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WP 19/2002

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An Empirical Application of Probabilistic CBA:

Three case studies on dams in Malaysia, Nepal and Turkey

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Abstract

This paper empirically applies cost benefit analysis to hydroelectric projects in Malaysia, Nepal and Turkey. The main characteristics of each dam and the development stage of each country largely differ. The study attempts to bring all the major issues attached to each hydro project together and analyses quantitatively what would be happening if these dams were to be constructed. The cost benefit analysis model in this study takes account of premature decommissioning of dams and the correlation between the parameters of generation capacity, total construction cost and construction period. The mean cumulative net present value at the 100^{th} year of the analysis with the 5% discount rate for Sharada-Babai dam in Nepal shows a positive figure, whereas the net present value for both Bakun dam in Malaysia and Ilisu dam in Turkey are negative. The mean value of the cumulative net present value for Sharada-Babai becomes negative when the pure rate of time preference is larger than 6%; for Bakun and Ilisu, it converges to zero as the pure rate of time preference becomes larger. The sensitivity analysis shows the dominant positive impact of the generation capacity parameter on net present value for Bakun; and the parameter expressing initial expected increase in economic output for Sharada-Babai and Ilisu.

Introduction

The serious negative effects of large dams have been widely discussed, and the roles of large dams have been questioned, over the past two decades (WCD 2000). However, there are still numerous plans to build massive dams worldwide, especially in developing countries. Are these dams really worthwhile to build? Will they contribute to the sustainable development process? This paper tries to answer the question based on an empirical application of probabilistic CBA (cost benefit analysis) to hydroelectric projects in Nepal, Malaysia and Turkey. The main characteristics of the dams and the development stage of the countries largely differ. This study brings the major issues attached to each hydro project together and analyses quantitatively what would happen if these dams were to be constructed. The CBA model in this study is developed from Morimoto and Hope (2001, 2002), to take into account the correlation between the generation capacity, the total construction cost and the construction period.

The next section describes the characteristics of three hydro projects. The third section explains the methodology and lists the variables used in the model. The fourth section presents the findings from the study including sensitivity analysis and the variation of cumulative Net Present Value (NPV) against the pure rate of time preference. The last section concludes the study.

Malaysia: Bakun Hydro Project

Malaysia is currently in a strong recovery after the effects of the Asian financial crisis in 1997-98. The current electricity demand growth in Malaysia is 8% per year, approximately 1.5 times the rate of the country's economic growth. There is a total electricity generation capacity of 14 GW[1]. The energy demand in Malaysia is traditionally met by four major sources: gas (73.3%), hydro (11.4%), oil (7.8%), and coal (7.5%) in 1999 according to Tenaga National Berhad (TNB). The

[1] www.atimes.com/reports/BJ28Aiol.html

government intends to balance this ratio and is trying to increase hydropower generation, which has led to the controversial Bakun Hydroelectric Project construction plan. The Bakun dam on Balui River in Sarawak state on Borneo Island will be South East Asia's largest dam with a generation capacity of 2.4 GW, and is supposed to cater for the rising industrial demand for electricity in Malaysia. Although this development of a remote part of Malaysia might improve the regional economy, through increased employment and infrastructure development (access roads, airports etc), there are also many costs associated with it. It will flood 70,000 hectares of rainforests and abundant timber sources, equivalent to the size of Singapore, and fertile agricultural lands. The construction costs for this gigantic project will be huge, despite the fact that there would be a possibility of insufficient demand to absorb its enormous generation of electricity. Another great concern of the project is the displacement of 10,000 indigenous people. The entire ecosystem of the area also might change; especially large negative effects on downstream fishery are anticipated. The area is already suffering from siltation due to timber extraction, which is highly likely to restrict power generation capacity in the near future. Poor working conditions at the dam site are also reported. The project has been delayed due to serious environmental, social and financial problems, but about 500 MW of electricity will start being generated by 2005[2].

