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Review

Critical analysis of existing economic tools available for assessing river water quality

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This review paper critically analyzes the economic literature on the approaches of measuring the environmental benefits. It focuses on the economic methodologies that are available for the evaluation of the effects (social costs and benefits) of environmental changes (degradation/preservation) on river water quality. Further, it shows how the monetary valuations of these effects can have an impact in making of economic policy for creating more efficient water quality management for environmentally sustainable aspects. Over 85 papers were reviewed and it was found that the economic assessment tools were studied independently without comparing the impact of one method over the other. The literature does not provide information on economics of the interventions to protect the river water quality and relate it to the increase in local flora and fauna and decrease in averting costs incurred by local people. Furthermore, the reviewed papers have not economically quantified various pollution control measures to improve water quality in rivers.

Key words: River water quality, river pollution control, monetary valuation, economic policy, environmental benefits.

INTRODUCTION

River systems are one of the most important natural resources which form the basis of human livelihoods. Rivers exhibit extraordinary phenomena, with physical, cultural and psychological expression in human societies; they bring life and death, civilization and devastation, opportunity and risk. These river systems have been an important source for irrigation, potable water, cheap transportation, electricity and other facilities and play an important role in human development. However, huge economic development and population growth result in continuing environmental degradation. Intensification of agriculture, industrialization and increasing urbanization are the most severe driving forces of water quality deterioration in rivers and these river systems are one of the most important vulnerable natural resource.

To value natural environmental resources like river water, it necessitated the need for non-market valuation methods because these resources are neither bought nor

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sold in the market but nonetheless have significant value (Boyer et al., 2004). Valuation of environmental impacts using nonmarket valuation methods has evolved from being completely a U.S activity in 1960s and 1970s to become a very important field also in Europe in 1980s and 1990s. At the same time, nonmarket valuation methods have been applied at an increasing rate in developing countries in Asia, Latin America and Africa (Navrud et al., 1997). Thus monetization of the benefits of water quality improvements is a central component of evaluating the cost-benefit performance of water quality regulations.

The basic concept of economic value incorporates a wide range of measurement techniques than use of market prices. Value theory begins by examining people in situations where they must make choices involving a trade-off, and there are basically two concepts that choice situations present: one in which people give up something to obtain an object of choice (that is, they pay for it), called Willingness to Pay (WTP) and another where they receive compensation in return for giving up an object of choice (that is, they sell it), called Willingness to Accept (WTA) (Hanemann, 1991).

As concern over the deterioration of water quality grows, regular analysis of water quality, diversion of sewerage lines, setting up of industrial wastewater treatment plants to prevent discharge of untreated wastes are some of the positive measures to prevent water pollution. Further effective management of river water quality requires the evaluation of benefits derived from water quality improvements. But as river restoration grows into huge investments a year effort, certainly there will be individuals who will ask whether the benefits of such efforts are worth the costs and hence it is necessary to establish their full value and incorporate this into the decision making process. Widely accepted and often used framework for decision making is Cost Benefit Analysis (CBA). It is an analytical tool conducted by aggregating the total costs and benefits of a project or policy, which represent welfare improvement only if net benefits of costs are positive and an option with highest net benefits is the optimal one, over space and time (Birol et al., 2006). Since 2000, World Health Organization (WHO) has been putting its efforts behind developing and applying approaches to cost–benefit analysis on issues of water, sanitation, hygiene and health. Work is now focusing on the development of methods appropriate for application at the country level to assist in analysis of the cost effectiveness and benefit–cost ratios of water, sanitation and hygiene interventions (Prüss-Üstün et al., 2008). However, values of water resources are not straightforward to estimate for CBA purposes because water bodies are public goods in nature and their values are more complex compared to private goods since water bodies are composed of both use and non-use values (Birol et al., 2006). Capturing the total economic value of water resources is crucial to policy and management decisions, thus enabling society to allocate its scarce economic and environmental resources efficiently.

Various economic methods have been developed to capture the total economic value of environmental resources. Most commonly used are revealed or indirect preference methods (Hedonic Pricing Method (HPM), Travel Cost Method (TCM), Averting Expenditure Method (AEM), and Cost of Illness (COI)) and stated or direct preference methods (Contingent Valuation Method (CVM) and Choice Experiment Method (CEM)).

