of CBAs have been applied to salmon recovery and its economic consequences, especially during the last decade, notably in the Northwestern United States (*e.g.* Huppert, 1999; IEAB, 2003).

These studies have considered the costs and benefits of implementing various *fish protection measures*, including river restoration, habitat improvement, fish hatcheries, fish passage improvements, and minimum instream flows. In addition, a number of studies have focused on the cost effectiveness of alternative fish protection measures (IEAB, 2004a, b). A short review of the literature is presented below.

There have been several studies on the recreational benefits of salmon fishing in US rivers (Olsen, Richards & Scott, 1991; Loomis, 2002), as well as the passive use value associated with restored rivers and recovered salmon populations in the US (Bell, Huppert & Johnson, 2003; Streiner & Loomis, 1995).

Further, licenses for hydroelectric projects in the U.S. require regular renewal, and renewal conditions often include compulsory fish passage improvements. Consequently, a number of major hydroelectric projects in the Northwest US have considered the costs of such upgrades (FERC, 1996; Puget Sound Energy, 2004). In addition, economic studies have examined the cost-effectiveness (IEAB, 2004a, b) of measures to improve the up- and down-stream migration of fish.

Mooney (1997) has examined the cost effectiveness of various measures to reduce the temperature in salmon watersheds. Other studies have examined the costs and impacts of artificial fish propagation (*e.g.* IEAB, 2002).

In addition, a number of detailed studies have examined the economic costs (*e.g.*, foregone revenue) and benefits (augmented use and passive use values) associated with maintaining minimum flows in regulated rivers. For example, Diamant & Willey (1995) estimated costs associated with purchasing peak power from alternative sources when hydroelectric facilities slowly draw down reservoir levels to assist fish migration, while Berrens et. al (1998) estimated the passive-use values associated with increased minimum flows for protecting endangered fish species.

Finally, a number of dams in the US have been removed, or selected for removal, based on economic analyses demonstrating that the costs of installing required fish passage structures exceed the costs (including future foregone energy production)

of decommissioning them. Examples include two dams on the Elwha River in Washington State (Elwha River Human Effects Team, 1995) and a hydroelectric dam on the White Salmon River in Washington State (FERC, 2002).

Most CBAs (in the US and elsewhere) concerning fish recovery have been relatively restricted analyses of the impacts of different projects. Usually these studies have investigated the total use and passive use values, for anglers and non-anglers, of increasing a fish stock, compared to the cost of producing less electricity. For example, Morey, Rowe & Watson (1993) focused on the benefits of hypothetical increases in salmon catches in a river in Maine, US, associated with reductions in hydropower production, while Navrud (1994) used a benefit transfer function[7] for valuing expected impacts on angling of a potential hydroelectric project. Kotchen *et al.* (2006) investigated not only trade-offs between reductions in hydropower production and improved recreational fishing, but also the economic impact of increases in electricity production from other resources, and consequent rises in air pollution and greenhouse gas emissions, that would accompany reductions in hydropower production.

Kotchen *et al.* (2006) stand out from many bioeconomic studies in that relevant biological data were available. This general lack of biological data is a source of great concern. Consequently, simulation models are often used to estimate the biological impacts of proposed measures. This, in turn, introduces uncertainties that may diminish the usefulness of CBA in bioeconomic studies. Applications and discussion concerning this matter can be found (*inter alia*) in IEAB (1997a), Hamilton *et al.* (1999), Hey, Neugebauer & Sandrieh (2002), Kotchen *et al.* (2006), Sethi *et al.* (2005) and Carson *et al.* (2005).