Nepal: Sharada-Babai Hydro Project

About 85 per cent of Nepal's population still does not have access to electricity, and the country's major sources of energy are fuelwood and kerosene (Mahapatra 2001). Nepal is rich in water resources, and its theoretical generation capacity is 83 GW according to the Nepal Electricity Authority (NEA). However the existing hydropower generation capacity is only 260 MW with 51 MW supply from diesel units. Although the present demand for electricity is just over 350 MW, the demand will grow to 610 MW by 2005 (Pokharel 2001). Lack of electricity may restrict

[2] ibid

economic growth, especially in the industrial and service sectors – the fastest growing economic sectors in Nepal (Pokharel 2001). Currently, there are many planned hydropower projects in order to utilize the resources.

The proposed Sharada-Babai hydropower project in the Mid Western Region of Nepal has an installed capacity of 93 MW, and requires a 5-year construction period. The project is located between the tropical and sub-tropical climatic regions of the country. The reservoir area is very fertile land, whose main crops are paddy and wheat. More than 300 families will be relocated from the core project area. The major impact of the project will be the submergence of rich forest and agricultural land. The impoundment and reduced flow downstream will change the hydrology of the basin, which is likely to affect the aquatic environment of the river. The holy pond and the Kali Vhagwati (a temple of religious and cultural importance) will be inundated due to the reservoir formation. Infrastructure relocation such as a school, a post office, and suspension bridges are also required.

Turkey: Ilisu Hydro Project

Turkey is currently in the middle of a serious economic crisis, which began in November/December 2000, and worsened sharply in February 2001. The crisis was triggered partly by underlying economic weaknesses (current account deficits, severe problems in the banking sector), and partly by political instability.

The proposed Ilisu hydro project is a part of the Southeastern Anatolia Project which aims to improve the living standards and develop the agricultural potential of the nine southeastern Anatolia provinces and to bring their socioeconomic level up to the national average.

The Ilisu dam is currently the largest hydro project in Turkey with a generation capacity of 1,200 MW. It is located on the Tigris River in South-East Anatolia, 65 km upstream of the Syrian and Iraqi border. The project is supposed to start producing power in mid-2006, though it is extremely controversial for a variety of political, social, environmental, economic, and archeological reasons.

The project will submerge approximately 52 villages and 15 small towns and affect 36,000 people (according to the UK government), mainly ethnic Kurds. The people living in the project area are mainly farmers who grow cereals, vegetables, fruits, cotton, tobacco and herbs and a small number of shepherds. Although there is no real commercial fishing in the River Tigris, farmers fish for local consumption. People moving to cities will face sharp changes in their daily activities and traditional ways of life which often cause significant problems of adaptation to the urban environment, family tensions, psychological stress and social disruption.

Hasankeyf, the main town to be inundated, is the only town in Anatolia which has survived since the Middle Ages without destruction, and is also known as an important pilgrimage center. The town's history dates back at least 2,700 years, and it hosts a formidable array of monuments, including cave churches, ornate mosques, and Islamic tombs. An astounding complexity of architectural and religious heritage spanning several civilizations has been created. Being a rich treasure of Assyrian, Christian, Abassidian-Islamic and Osmanian history in Turkey, Hasankeyf was awarded complete archeological protection by the Turkish department of culture in 1978, and 22 monuments have been entered on the Turkish Cultural Inventory List in 1981. Lack of funds and time means that it will be difficult to relocate the treasures that will be inundated. Moreover, even after successful relocation, they may not create the same aesthetic impact in a new site. Hasankeyf is also a tourist destination and a holiday resort, so inundation of this town is likely to affect tourism in the area.

The area to be flooded by the reservoir includes 7,353 ha of good agricultural land, 4,820 ha of medium-low quality land, and 15,675 ha of land not suitable for growing crops. Since the amount of trees and shrubs in the area to be flooded is relatively small, the CO_2 release from the reservoir is assumed to be small compared to the other reservoirs of the same size in dense forest (IEG 2001).

Solid waste and wastewater of major cities are being dumped into the Tigris River without any treatment. The Ilisu reservoir will vastly reduce the auto-purification capacity of the Tigris. This is then highly likely to cause water quality degradation and possibly affect the downstream fishery negatively.