Aim and objectives

i) Conduct an in depth review of various existing economic tools and techniques for assessing river water quality.
ii) Explain the limitations of these techniques.
iii) Describe the need for economically quantifying various pollution control measures to prevent pollution and improve water quality in rivers.

EXISTING ECONOMIC METHODS

Various researchers have made an attempt to measure the economic value of water quality (Steinnes, 1992; Rogers et al., 2002; Ward et al., 2002; Elsin et al., 2010; Olmstead et al., 2010). This paper is an attempt to review the existing tools the economists use for valuing river water quality for pollution control.

i) Physical Linkage Method [Damage Function Method] and
ii) Behavioural Linkage Method [Direct Methods - Contingent Valuation Method (CVM) and Choice Experiment Method (CEM)] and [Indirect Methods - Averting Expenditure Method (AEM), Travel Cost Method (TCM), Hedonic Pricing (HP) and Cost of Illness (COI)].

Physical linkage method

This measure the benefits based on technical relationship between an environmental resource and user of that resource. Common estimation method is damage function method (Callan et al., 2010).

Damage function method

This uses a functional relationship to capture the link between contaminant and any associated damages. Using this method, incremental benefits are measured as reduction in damages arising from policy-induced decrease in contaminant. This damage reduction is then monetized to obtain the value of benefits brought about by the policy. (Callan et al., 2010).

Behavioural linkage method

Direct methods

These are also called Stated Preference Methods. These valuation methods have been developed to determine the economic benefits of valuing those environmental resources that are not traded in any market, including surrogate ones like water bodies. The commonly used direct methods are Contingent Valuation Method (CVM) and Choice Experiment Method (CEM).

a) Contingent valuation method: Contingent valuation method (CVM) has become a popular way of placing a monetary value on various aspects of the environment with the aim of determining whether the benefits of a proposed project outweigh the costs. The CVM has risen to prominence among these tools (Spash, 2000). With CVM, valuation is dependent or 'contingent' upon a hypothetical situation or scenario whereby a sample of the population is interviewed and individuals are asked to state their maximum WTP (or minimum willingness to accept (WTA) compensation) for an increase, or decrease, in the level of environmental quantity or quality (Birol et al., 2006). The contingent valuation surveys have been conducted by several researchers to see how people were willing to pay for improvements in river water quality (Carson et al., 1993; Kwak et al., 1994; Douglas et al., 1999; Loomis et al., 2000; Turpie et al., 2001; Alam, 2006; Imandoust et al., 2007; Monarchova et al., 2009; Nallathiga et al., 2010; Tu, 2013). CV studies have also been conducted on coastal water quality improvements by Soderqvist (1998), Hokby et al. (2003), Hanley et al. (2003) and Zhai et al. (2009).

Kristrom (1993) explored two commonly used methods to elicit an individual's WTP for a public good in CV studies. According to him, the most preferred method is discrete valuation question where the respondent accepts or rejects a suggested cost for the good. The other method, the traditional one is the CV question which simply asks an individual to state his WTP for the suggested change in the provision of a public good.

An interesting survey carried out by Lindhjem et al. (2009) on the aggregate welfare measures for change in the provision of public goods found it would be higher if the same elicited mean willingness to pay was added up over individuals rather than households. It was revealed that when people were prompted to answer for response unit, an average of 43% decided to state higher willingness to pay than individual willingness to pay, while 52% stated the same willingness to pay. Also more people stated higher household willingness to pay if individual willingness to pay were asked first.

