Thematic Review on Economic Cost, Benefit Analysis of Hydropower Projects

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Abstract

While taking investment decisions on hydropower projects cost and benefit analysis (CBA) is important technique. It was started from United Kingdom for transportation sector later on it is used widely in mega projects all over the world. CBA contributes to identify all relevant benefits and costs and provides tools to quantify in monetary value. The CBA measurement variables defers from country to country on the basis of geography, population, natural resources, technology, market etc. This article aims to present a conceptual frame work to select a hydro power project and its viability. Basically in developing countries like Nepal this frame work plays important role in selecting particular hydropower projects.

***Key Words**: Hydropower, cost - benefit, framework, monetize.*

Introduction

Cost Benefit Analysis (CBA) technique is essential in the decision making. CBA is a popular evaluation technique that is widely used by both public and private organizations for the decision making process. It is useful to identify all the benefits and costs of a particular projects and quantifying in terms of monetary value. The practice of CBA was introduced in the United Kingdom in 1960s for use in the transportation sector. Later on CBA was extended to cover a wider range of applications, such as water resource management, motorways, nationalized industries, airport locations, forestry, recreational facilities and a wide range of urban investment projects (Paul, 2000).

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 different such as risks of disease, economic costs and death, environmental improvement or damage but are assigned a common monetary value. The option of the highest net benefit is usually recommended, although it neglects distributional aspects.

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. 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. (Cecilia Hakansson, 2007)

Private sector investment is directly concerned with monetary costs and benefits. The profitability increases investment and output. Public sector investment must evaluate all costs and benefits in some other way. Welfare economics helps to resolve such issues as how to assess costs and benefits of a non-monetary environment and how to assess the community benefits when no charge made for public facility and how to fiddle with the market failure.

CBA is a widely applied technique which evaluates public spending and aims to avoid inappropriate distribution of public resources. In theory, it helps public decision-makers to invest only in the projects which create more profitability from the viewpoint of the community. To function perfectly, the CBA procedure needs to be engaged prior to the decision is made, so that the potential of the range of project proposals can be compared and evaluated. CBA aims to evaluate direct and indirect effects of a project and its financial and non- financial effects on the economic agents concerned with the investment. These effects are synthesized, after monetary evaluation, to assure a socio-economic balance which establishes the return on the investment, with this return being estimated on the basis of specific indicators" (Auzannet, 1997).

Boardman et al. (2006) presented the major steps in CBA for the set of alternative projects, decide its benefits and cost evaluation, catalogue the impacts and select measuring indicators, predict the impacts quantitatively over the life time of the project monetize all impacts, discount benefits and costs to obtain present values, perform sensitivity analysis and Make a recommendation.

Objective of the study

The study has set the objective to present a theoretical framework and anticipated assessment of costs and benefits of hydropower projects. The specific objectives of the study is to present a conceptual framework of economic cost- benefit analysis of hydropower projects

Issues on Economic Cost Benefit Analysis

CBA technique is used to evaluate the investment projects through predicting the cash flows of the project. Economic analysis is not essential in private sector investment whereas CBA is mandatory in public sector for large investment projects. It is necessary to prove feasible and the public money is not spent in vain. So, CBA is most important in public sector investment because this instrument is applicable to measure social benefits.

Each CBA represents a series of calculations to conduct the analysis of final conclusion. These calculations are focused around the financial analysis, respectively the economic analysis. Financial analysis is based on financial indicators while economic analysis incorporates the social benefits by implementing an investment project. The most challenging issue of CBA is to monetize economic cost and benefits because these are not easy to be identified. Benefits identification is a long process during that period all positively affected parties should be nominated presuming that the investment project will hold added value of environment, to their life and wealth. Similarly, all benefits should be quantified exactly by comparing the opportunity with the possible state of the art after implementing the investment project. The last stage of monetization requires the ascertainment of the value of each unit of benefit to calculate the monetized value of all benefits. While analyzing costs and benefits of hydropower projects in Nepal, specified framework is not presented and academic research of comparative analysis on reservoir and run of river hydropower projects are insufficient. This study has therefore raised the research questions; What can be a conceptual framework of costs and benefits of hydropower projects?