Methodology

Table I lists the variables used in the CBA model: the core variables included in all the case studies are PG (power generation), CP (clean power), EG (economic growth), CC (construction cost), OM (operation & maintenance cost), RE (resettlement cost), IN (losses due to inundation of land), AC (accident cost). The project specific variables are FI (impacts on downstream fishery) for Bakun; IF (infrastructure cost) for Sharada-Babai; and LT (tourism loss) and AS (archaeological loss) for Ilisu. A brief summary of the equations used in the model, and all the parameters in the model and their values are listed in Appendix A-I and A-II respectively.

Table I Variables used in the CBA model

Variable (core variables in **bold**)	**Description**
EG (economic growth)	The forgone economic costs for electricity not served, which will occur during the time when an alternative power generation technology is not available.
PG (power generation)	Calculated by multiplying the quantity of electricity generated by the price of electricity. A possible reduction in the quantity of electricity generated due to sedimentation, and changes in electricity prices, are also included in the equation.
CP (clean power)	The environmental benefit of avoiding damage from air pollution when generating an equivalent amount of power by thermal power. This benefit will occur during the time when an alternative power generation technology is available.
IN (losses due to land inundation)	Financial values of forests and agricultural lands to be inundated
AS (archaeological loss)[3]	Approximated by the values of cultural antiquities being sold on the market.
CC (construction cost)	Construction costs of the power station and transmission facilities.
FI (impacts on downstream fishery)	Decline in revenues from fishery due to dam construction.
LT (tourism loss)	Losses in tourism revenue as a result of the dam construction
OM (operation & maintenance cost)	O&M costs for running the hydropower station.
RE (resettlement cost)	Compensation to individuals and development costs for new houses and infrastructure. Theoretically, estimations

[3] How archaeology is perceived is different from place to place and generation to generation (Carver 1996). Although there are many studies on how to place values on archaeological sites, there is no simple conclusion for this argument. See Carman et al (1999); Carver (1996); Darvil, Saunders, and Startin (1987); Lipe (1984); Schaafsma (1989).

	of what resettled people are willing to accept are preferred as better estimates. However, those data are difficult to obtain and their results are not very reliable, especially in developing countries.
IF (infrastructure relocation cost)	Costs required to relocate infrastructures to be inundated
AC (accident cost)	During construction, O&M & special circumstances (technical failure, terrorism attack or earthquake). Calculated by multiplying the estimated number of deaths and injuries due to the project by the economic value of deaths and injuries. Assumes that accident risks are not internalised in wages[4].

Some inputs are clearly correlated. If the generation capacity were to be reduced, the total construction cost and the construction period would also be reduced accordingly. Hence, we assume that a minimum value for one of these variables implies a minimum value for the others. The same assumption is made for most likely and maximum values. The correlation coefficients that this implies for each project are shown in Table II[5].

There is a wide range in the data for GC (generation capacity) in the Bakun case, as the project size might be drastically reduced due to the protests. The minimum, most likely and max values are 0.5, 0.7 and 2.4 GW respectively. Therefore the consideration of this input dependency would be particularly important for Bakun.

[4] This method does not take into account accident costs for alternative sources of supply for simplicity, as different risks are included for the alternative cases.
[5] The calculation is based on the following formula: correlation coefficient [x,y] = {covariance [x,y]}/{(standard error [x]*(standard error [y])}

Table II Correlation coefficients

	GC-TCC	GC-Tc	TCC-Tc
Bakun	0.996	0.996	0.983
Sharada-Babai	0.98	0.9	0.79
Ilisu	0.99	0.82	0.9

Note: GC=generation capacity parameter; TCC=total construction cost; Tc=construction period

The data are given as ranges being based on my own judgments, collected mainly from the existing project reports including EIA reports and energy reports. Supplementary data are based on an extensive collation of information from past studies on similar topics, newspapers, Internet and other relevant sources. The most appropriate data for each parameter are selected using my best knowledge on the energy policy of the country, their current situation and future direction of power generation. Best efforts are made to find as accurate and representative data as possible. Visiting the project site and interviewing government officials, energy experts, policymakers, researchers/academics, environmentalists and locals during my fieldtrip in Malaysia, Nepal and Turkey have greatly helped such decision making process.