2.3 The Ume/Vindel River case

The flow of the Ume River, northern Sweden, is completely controlled, and its largest natural tributary is the Vindel River. The wild salmon deposit their eggs in the Vindel River and the eggs hatch the following spring. When they are one to four years old the fish migrate to the Baltic Sea, where they stay for one to three years before starting their journey to their home river to spawn. Salmon from the Vindel River undertake their spawning migration in the lower Ume River in early summer and migrate upstream until early October. On their way they enter a so-called confluence area in which the water from the Stornorrfors hydropower plant and the bypass channel (the old river course) come together (see Figure 1). The amount of water in each pathway depends on the amount of electricity being generated and the stipulated flow in the bypass channel. However, at the current water speed, many of the salmon are not attracted into the bypass channel due to low flows in the channel (Rivinoja, P., S. McKinnell & H. Lundqvist, 2001; Leonardsson *et al.*, 2005; Lundqvist *et al.*, 2005; Rivinoja, 2005). Lundqvist *et al.* (2005) showed that about 70% of the salmon that enter the river mouth do not pass upriver through the flow-controlled area around the Stornorrfors power station.

[7] The term benefit transfer refers to the value of a change in a natural resource estimated using information from existing studies.

Fish ecologists suggest that this hindrance could threaten this wild salmon population in the long term (for further details about this problem, see Rivinoja, P., S. McKinnell & H. Lundqvist, 2001; Lundqvist et al., 2005; Leonardsson et al., 2005, Rivinoja, 2005).

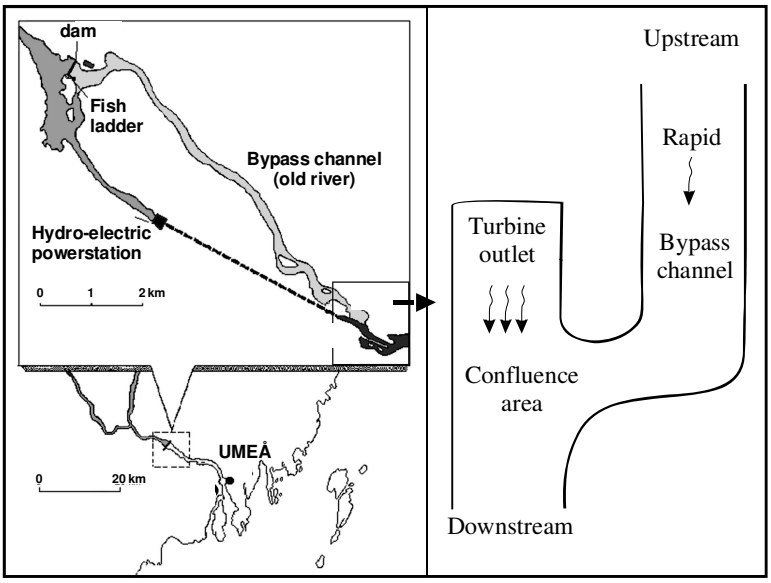

Figure 1. Map of the study area in the Ume/Vindel River, c. 22 km upstream of the river's mouth at the Baltic sea (Leonardsson et al., 2005; modified from Montén, 1988).

Ferguson & Williams (2002) present an extensive report on improving fish passage at Stornorrfors power station including various recommendations for increasing the numbers of wild salmon in the Vindel River. Lundqvist, Leonardsson & Rivinoja (2006) provide estimates of how much each potential passage alternative would increase the number of salmon that pass the power station. Allocating more water to the bypass channel is one approach that could be used to increase the amount of salmon that reach the spawning grounds in the Vindel River (Ferguson & Williams, 2002). However, none of these reports provided assessments of the economic benefits and costs associated with each alternative.

3 Valuation methods

In this section I introduce valuation methods. Since my thesis is focused on stated preference methods, I only give very brief background information regarding the revealed preference methods. It should be noted that both stated and revealed preference methods have specific problems, although I only discuss those associated with stated preferences in detail. Generally, the stated preference methods are more controversial, mainly due to their hypothetical nature. However, revealed preference methods cannot generate sufficient information for making

efficient decisions when non-market goods are involved (see Section 3.3 for further discussion.).