Literature Review

While assessing the costs-benefits of a particular infrastructure project, value is required to calculate. Value is simply the benefit or cost that an individual or society obtains from a goods or service. It reflects the economic efficiency and seeks to maximize social welfare as measured by this notion of value as the net benefits to individuals or society of individuals (Kahn, 2005). Economic value theory explains the concept of value with two characteristics they are economic value is anthropocentric, it is determined by people themselves and economic value is determined by the willingness to make trade-offs between goods, for example, buying one goods instead of other goods. This is best explained by the notion of budget constraint; namely, when an individual spends money on one good or service, there is less money available to buy other goods (Kahn, 2005). Thus, the individual should trade-off between different goods and services and expected to choose the good, which provides the highest benefit.

The economic value of hydropower production is determined by three production factors namely the cost of labor, the cost of capital and energy. The water required for electricity production can be counted as the required energy (Geissmann, 2012). Thus, externalities can be either positive or negative, depending on the circumstances of the action. For example, a hydropower project has internal and external costs and benefits. Internal benefits are the revenues gained from electricity production, whereas an example of an internal cost is the work or coal needed to generate electricity. Together, they form a private value arising from this economic activity. External benefits include gains due to the employment of people at the power plant, whereas external costs are air pollution and acid rain resulting from burning the coal. These are the external effects of social value. Together, the private and social value of goods represents the economic value of that good (i.e. Economic Value = Private (Financial) Value +Social (External) Value).

External costs such as environmental damages are difficult to determine, as for these types of values often no market, and thus no market price, exist. This means that most market prices do not reflect the "true" economic value of a product. This is also called a market failure. For example, many goods are traded at prices that do not account for the environmental damages occurring during the good's manufacturing or use, and are therefore traded at a too low price. If the external cost would be internalized, i.e. accounted for in the market price, the good would be more expensive. This is further explained by Pearce and Nash (1981) who state that a Pareto optimum exists when the marginal external cost (MEC) equals the marginal net private benefits (MNPB). The MNPB for a firm is defined as:

MNPB = P – MC, Where, P is the product price and MC is the marginal private cost.

If MNPB = MEC, then the first equation can be rewritten as MEC = P – MC or further MEC + MC = P = MSC, Where, MSC is the marginal social cost (Pearce & Nash, 1981). Under this condition, the product price equals the marginal social cost. However, this condition rarely holds in reality and thus product prices rarely reflect the marginal social value (i.e. external costs or benefits).

The CBA is structured as depicted by Hanley and Spash (1993), who defined seven stages for conducting a CBA. These include (1) defining the project and scenarios, (2) identifying impacts that are economically relevant, (3) physically quantifying impacts, (4) calculating a monetary valuation, (5) discounting, (6) weighting, and (7) conducting a sensitivity analysis. Stage one is the definitional step, which explains the proposed project or scenarios used in the analysis. It defines the reallocation of resources being required for the project and which are the potential populations of gainers and losers. Limitations are sometimes also explained in this step, but this can also be done at the end of the analysis.

The second stage has two purposes. First, it identifies all negative and positive effects or impacts resulting from the project implementation. Second, it determines those impacts that are economically relevant and that should be considered in the analysis. Regardless of whether impacts have a market price or not, they can be regarded as economically relevant as long as they affect the costs, benefits or utility of a project. For environmental externalities to be accounted for as impacts, one out of two conditions should be satisfied. These conditions are: (1) that at least one person in the relevant population becomes more or less affected in his or her utility, and/or (2) that the level of a positively valued output changes.

Stage three involves the physical quantification of the relevant impacts. This means that the formerly identified costs and benefits are explained in terms of their flows, their occurrence in time or, if applicable, their probability of occurrence. All calculations in this stage can be performed with different degrees of uncertainty. In the next stage, stage four, the impacts are converted into one common unit of value in order to be co-measurable. The most common unit for a CBA is a monetary value because prices carry important information about people and their behavior. This is because markets create relative values for all traded goods and services, which are expressed in prices. In this stage, the task of the researcher is to adjust market prices where necessary or create prices where they do not exist. Adjusting market prices might be required under certain circumstances, for example, in the case of imperfect competition or government intervention in the market that distorts prices. When a market does not exist (e.g. in the case of landscape quality change), monetary values can be created by using shadow prices or stated or revealed preference prices that reflect the non market scarcity value of an environmental impact as experienced by those affected.