Some of these data may not be very accurate or precise. Many of the values in Table A-1, A-2, and A-3 are tentative and open to criticism. However, this is inevitable, as many variables are not readily quantifiable and some data have a limited availability because of the project complexity or simply they do not exist. Repeated runs of the model obtain a probability distribution of possible outcomes, which is a more defensible procedure than just using single values for inputs that are in reality not well known.

Dixon *et al.* (1994) argue that the appropriate time horizon should be long enough to encompass the useful life of the proposed project, therefore the project life of 100 years is selected in this study[6].

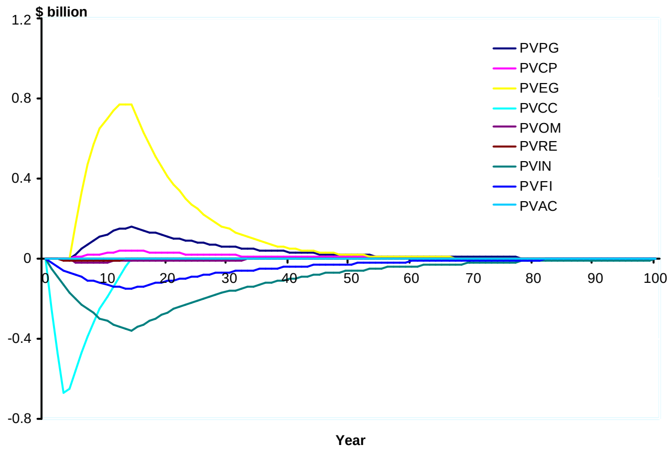
[6] This 100 years project life is used in all other case studies for an easy comparison of the results.

Results

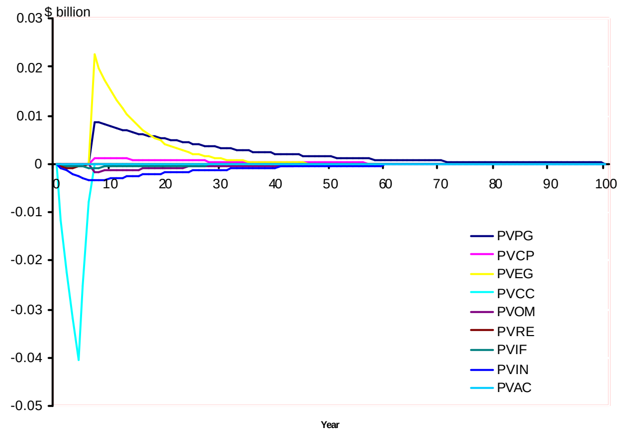
Table III and Figure 1 depict the impact of each variable on NPV for each project; EG (economic growth), PG (power generation), and CC (construction cost) are significant in all the projects; IN (inundation loss) for Bakun and Sharada-Babai; and AS (archaeological loss) for Ilisu. The impact of CC (construction cost) is huge, as much as EG (economic growth), but not as prolonged. The sharp decay of the positive impacts of EG and PG can be explained as a result of serious sedimentation problems. In comparison, AS (archaeological loss) and LT (tourism loss) are long lasting negative impacts. They are also not recoverable once the dam is constructed.

Table III Mean cumulative present values for the variables at t=100 in $ billion.