The literature on stated preference methods is huge. For example, Carson (2004) has compiled a bibliography of more than 5000 valuation studies from more than 100 countries. The latest compilation of valuation studies carried out by Swedish authors was by Sundberg & Söderqvist (2004), who consider valuation studies concerned with environmental changes in Sweden. Information from more than 100 primary studies is presented, about 70% of which used the CVM or another stated preference method. In 20% of the studies revealed preference methods were used, and in about 10% of the studies non-monetary methods were used. The stated preference method that has been most widely used is the CVM, which has been used in 82% of the scenario studies.

Sundberg & Söderqvist (2004) found that at the time of their analysis only five Swedish environmental valuation studies seemed to have been used in a CBA, or for decision making. However, in the Swedish Environmental Objectives Proposition (2004/05:150.4) a number of existing valuation studies were indirectly used for decision making. The proposition presents results from a first attempt to obtain indications of the monetary value of meeting different environmental objectives. The results were acquired, by the Swedish National Institute of Economic Research (Konjunkturinstitutet), by manipulating data from existing valuation studies and applying them to different objectives.

3.1 Revealed preference methods[8]

As mentioned above, the main strength of the revealed preference methods is that they are based on real market actions, while one of their main weaknesses is that they cannot capture passive use values. Another disadvantage is that it is often laborious to acquire the required information from them, *i.e.* the data collection is often very time consuming.

The most widely used revealed preference method is the travel cost method, the basic premise of which is that the time and travel cost expenses that people incur to visit a site represent the "price" of access to the site. Thus, peoples' WTP to visit the site can be estimated based on the number of trips that they make at different travel costs. This is analogous to estimating peoples' WTP for a marketed good based on the quantity demanded at different prices.

The hedonic price method is another method that is quite widely used; however, this method has a more restricted range of applications. The hedonic pricing method is used to estimate economic values for services that directly affect market prices, *i.e.* the basic premise of the method is that the price of a marketed good is related to the services it provides. The method is most commonly applied to

[8] See for example Boyle (2003b), Parsons (2003) and Taylor (2003) for general presentations of the theory and methodology, and discussion regarding the methods' strengths and weaknesses.

variations in housing prices that reflect the value of local environmental attributes (for example environmental quality, including water pollution and noise).

3.2 Stated preference methods

CVM is the most commonly used stated preference method not only in Sweden, but also throughout the world. CVM involves directly asking people, in a survey or interview, how much they would be WTP for a specific good/service. (In some cases people are asked for the amount of compensation they would be willing to accept (WTA) to give up for a specific good/service.) CV surveys were first proposed by Ciriacy-Wantrup (1947). However, they were not applied in any published studies until the beginning of the 1960s (Davis, 1963). They subsequently became very prominent in the US in the1980s when government agencies were given the power to sue for damage done to environmental resources. A major oil spill in Alaska, the Exxon Valdez oil spill in Prince William Sound in 1989, was the first case in which CV surveys were used in a quantitative assessment of damages. The use of this technique and other stated preference methods, which have been developed from CVM, has expanded from these beginnings.[9]

Choice experiment, conjoint analysis, and contingent ranking are similar to CV, in that they can be used to estimate economic values for virtually any goods and services, including both non-uses and use values. However, instead of only asking for the respondent's WTP for a project, those methods focus on trade-offs among scenarios with different characteristics and the methods are especially suitable for aiding policy decisions where a set of possible actions may affect resources or services in contrasting ways. For example, improving the water quality of a lake will improve the quality of several services provided by the lake, such as drinking water supplies, fishing, swimming, and biodiversity.[10]

3.3 Research on stated preference methods

It has been argued that hypothetical questions give hypothetical answers. Clearly, it is important to obtain indications of the true WTP of respondents, so this issue has been intensively investigated. Some studies that have examined both actual and hypothetical behaviour have found that actual behaviour can be predicted from data on hypothetical behaviour with relatively small margins of error if the valuation study is well designed, see for instance Whitehead (2005) and Murphy *et al.* (2005) for recent studies. This indicates that stated preference methods can give quite accurate valuations, *i.e.* stated preference methods have potential. However, there are many sources of uncertainties:

[9] See, for example, Bjornstad & Kahn (1996) for a detailed presentation of the CVM method.