After the monetary valuation of the relevant impacts, all values need to be converted into their present value terms. This is done in stage five, which is the discounting step of the analysis. Discounting is an important tool in CBA and it arises due to the time value of money, or time preference. Therefore, they need to be made comparable regardless of when they occur which is done by calculating their present values. The discount factor usually referred to as the discount rate, can vary considerably between studies and is subject to a person's preference for things now rather than later. For example, the higher the discount rate, the higher one values present benefits as opposed to the benefits occurring in the future. The procedure of discounting is usually done by calculating the present values for each element of the project and then summing up all discounted values. Subsequently, in stage six, the discounted costs (C) and discounted benefits (B) are weighted against each other, using a discount rate. This is done by calculating the NPV of the project or scenarios. If the sum of discounted benefits exceeds the sum of discounted costs, then the project represents an efficient allocation of resources.

The final stage involves the sensitivity or uncertainty analysis in order to identify to which parameters the NPV results are most sensitive. This is an important step because during the CBA calculations, many assumptions need to be made concerning physical and monetary flows that can introduce uncertainty into the analysis. Therefore, it is essential to recalculate the decision criteria with a changed set of parameters, for example, the discount rate, changed physical quantities or the project life span. An investigation conducted by Filippini, Banfi, Luchsinger, and Wild (2001) provides a first overview of the economic perspectives of hydro power production in Switzerland concerning its competitiveness in a more liberalized energy market. It was found that the competitiveness of hydro power production is mainly determined by both European electricity prices and the frontier technologies for base and peak load electricity production. According to this study, base-load electricity prices are determined by gas fired combined cycle power plants and nuclear power plants, whereas peak load electricity prices are determined by gas turbine power plants. The authors estimated an average electricity price at 5.6 Rp./kWh. The results show that especially for those plants producing peak load electricity the average costs of production (e.g. 7.8 Rp./kWh for pumped storage plants) exceed the average market price for electricity. Thus, to stay competitive in a more liberalized market, these plants need to introduce measures that would help them decrease their costs of production.

Canzler, C. (2012) on behalf of the Federal Office for Energy were released. It represents the evaluation of nature protection, repair and replacement measures due to Swiss hydropower plants. The goal of the study was to elaborate methodological techniques for the assessment and evaluation of adverse ecological effects from hydropower plants on particular ecosystems and on the environment in general. Furthermore, the study discusses methods and techniques for the monetization of costs and benefits of nature protection, repair and replacement measures that need to be undertaken due to the ecological effects of hydropower plants. One section of the report deals with direct and indirect benefits of hydropower production in monetary terms. In contrast, for the cost side the effects are only discussed qualitatively and methods for the quantification of these effects are proposed. As for the direct or financial benefits, it is concluded that the real market prices of electricity reflect the gains generated by hydropower production. A comparison of different studies is presented, which revealed that the mean prices for peak load and base load electricity as of 2007 amounted to 9.2 Rp./kWh and 6.7 Rp./kWh, respectively. Furthermore, the report states that large benefits are generated due to the possibility of creating balancing energy (energy that balances the peak demands for electricity) with storage and pumped storage plants for peak demands. These benefits are expected to increase further in the future when more balancing energy is needed to regulate the production volatilities of other renewable energy sources, such as solar and wind power. With regard to the so-called indirect benefits, it is stated that electricity production in general leads to many negative effects or external costs, such as loss of biodiversity, GHG emissions due to fossil fuels, or radioactive waste from nuclear power plants. However, it is argued (and quantified empirically) that the external costs of electricity production other than hydropower production exceed the external costs from hydropower production. Therefore, hydropower production creates net external benefits or avoided external costs. The study compares the net external benefits of hydropower production to six other types of electricity production, namely nuclear, oil, gas, wind, biomass, and solar powered electricity production. It is shown that hydropower production has a net external benefit as compared to the other types of electricity production (except for wind power with a net external benefit of 0.4 Rp./kWh).