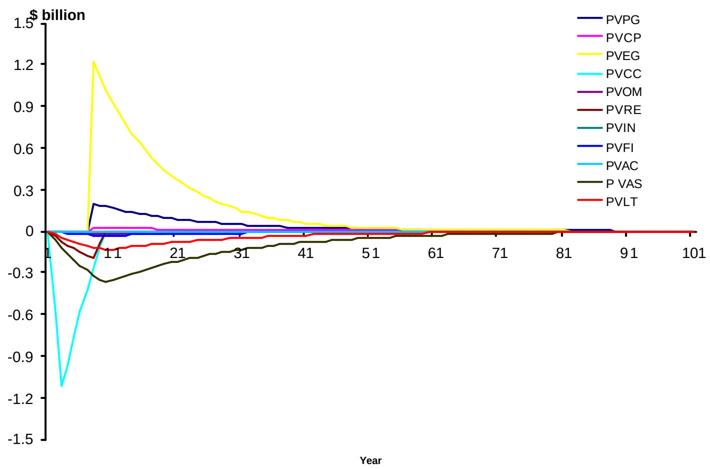
		Bakun	Sharada-Babai	Ilisu
PVEG	**Economic growth**	**+13**	**+0.18**	**+13.8**
PVPG	**Power generation**	**+3.6**	**+0.21**	**+3.3**
PVCP	Clean power	+0.9	+0.03	+0.5
PVIN	**Inundation loss**	**-10.5**	**-0.09**	-0.2
PVAS	**Archaeological loss**	-	-	**-9.5**
PVCC	**Construction cost**	**-4.5**	**-0.14**	**-4.9**
PVFI	Fishery loss	-4.4	-	-0.9
PVLT	Tourism loss	-	-	-3.5
PVOM	O & M cost	-0.4	-0.03	-0.5
PVRE	Resettlement	-0.1	-0.003	-1.0
PVIF	Infrastructure relocation	-	-0.02	-
PVAC	Accident cost	-0.03	-0.0004	-0.04



Bakun



Sharada-Babai



Ilisu

Figure 1 Present value of the variables of Table I by year

For Bakun, the 5th percentile, mean and the 95th percentile of cumulative NPV with a premature decommissioning option at a 5% discount rate at t=100 years are $ -9.6, -2.8, and 7.0 billion respectively (without decommissioning they are $ –9.9, -2.9, and 7.0 billion respectively; showing that the option of premature decommissioning gives a slight improvement)[7]. The mean, the 5th and the 95th percentiles of the cumulative NPV are all initially strongly negative due to the large construction cost as shown in Figure 2. The 95th percentile recovers quickly after the

[7] The premature decommissioning option allows the dam to be closed early if the annual revenue drops below the annual avoidable costs

construction is complete since the benefits of increased economic growth soon outweigh all the costs. Its peak is at t = 40, as after this date the revenue is insufficient to cover the total annual costs. Both the 5^{th} percentile and the mean remain negative throughout the life of the project. The mean shows a slight recovery from year 10 until year 30 followed by a permanent downward movement. The 5^{th} percentile shows a similar pattern to the mean, though it already starts declining at t = 20 due to the large anticipated costs such as inundation and fishery losses.

For Sharada-Babai, the 5^{th} percentile, mean and the 95^{th} percentile of the NPV at the 5% discount rate at t=100 years with premature decommissioning option are $ -0.009, 0.14, and 0.34 billion respectively. The results without the premature decommissioning option are exactly the same since the recoverable costs such as AC (accident costs during operation & maintenance period) and OM (operation & maintenance cost) are small for this project. The range of cumulative NPV over time in Figure 2 shows that the huge initial capital costs are gradually outweighed by the anticipated large benefits from power generation and increased economic growth.

For Ilisu, The 95^{th} percentile is positive whereas the mean and the 5^{th} percentile are negative as shown in Figure 2. The mean, the 5^{th} percentile and the 95^{th} percentile of the cumulative NPV at the 5% discount rate with the premature decommissioning option at t = 100 are $ –9.9, -3.5, and 4 billion respectively. As Figure 2 illustrates, the benefits never outweigh the costs throughout the period for the 5^{th} percentile and the mean, while the 95^{th} percentile turns to be positive soon after the completion of construction. The 95^{th} percentile starts declining gradually after its peak at t = 40. The NPV are all negative at the beginning because of large construction and resettlement costs. The NPV increases rapidly once electricity starts to be generated, however the mean and the 5^{th} percentile remain negative as a result of huge archaeological losses from the destruction of this important area in Turkey which has numerous unique archaeological sites as well as tourist and pilgrim attractions. The result also shows that the consideration of premature decommissioning would not improve the result, since those recoverable costs after premature decommissioning such as operation & maintenance cost, accidents costs during operation, and land inundation loss for this project are relatively small.