[10] See, for example, Bjornstad & Kahn (1996) for more information about the methods.

- It is unclear if responses relate to the WTP of individuals or households, although respondents are generally asked to state one or the other (*e.g.* Brown, 2003).

- There are several question modes, which often give different results (*e.g.* Loomis & King, 1994; Mannesto & Loomis, 1991).

- The degree of knowledge concerning substitutes, complements and budget constraints can substantially affect the results (*e.g.* Kotchen & Reiling, 1999; Whitehead & Blomqvist, 1995).

Other potential sources of bias are related to issues such as the need (or lack of need) for information and knowledge about the good that is being valued (*e.g.* Ajzen, Brown & Rosenthal, 1996) and with the way in which non-responses are handled (*e.g.* Edward & Anderson, 1987). Other issues could also be mentioned, but these examples are sufficient to illustrate a fundamental question that needs to be addressed: Why are stated preference methods so widely used? The answer has been mentioned above, but let us articulates it once more:

> *"There are simply not enough of the right kinds of revealed preference data to do what needs to be done."* (Bishop, 2003, p. 538)

That is, if economists wish to address the important issues involving non-market goods, it must be accepted that stated preference methods are needed and thus the challenge of refining the validity of the methods is of utmost relevance (Brown, 2003).

Of the areas that need extensive research I will consider more deeply three that are of specific relevance for my thesis. Two are the closely linked areas of WTP question formats and valuation uncertainty. The third concerns the lack of knowledge about ecological systems. I will leave it to others, for example Bishop (2003) and Boyle (2003a), to review recent studies on ways to improve the validity of CV studies as well as proposals for important areas for future research in this field.

3.3.1 WTP question formats

For a long time the CVM was the only stated preference method. However, in response to criticisms of CV surveys, a panel of high-profile economists[11] was convened under the aegis of the National Oceanic and Atmospheric Administration (NOAA) in 1993 (Arrow *et al.*, 1993). The panel presented guidelines for a "good" CV study. (for more recent guidelines for valid valuation studies see, for example, Bishop & McCollum, 1997).

One suggestion that influenced the subsequent development of CVM regarded the WTP question format. The NOAA panel recommended so-called close-ended

11 Chaired by Nobel Prize winners Kenneth Arrow and Robert Solow.

question formats based on dichotomous choices, where respondents are asked if they accept or reject a project for which they would pay a given amount of money. Consequently, most valuation studies since then have used close-ended formats. Many studies support the idea that the dichotomous formats are superior to the open-ended formats (cf. McCollum and Boyle 2005). However, there is no definitive proof that close-ended formats generate more accurate WTP estimates than open-ended formats, or vice versa.

The panel's opinion is that open-ended questions are less likely to provide reliable valuations than close-ended questions. Two arguments are presented in support of this belief. First, it is argued that people are more familiar with dichotomous choice formats than with open-ended ones; second, that open-ended questions encourage free-riding and hence strategic overstatement (Arrow et al. 1993, p.4606). However, the panel's recommendation conflicts with some of the studies that have compared hypothetical and actual WTP in CV and laboratory experiments (cf. Brown et al. 1996; Poe et al. 2002). Further, other studies argue that the open-ended format should be considered for a number of reasons, such as avoiding yea-saying biases (Kanninen 1995) and eliminating the problems associated with defining equally valid bid level vectors when a survey is carried out in more than one country (Bateman et al. 2005).