Despite the strengths of CVM regarding its ability to estimate non-use values and evaluate irreversible changes, this method has been criticised for its lack of validity and reliability (Diamond et al., 1994; Carson et al., 2001; Whittington, 2002; Cooper et al., 2004). This is on account of potential problems including information bias (Park et al., 1991; Whitehead et al., 1991; Poe et al., 1997), design bias -starting point bias and vehicle bias (Johansson, 1996; Morrison et al., 2000; Ivehammar, 2009), Yea-saying bias (Remoundou et al., 2009), hypothetical bias (Balistreri et al., 2001; Vossler et al., 2006; Murphy et al., 2010), selection bias (Svento, 1993; Yoo et al., 2001), protest bias (Jorgensen et al., 1999; Strazzer et al., 2003), sequencing bias (Halvorsen 1996), elicitation bias (Loomis, 1997; Loomis et al., 1997; Bohara et al., 2001; Crooker et al., 2004; Farmer et al., 2008; Watanbe et al., 2009), anchoring bias (Frykblom et al., 2000; Arana et al., 2007) and embedding effects (Diamond et al., 1994; Hanemann, 1994). Hypothetical bias contends that respondents may be prepared to reveal their true values but are not capable of knowing these values without participating in a market in the first place. Strategic bias occurs when respondents deliberately under- or overstate their WTP. Respondents may understate their WTP if they believe that the actual fees they will pay for provision of the environmental resources will be influenced by their response to the CV question. Conversely, realizing that payments expressed in a CV exercise are purely hypothetical, respondents may overstate their true WTP in the hope that this may increase the likelihood of a policy being accepted. Yea-saying bias indicates that respondents may express a positive WTP because they feel good about the act of giving for a social good although they believe that the good itself is unimportant while embedding bias implies that WTP is not affected by the scale of the good being offered (Remoundou et al., 2009).

b) Choice experiment method: Choice Experiments (CE) involve eliciting responses from individuals in constructed, hypothetical markets, rather than the study of actual behaviour. The Choice Experiment technique is based on random utility theory and the characteristics theory of value, where environmental goods are valued in terms of their attributes and by making one of these attributes a price or cost term, marginal utility estimates can be converted into willingness-to-pay estimates for changes in attribute levels, and welfare estimates obtained for combinations of attribute changes (Hanley et al., 2006). Researchers (Carlsson et al., 2003; Hanley et al., 2006; Viscusi et al., 2008; Borg et al., 2009; Birol et al., 2010) have applied CE in valuing the improvements in water quality.

Carlsson et al. (2003) conducted CE for valuing wetland attributes in Staffanstorp, southern Sweden and found that attributes like biodiversity and walking facilities were the two greatest contributors to welfare while a fenced waterline and introduction of crayfish decreased welfare.

Birol et al. (2010) used the Choice Experiment method to estimate around 150 randomly selected local public's willingness to pay (WTP) for improvements in the capacity and technology of a pilot scale sewage treatment plant (STP) in Chandernagore municipality, located on the banks of the River Ganga in India. The benefit estimates reported in this study reveal that an average household in the sample would be willing to pay Rs 8.36 per month (Rs 4.82 for high quality of treated water plus 3.54 for high quantity of treated water) in municipal taxes, in order to improve the capacity and technology of the STP. This would amount to Rs 100.32 per annum in additional municipal taxes per household. When aggregated over the entire population (32,939 households), Chandernagore municipality residents' WTP for increasing the capacity of the STP amounts to Rs 3,304,441 per annum. Thus the results reported in this paper are indicative of local public's demand for higher quality and quantity of treated wastewater to minimize the high levels of environmental and health risks in the Ganga.

Alpizar et al. (2001) highlighted the advantages of choice experiments stating that values for each attribute as well as marginal rates between non-monetary attributes can be obtained. According to Johnston (2007), CE results are well suited for benefits transfer because CE are designed to account for variations in environmental resources and site characteristics, as well as potential implications of these variations for willingness to pay. The main objective of the study by Brouwer et al. (2010) was to examine how repeated choice affects preference learning in stated preference experiments. Choice consistency tests suggested that preferences in the choice experiment were stable and coherent. Thus respondents felt significantly more confident and certain about their choice at the end of the choice experiment than they were at the beginning. The research by Taylor et al. (2010) explored the incentive properties of repeated, attribute-based choice questions when subjects are provided with an explicit connection between choices and outcomes. Their study results indicated that the choice-modeling studies that have no explicit provision rule can have a relative error that is more than double the contingent-valuation average error when applied to public goods (96%/39% = 2.5). They also found that when an explicit provision rule discussion is included, the average error in the choice experiments decreased to 57%, which is still larger than that found in contingent valuation studies (57% vs. 39%). These results clearly indicated that the inclusion of a provision rule is necessary for a credible choice-modeling study.