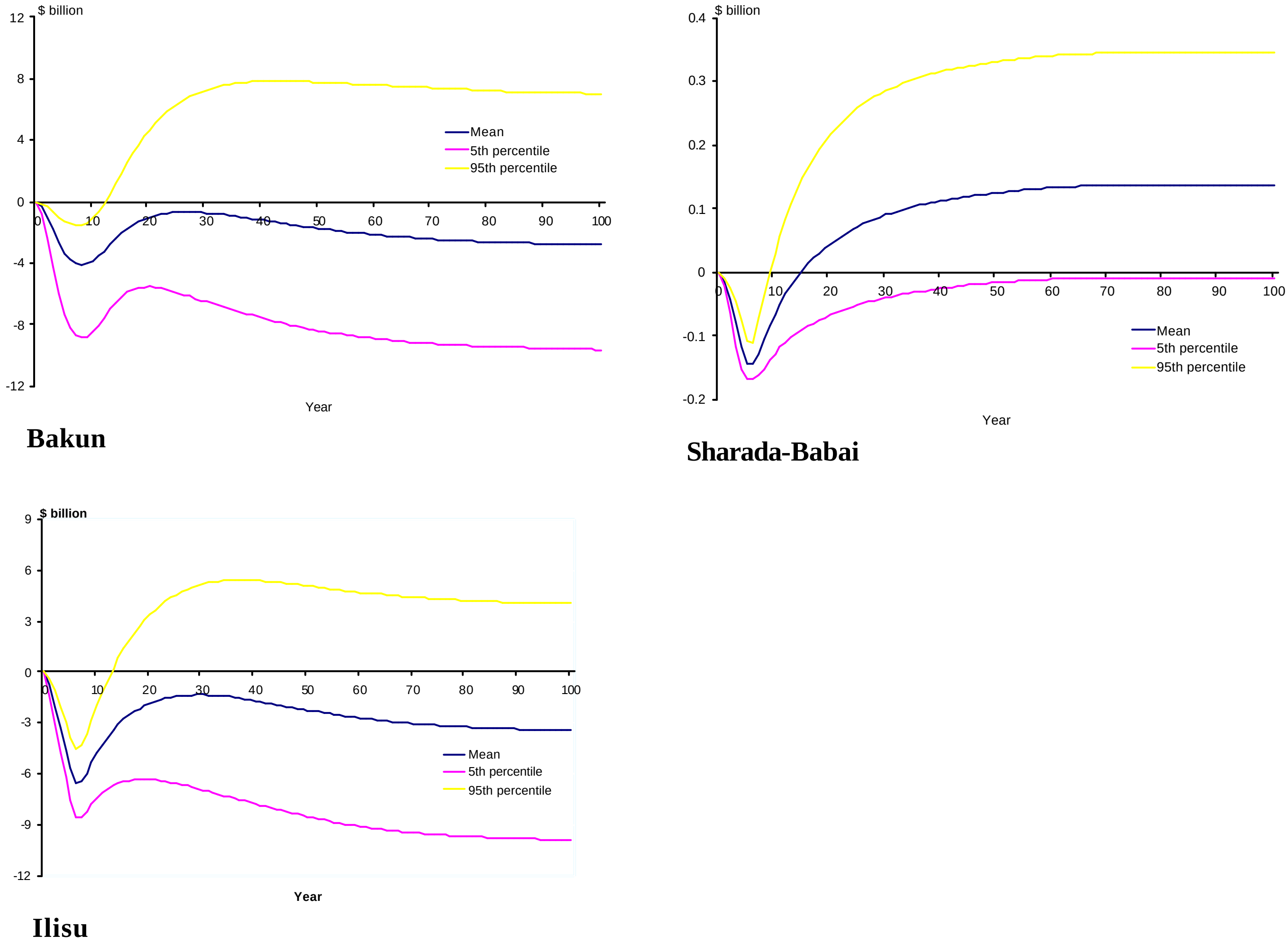


Figure 2 Range of cumulative NPV at the 5% discount rate by year

Sensitivity analysis

The sensitivity analysis shows the dominant positive impact of GC (generation capacity) on NPV for Bakun, and EO (initial expected increase in economic output) for Sharada-Babai and Ilisu as presented in Table IV. The parameters TCC (total construction cost), P0 (Initial proportion of time during which an alternative power generation technology is not available), and NT (number of tourists visiting the dam site in absence of the dam) also have significant impacts on NPV for at least one of the sites.