Conceptual Framework

Variables for economic and financial analysis/CBA

The following variables on benefits and costs will be regarded while analyzing the economic and financial analysis.

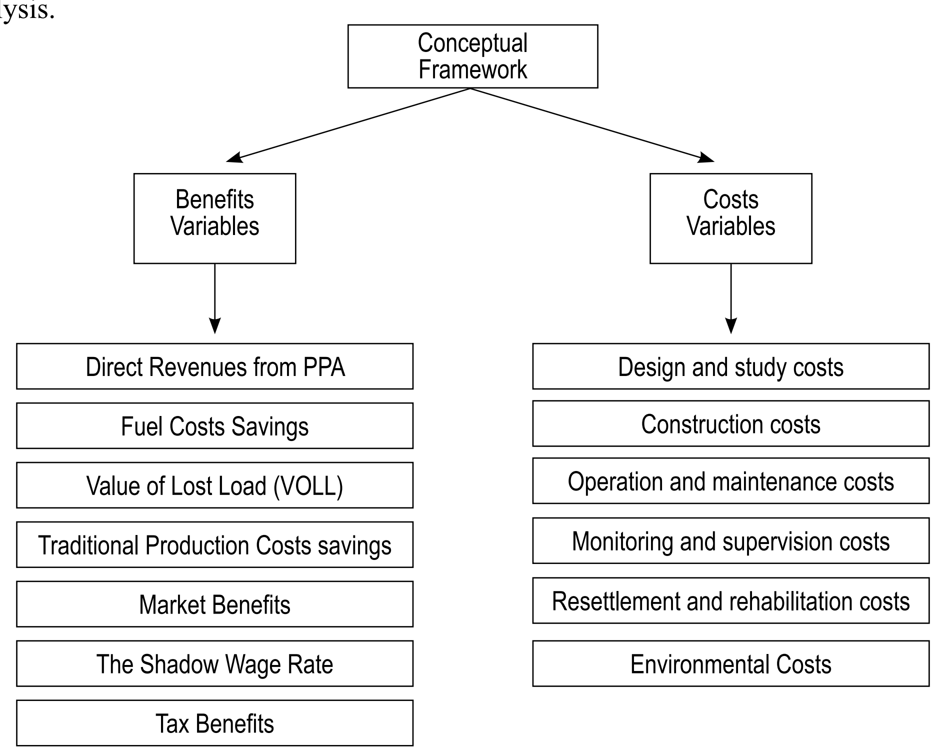

Figure 1 Conceptual framework of the study

Operational Definition

Benefit Variables

Direct Revenues from Power Purchase Agreement (PPA)

Data on Total revenues will be generated from the sale of electricity by using the following formula. For this separate price structures will be adjusted for dry season and wet seasons as the PPA prices are different in two different seasons.

Revenues from sale of electricity (R) = R=Rs/kWh $\times$ kWh

Where, R = Revenue, Rs/kWh = Rupees/Kilowatt Hour Power

Fuel Diversification and Fuel Market Benefits (Fuel Costs Savings)

This benefits includes the money that is saved from less or no HFO for thermal power generation because of energy generated from hydropower projects and can be generated the following formula:

$$\mathrm{FDF} = \sum_{k\ 0}^{n} \mathrm{VOLL}\ (\mathrm{PetroP}) + \mathrm{u}$$

Where, FDF = fuel diversification benefit, VOLL = value of lost load,
Petro P = petroleum price

Traditional Production Costs savings

This benefit includes anticipated savings on the costs of production as a result of reliable and relatively cheap supply of energy and derived from the following formula:

$AVC_i = a_0 + \beta_1 ELectP_i + \beta_2\ \Delta OTh_{cost} + u$

Where, AVC_i = Average Variable Cost, $ELectP_i$ = Electricity prices,
ΔTh_{cost} = Change in other costs, u= dummy variable

Market Benefits

This benefits aggregates the Benefits generated from the growth of firms/industries, increased employment opportunities, and increased market liquidity and derived from the following function:

$Local_{GDP} = a_0 + \beta_1 ELectP_i + D + u$

Where, $ELectP_i$ = Electricity prices, D = dummy variable

The Shadow Wage Rate

It is the ratio between the shadow wage and the observed market wage and can be generated from the following formula:

$SWRF = n(\Delta u/\Delta L) + zd$

Where,
ΔL = project labor input,
Δu = decrease in unemployment (number of units),
n = reservation wage and
z = again the relocation costs.