3.3.2 Valuation uncertainty

A number of authors have questioned the ability of respondents to state their preferences accurately (*e.g.* Kahnemann & Snell, 1992; Bodner & Prelec, 2003; Brocas & Carillo, 2003). The most widely used method for letting people express valuation uncertainty in CV studies has been to add a "don't know" alternative for responses to WTP questions. In recent years, more complex types of question, all close-ended, have been designed to capture valuation uncertainty (*e.g.* Li & Mattson, 1995; Champ *et al.*, 1997; Ready, Whitehead & Bloomquist, 1995; Welsh & Poe, 1998). Ready, Whitehead & Blomquist (1995) have presented a single-bounded question format which allows the respondents to reveal their uncertainty to a given single bid amount by choosing from six response categories: "definitely yes", "probably yes", "maybe yes", "maybe no", "probably no" and "definitely no". Welsh & Poe (1998) propose the use of the multiple bounded discrete choice (MBDC) question. The MBDC question provides a set of ordered thresholds, and the respondents are asked to express their valuation uncertainty for each threshold value by selecting response categories similar to those used in the type of question designed by Ready, Whitehead & Bloomquist (1995). The MBDC question can be viewed as a type of valuation question that has developed from so-called payment cards. A payment card consists of an ordered set of threshold values, and the respondents are asked to circle the highest amount they would be willing to pay. It is assumed that the respondents' true point valuation lies somewhere in the interval between the circled value and the next lowest option. An alternative approach to dealing with valuation uncertainty in CV studies was introduced by Li & Mattsson (1995). In their method, a question about uncertainty follows a discrete choice question, such that the respondents can express uncertainty about their WTP on a scale from 0 to 100%. Champ *et al.* (1997) use a

similar follow-up question to a discrete choice question, in which respondents' expressed their uncertainty on a scale from 1 to10.

There are difficulties in interpreting answers obtained from all of the types of questions described above. Three assumptions must be made when analyzing the uncertainty expressed by the respondents. First, that the respondents can accurately assess the degree of their certainty in answering the WTP question. Second, that all respondents interpret the scale in the same way (Loomis & Ekstrand, 1998). Finally, that the researcher knows how to interpret the resulting information, *i.e.* how to model the uncertainty.

Various approaches have been described for estimating WTP distributions when valuation uncertainty is present; including those presented by Cameron & Huppert (1989), Li & Mattsson (1995), Ready, Whitehead & Bloomquist (1995), Champ *et al.* (1997), Loomis & Ekstrand (1998) and Vázques, Araña & León (2006). However, the best way to interpret the information is unclear. Assume, for example, that some respondents answer "60%" (on a scale from 0 to 100%) to the question of how certain they would be about paying 100 SEK for a project, or that some respondents answer "maybe yes" to a question asking whether they would pay 100 SEK for a project. Does this imply that the respondents would pay 60 SEK on average? Other interpretations are possible, *e.g.* that there is a 40% chance that they would not pay anything.

3.3.3 Renewable resources and uncertainty

The protection and restoration of biodiversity have become important goals that are enshrined in a number of international agreements and conventions, notably those arising from the Earth Summit in Rio de Janeiro in 1992. This may be one reason why many recent valuation studies (*e.g.* Jakobsson & Dragun, 2001) have focused on valuing the conservation of species, to provide sound foundations for political decisions. Valuing renewable resources involves significant challenges and requires cooperation between economists and natural scientists. One of the challenges is the uncertainty that arises due to lack of information regarding resource dynamics and interactions with other species in the ecosystem (see for example Sethi *et al.*, 2005).

From an ecological perspective the challenge is to present this knowledge in such away that the information can be understood and used by economists. For the economists the challenge is to identify values generated by ecosystems. The common challenge for both ecologists and economists is to develop new methods, or modified forms of available methods, that can provide estimated values of changes in renewable resources and services (such as regulation of the climate, oxygen, and recycling of nutrients) caused by human activities.