Limitations of CE were discussed by Hanley et al. (1998), Meyerhoff et al. (2008) and Morkbak et al. (2010). Hanley et al. (1998) stated that the principle problems in using the CE method are often the complex nature of statistical/experimental design and the selection of appropriate attributes and levels. Meyerhoff et al. (2008) studied the protest responses in a CE and CV. They used an attitude scale based on respondents' protest beliefs and found a significant negative effect of this attitude on willingness to pay in both methods. However, in one of the two study regions, the effect was found to be weaker in CE than in CV. Morkbak et al. (2010) addressed the issue of defining the levels of the cost variable in Choice Experiments. The main focus was on changes in the maximum price level—the expected choke price affecting consumers' preferences and WTP. The results showed that increasing the maximum price level gave rise to statistically significant increases in the WTP estimates for all attributes. So the high maximum price would indicate to the respondents that the good in question is more valuable, and that they should pay more money to obtain the good. Their results showed that increasing the maximum price level 50%, gave rise to increased WTP estimates of up to 68%, which very well could alter the outcomes of a cost-benefit analysis. So they concluded that setting the choke price can be crucial and hence it deserved attention in the experimental design stage.

Indirect methods

These are also called Revealed Preference Methods. These methods look for related or surrogate markets in which the environmental good is implicitly traded. These methods are suitable for valuing those water resources that are marketed indirectly and are thus only able to estimate their direct and indirect use values. The commonly used indirect methods are Averting Expenditure Method (AEM), Travel Cost Method (TCM), Hedonic Pricing (HP) and Cost of Illness (COI).

a) Averting expenditure method: This method is based on function theory of consumer behaviour and is used to indirectly estimate the willingness to pay for non-marketed commodities like clean water. In the context of water resources, households may respond to increased degradation of water quality in various ways that are generally referred to as averting or defensive behaviours so as to avoid the adverse impacts of water contaminants (Birol et al., 2006). According to Courant et al., (1981), between two differently located but otherwise identical individuals, the difference in their averting expenditures may or may not be a close estimate of their willingness to pay for the preferred location.

There are however important limitations to this method. Individuals may undertake more than one form of averting behaviour in response to an environmental change and the averting behaviour may have other beneficial effects that are not considered explicitly. Furthermore, averting behaviour is often not a continuous decision but a discrete one, depending on the situation. Generally, the averting expenditures does not measure all the costs related to pollution that affect household utility and are therefore only able to provide a lower bound estimate of the true cost of increased pollution (Birol et al., 2006).

Thus if general environment is improved by certain policy initiatives, individual can spend less on substitute goods and this gives an indirect estimate of individual's willingness to pay for associated incremental benefits (Callan et al., 2010).

b) Travel cost method: Travel cost approach is mainly applied to study the recreational value of sites like water bodies, for boating, fishing, watching birds. It uses information about number of trips to particular sites and cost of those trips to infer people's willingness to pay for access to the sites (Boyer et al., 2004). Several researchers have employed travel cost method to measure the welfare effects to changes in water quality and include the work done by Caulkins et al. (1986), Kealy et al. (1986), Hellerstein (1993), Englin et al. (1996), Ortacesme et al. (2002), Carr et al. (2003), McKean et al. (2005), Shrestha et al. (2007) and Hosking (2011). The travel cost method was applied to evaluate the recreational value of the RAMSAR site of the estuary of Massa River (El-Bekkay et al., 2013).

Even though the TCM have been regularly used to determine the value of recreation, a key site attribute often omitted is that of congestion, which describe the number of other individuals encountered during the recreation experience. Researchers (Michael et al., 1997; Boxall et al., 2003; Timmins et al., 2007) studied the recreational congestion. The results of Michael et al. (1997) indicated that failing to account for heterogeneous preferences for congestion by time of visit led to overestimates of the benefits of relieving peak-time congestion, while accounting for expectations raised questions about the validity of the standard optimal use model. Further, the results of this study indicated that the effect of congestion on recreation benefits was best modeled by the difference between actual and expected congestion rather than by simple objective measures of actual congestion.

c) Hedonic pricing: This is a measure of variations in housing prices that reflect the value of local environmental resources like water quality, aesthetics, local flora and fauna. The relationship between land prices and surface water access (both in quantity and quality terms) has been studied in the hedonic framework by Epp et al. (1979), D'arge et al. (1989), Garrod et al. (1994), Lansford et al. (1995), Doss et al. (1996), Mahan et al. (2000), Poor et al. (2007) and Higgins et al. (2009). Mahan et al. (2000) used data on more than 14000 home sales in Portland, Oregon metropolitan area to estimate the effect of proximity to wetlands on property values and found that a decrease in the distance to the nearest wetland by 304.8 m from an initial distance of 1 mile resulted in an increase in property value of €371.6.