Tax Benefits to the Government

This benefit includes the tax benefits generated from the construction of hydropower project through anticipated tax benefits (revenues) from assumptive rates, assumptive indirect tax (VAT, Excise Duties, and others) and assumptive direct tax (income taxes including social security tax) which can be derived from the following formula:

Indirect Tax Benefit ($GT_{R\,i}$) = $T_{ind}R * T_{ind}A$

Direct Tax Benefit (GT_{Rd}) = $T_dR * T_dA$

Where, $T_{ind}R$ = Rate of Indirect Tax
$T_{ind}A$ = Amount of Indirect Tax

Cost Variables

The overall costs include:

Design and study costs: Total costs generated from the bills of quantities inclusive of all resource costs,

Construction costs: Total costs generated from the bills of quantities inclusive of all resource costs),

Operation and maintenance costs: Anticipated operation and maintenance costs (anticipated monitoring and supervision costs may be as a certain percentage of total costs),

Monitoring and supervision costs: Anticipated monitoring and supervision costs (Anticipated monitoring and supervision costs may be as a certain percentage of total costs),

Resettlement and rehabilitation costs: Cost estimates of acquisition of land and structure, loss of crops and trees, loss of income from business, rehabilitation of vulnerable and indigenous communities including those less able to care for themselves, costs of the lost of common property resources and access to common property etc., and

Environmental Costs: Cost estimates of spoil disposal of materials, and other construction waste, impact on vegetation and wildlife, cost for the protection and reinstatement of public and private utilities, cultural, historical and religious sites, dust and noise pollution, labor camp management and safety etc.).

Thematic Remarks

Hydropower projects require calculating financial cost-benefit and economic cost-benefit calculation. Private sector investment is concerned with financial cost benefit analysis but public sector investment is concerned with both financial as well as economic benefit for the local benefit, fuel diversification, wage benefit, environmental conservation, sensitivity analysis etc. For the viability of a project clear cut conceptual framework is required and it depends on economic, geographical, climatic and technological situation. This article has presented viable conceptual framework.

References

Auzannet, (2011). Cost-Benefit Analysis of High-Speed Rail Link between Hong Kong and Mainland China, *Journal of Engineering, Project, and Production Management*, 1(1), 36-45.

Boardman, A. E. (2006). *Cost-benefit analysis: concepts and practice*, Upper Saddle River, N.J.: Pearson Prentice Hall: New Jersey, 3rd ed., Pearson international ed.

Canzler, C. (2012), *The Economics of Swiss Hydropower Production: A cost-benefit analysis of hydropower production in Switzerland*. IVM Institute for Environmental Studies, VU University: Amsterdam.

Filippini, M. and Wild, J. (2001), Regional Differences in Electricity Distribution Costs and their Consequences for Yardstick Regulation of Access Prices, *Energy Economics*, 23(4), p. 477-488.

Geissmann, T. (2012). Economic Analysis of Switzerland Water System. (*Unpublished master's thesis*). SwissFederal Institute of Technology Zurich (ETH), Switzerland.

Hakansson, C. (2007). Cost Benefit Analysis and Valuation Uncertainty: Empirical Contributions and Methodological Developments of a Study on Trade-offs between Hydropower and Wild Salmon. *Doctoral dissertation*. Umea: Swedish University of Agricultural Sciences.

Hanley, N., Spash, C. (1993) *Cost-Benefit Analysis*. Edward Elgar Publishers, Aldershot.

Kahn, J.R. (2005). *The economic approach to environmental and natural resources* (3rd ed.). United States: South-Western College Publishing.

Pearce, D.W. & Nash, C.A. (1981). *The social appraisal of projects: a Text in Cost-Benefit analysis*. London: The Macmillan Press Ltd.