4 Summary of papers

4.1 Contribution

4.1.1 Empirical contributions

The studies underlying this thesis helped to fill gaps in the CBA literature, and on trade-offs between environmental changes and hydropower production more specifically, by presenting a CBA of the economic consequences of applying measures that would boost salmon populations but impose constraints on hydroelectric operations (Papers I and III).

The project under consideration is to increase wild salmon in the Vindel River, northern Sweden. As described in the papers, diverting more water from hydropower production at Stornorrfors Hydropower Station to the bypass channel (see Figure 1) is one of several approaches that could be used to increase the numbers of salmon that reach their spawning grounds in the river (Ferguson & Williams, 2002). Paper I presents the theoretical framework for dynamic CBA and applies it to the salmon passage-hydropower production conflict. The approach has wider applicability than suggested here, and should be useful in other, similar contexts.

A useful element of the empirical analysis is that estimated changes in resource conditions are based on detailed river-specific data. In previous studies biological data were often not available, and hence simulation models and assumptions were used to estimate the biological impacts of proposed measures. The studies presented in Papers I and III introduced resource dynamic considerations into both the scenarios and the WTP questions, using an estimated salmon population model for the Vindel River (the increase in salmon numbers over time) as a base (Leonardsson, Lundqvist & Rivinoja, 2002). The valuation question itself was generated from the project's cost-benefit rule, which explains how benefits and costs are to be interpreted. A model for predicting the effects of varying the water flows on the salmon's migration behavior (Leonardsson *et al.*, 2005) was used as an input when estimating the cost of increasing the number of salmon in the Vindel River (in terms of lost electricity production).

The valuation study included a sample of the Swedish population (see Section 4.1.2 for details). A questionnaire was sent out where the respondents were asked about their WTP for increasing the number of wild salmon that reach the spawning grounds in the Vindel River to spawn each year. The average number of wild salmon per year that reached the Vindel River's spawning grounds between 1995-2004 was ~3000 (Vattenfall 2006). This figure was used as a baseline.[12] The increase in the number of salmon during the first year of the project and over the years, varied between different versions of the WTP question.

[12] The average number of successful wild salmon migrations during the last ten years has been c. 3000 per year, however, the number of succeeding wild salmon during this period fluctuated between 1281 to 6065 per year due to factors such as variations in mortality.

The difference between the marginal WTP for an increase in salmon in the interval 4000-9000 was shown to be low, which is indicative of a "flat demand curve". Due to the low marginal WTP in the interval 4000-9000 wild salmon all versions of the WTP question are assumed to represent a project for increasing the amount of salmon from 3000 to 4000 salmon/year in the Vindel River.

According to the survey most Swedes seldom visit the Vindel River. Thus, it was assumed that passive use values are the major contributors to the benefit (96-517 MSEK) of increasing the wild salmon stock in the Vindel River from 3000 to 4000 salmon/year, which in turn may explain the flat demand curve. The sensitivity analysis suggests that the opportunity costs in terms of lost electricity are typically higher than the estimated benefits.

Even though river-specific information is available, the uncertainties regarding the cost of the project are substantial. However, it seems reasonable to assume that a study based on hypothetical environmental changes, as is often the case, will add even larger uncertainties to a CBA. Nevertheless, the lack of knowledge regarding economic and ecological interactions needs to be acknowledged. Indeed, CBA is a decision-support tool, and it cannot provide definitive, absolute answers to the questions addressed.

4.1.2 Methodology developments

The studies underlying this thesis also provided improvements to the validity of valuation studies/CBA by introducing a new valuation method/question mode (Paper II) and methods to analyze data obtained from the new valuation question (Papers II and III).

Valuation question

I have introduced a type of open-ended valuation question in which respondents state their WTP in the form of an interval rather than a point estimate; the "*classic and interval open-ended question*" (CIOE).