A limitation of the HPM is that it only measures direct use values of water resources as perceived by the consumers' of the good in which it is implicitly traded. Services such as flood control, water quality improvement, habitat provision for species, and groundwater recharge may provide values that benefit individuals far away, beyond the consumers of the good, which the HPM is unable to capture (Boyer et al., 2004). Leggett et al. (2000) found that hedonic studies of environmental quality are particularly vulnerable to omitted variables bias: the emitters of pollution often have direct effects on the value of nearby properties-for reasons completely unrelated to water quality.

Another limitation discussed by Koundouri et al. (2003) is the effect of selectivity bias on hedonic price analysis. They stated that these valuations can be misleading when the quality characteristics intended for the valuation have sample selection implications and considered the case of land close to seaside that could be used either as an input in agricultural production or for tourist development. The proximity to the sea could reduce the quality of land as an input in agricultural production due to salinization of groundwater supplies, but increased the probability of switching the land usage from agriculture to the lucrative tourism market. Thereafter, the deterioration of groundwater supplies could appear to have a positive effect on the price of agricultural land. They have cautioned that this technique can give rise to misleading conclusions about the effect of an environmental attribute on producers' or consumers' welfare if potential biases from inappropriate sample selection criteria are ignored.

d) Cost of illness method: This method measures the direct (medical costs, nursing care, drugs) and indirect (opportunity) economic costs associated with a disease and estimate the potential savings from the eradication of the disease. This approach also values loss of life based on the foregone earnings associated with premature mortality. The notion is that people should be willing to pay at least as much as the value of the income they would lose by dying prematurely (Remoundou et al., 2009).

Two important limitations of this approach is that it does not consider the actual disutility of those who are ill, nor does it account for the defensive or averting expenditures that individuals may have taken to protect themselves

RESULTS AND DISCUSSION

For this review, the journal papers were collected, collated, reviewed and analyzed intensely to find out the gaps and limitations of various methods were discussed and presented.

In the wake of rampant pollution of water sources, the need of the hour is proper management of water bodies to maintain their purity and sanctity. This paper is an attempt to critically assess and bridge the loopholes of the economic tools for evaluating river water quality and use it to quantify the environmental degradation by monitoring the water quality of the rivers.

The researchers have used the economic assessment tools independently without finding the impact of one method on another. For instance, the water bodies used for recreation are valued using TCM only (McKean et al., 2005; Shrestha et al., 2007; El-Bekkay et al., 2013) without considering the Damage Function and Cost of Illness of local people, which might still result due to microbial contamination of water. Similarly, Hedonic Pricing measures the land prices near water bodies without considering the local flora and fauna in the vicinity of water bodies (Higgins et al., 2009; Mahan et al., 2000). Also the literature does not provide information on economics of the interventions to protect the river water quality and relate it to the increase in local flora and fauna and decrease in averting costs incurred by local people. Further, the literature does not quantify economically various pollution control measures to improve water quality in rivers.

The following discussions are drawn based on the critical review of papers related to Economic tools.

i) Select social discount rates to assess future benefits from policy interventions and carry out a cost - benefit analysis of the interventions.
ii) Develop a mathematical relationship considering various parameters of concern to quantify (in terms of monetary valuation) the pollution abatement investments of the rivers.
iii) Justify investments made for pollution control in the riverine systems through economic quantification.

Conclusions

This review is certainly a step forward in understanding the principles of Environmental Economics by quantifying the impacts of pollution in the rivers and studying the implications of various pollution prevention projects undertaken by the Government, industries and private organizations to improve the quality of water in these rivers. Economic quantification is the basis for assessment of the investments in the form of interventions to protect the river water quality and social benefits like improvements in health of people, local flora and fauna and water quality of rivers. This research is unique because the flaws of existing economic tools are studied for assessing river water quality and this assumes significance in the light of the investments to improve the water quality of these rivers. A major limitation of existing economic tools is the lack of mathematical models for quantifying investments on river water protection. Future work is to combine different economic tools and study the effects of investments made for water protection and pollution control.

Conflict of Interest

The authors have not declared any conflict of interests.

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