Interpretation of the resulting valuation uncertainty is more straightforward with this type of question than with other types of valuation question. It is assumed that the intervals reflect the respondents' uncertainty around a point value, *i.e.* that individuals state an interval because they only know that their valuation is within the stated range. Note that the respondent does not need to characterize his/her uncertainty as "maybe yes" and so on. One general advantage of open-ended questions is that they are presumed to produce a richer set of information about individuals' preferences compared to close-ended questions. Open-ended WTP formats also have advantages for surveys carried out in more than one country (Bateman *et al.*, 2005).

In the main survey in 2004 a total of 1785 individuals received a questionnaire including the CIOE question.[13] The individuals in the survey were sampled from

[13] Two pilot studies were carried out before the main survey.

two inventories: a general register of the Swedish population (SPAR), and the largest register of Swedish anglers (held by Sportfiskarna). All individuals less than 18 years of age were excluded from the registers prior to sampling. The respondents randomly selected from the SPAR register represented the sample "Swedes", and those randomly selected from the register containing anglers represented the sample "Anglers". These were then divided into 16 sub-samples, depending on whether the respondents lived in northern or southern Sweden, and on which version of the WTP question they were given. In the valuation study, of the respondents who were willing to pay, about 50% in each sub-sample expressed their answer as an interval (the average for all sub-samples was 55%). The 10 sub-samples obtained from the sample Swedes was used in the presented CBA. The response rate for all 16 sub-samples was 66%, while it was 59% for the sub-samples used in the CBA. That is, the respondent rate for the sample Anglers was higher than for the sample Swedes, which could be expected since it can be assumed that a sample of anglers have a higher interest in wild salmon than a sample of general Swedes.[14]

The internal loss was very low in each sub-sample, *i.e.* few respondents who stated that they had a positive WTP chose not to answer the CIOE question. One objection to open-ended questions is that people are unfamiliar with answering questions of this kind, and their unfamiliarity leads to high non-response rates. The low internal loss found in this study suggests that this objection does not apply to the CIOE question. Furthermore, respondents did not tend to answer the CIOE question by stating a value or an interval arbitrarily, which would be expected if they felt uncertain about how to answer open-ended questions.

Methods for analyzing data obtained from the new valuation question

It can be argued that the CIOE question has advantages over traditional WTP questions, but the lack of knowledge about sources of valuation uncertainty should not be overlooked. At present, insufficient is known about valuation uncertainty to represent mean WTP solely as an exact value; thus, lower and upper boundaries for the mean WTP should complement the point estimate. Paper II presents a method for finding a mean WTP point estimate for the CIOE question as well as a method to estimate lower and upper boundaries for the mean WTP, while Paper III presents a method to estimate a confidence interval for the total present benefit (total mean WTP).

When estimating the confidence intervals for the total present benefit the *Central Limit Theorem* is applied.[15] While it is fairly straightforward to estimate lower and

[14] The total number of questionnaires was 2774, and the total response rate was 66%. Six of the sub samples have been excluded from the analysis presented herein because another valuation question than the CIOE question was used or the sampling was unreliable, and/or the WTP question was related to a project whose results were not comparable with the other projects presented in the survey.

[15] In this case it implies that the total present benefit (total mean WTP) for an increase in wild salmon in the Vindel River is considered to be normally distributed for the Swedish population, which follows from the assumption on independency of WTP for individuals.

upper boundaries for the mean WTP, it is by no means trivial to estimate the point estimate from data obtained from the CIOE question, *i.e.* using both exact values and intervals to estimate the mean WTP. Jammalamadaka & Mangalam (2003) have presented a method, the *"middle censored method"*, for analyzing data with the same characteristics as data obtained from the CIOE question. This method was applied to estimate the mean WTP.

The results from the survey show, that the mean of the open-ended responses is contained within the corresponding intervals, in virtually all sub-samples, as though the upper and lower boundaries provide a kind of confidence interval. Since the interval and open-ended responses are generated by different individuals, there is no particular systematic reason why this result should occur. However, the result indicates that the two response groups belong to the same distribution (or to similar distributions) of WTP. As discussed in Paper II, such a result suggests that the means of the left and right ends of the interval, respectively, can be seen as lower and upper boundaries for the mean WTP.

Further, the mean of the CIOE responses, *i.e.* the mean WTP obtained using both exact values and intervals, coincided with the mean of the intervals for all but one of the sub-samples; a similar finding to that mentioned above. Again, it is as if the upper and lower boundaries provide a kind of confidence interval. This supports the idea of using those lower and upper boundaries for the mean WTP to complement the WTP estimate. The observed relationship between the different WTPs is encouraging in terms of the potential utility and validity of the new WTP estimates.

4.2 Future research

There are five issues in particular that I would like to highlight as important areas for further research:

1. Increasing the allocation of water to the salmon passage-way might not be the most cost-efficient measure for carrying out the project. Results from the valuation study show that the benefit of the project is the same regardless of which natural method is used. Construction of a new fish ladder and increasing the water flow through the old river course are examples of natural methods, while an example of a non-natural method would be to catch all of the salmon below the power station and then transport them to their spawning grounds further up-river. The most cost-efficient solution can therefore be found without carrying out new valuation studies. If one or more of those methods are found to be able to increase the salmon stock to 4000 salmon/year without exceeding the total benefit (96-517 MSEK) of doing so, it could be argued that the project would be beneficial for Swedish society.

2. Empirical data obtained from the valuation study can be used as a base for analyzing the distributional effects that would arise if the project

presented in the CBA was carried out. For example, distributional effects due to gender and geographic location. In general, further investigation is needed concerning distributional issues. Economic theory provides a useful working definition of an efficient environmental policy, but it cannot claim to offer a definitive description of the features of a "fair" environmental policy.

3. Further investigation is needed to explain why some people express valuation uncertainty. One way of obtaining more information about this issue could be to compare the individuals who provide an interval with those who provide an exact value when responding to the CIOE question. Comparing the results from different types of WTP questions could be another approach. Data for both such analyses are already available.

4. Research is needed in order to find out if the CIOE question, formulated according to the new design, captures the actual uncertainty more accurately than earlier question formats. Vossler & McKee (2006) present results suggesting that WTP formats that allow the respondents to reveal uncertainty send out signals to respondents to exercise the option to express uncertainty, *i.e.* there is a difference between stated and actual uncertainty. Their study focused on a number of existing WTP formats used to capture valuation uncertainty, in which respondents are asked to consider whether they have a specific WTP or not and are then asked to consider their degree of certainty. However, the design of the WTP questions, rather than the option to express uncertainty may be the cause of the problem described above. By expressing their WTP either as a point or as an interval (the wider the stated interval, the larger their uncertainty), respondents to the CIOE question have to consider their WTP and degree of certainty at the same time. It needs to be investigated whether the CIOE question send out a signal to respondents that they should exercise the opportunity to state a wider interval than the one corresponding to their actual uncertainty (if any).

5. There is a need for complementary tools to analyze CIOE data. The method used in this study, presented by Jammalamadaka & Mangalam (2003), is non-parametric and does not use explanatory variables additional to WTP. Hence this background information is ignored, indicating that this method requires a larger data set of responses than a (semi-) parametric method in order to give the same accuracy of the mean WTP estimate. However, results from the valuation study presented in Paper II indicate that the values of the mean WTP estimates (and the variances) presented in this study are moderate. Hence we can use normal approximation when estimating total present benefit, i.e. total mean WTP. Nevertheless, there is still a need to compare different methods since (semi-) parametric methods might be more suitable to estimate mean WTP from CIOE data, than the method presented by Jammalamadaka & Mangalam (2003). However, at present no (semi-) parametric methods are

available for analyzing CIOE data, so it is essential to develop such methods.

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Nana, Lina, Mia: Vad fan skulle jag gjort utan er? (in Swedish)