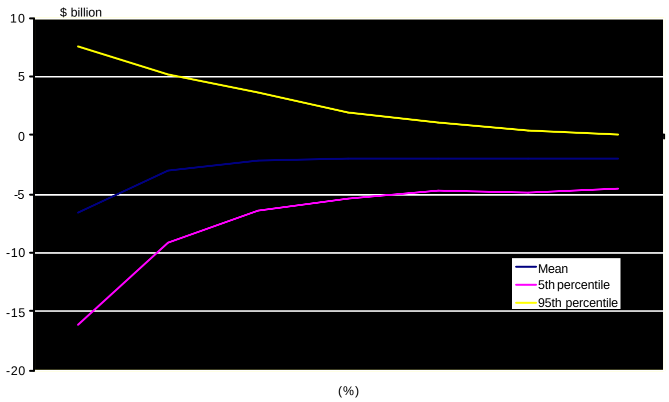
Table IV Student b coefficients

Bakun		Sharada-Babai		Ilisu	
GC	**+0.96**	**EO**	**+0.78**	**EO**	**+0.83**
EO	+0.63	P0	+0.34	NT	-0.33
TCC	-0.61	GC	+0.30	TCC	-0.28

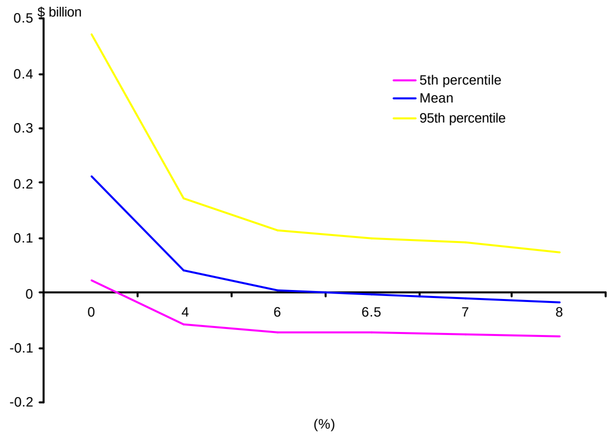
Note: The input parameter values are regressed against the output (NPV). The student b coefficient is a coefficient calculated for each input parameter in the regression equation.

Cumulative NPV against pure rate of time preference

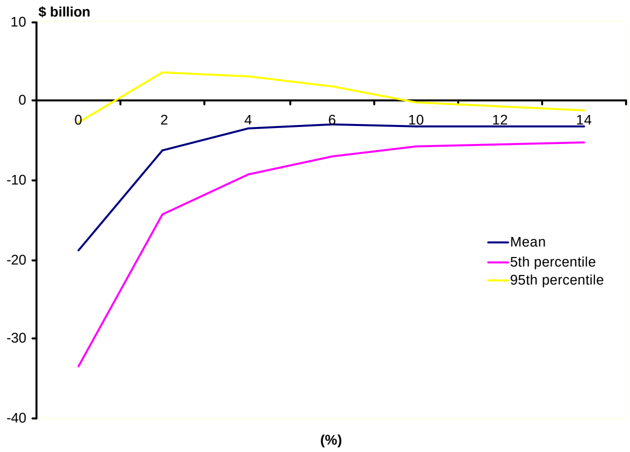
Figure 3 plots the cumulative NPV against the pure rate of time preference, as NPV is sensitive to the change in discount rates. The mean value of the cumulative NPV for all projects converges towards zero as the pure rate of time preference becomes larger. For Bakun, the 95^{th} percentile becomes negative when the pure rate of time preference is larger than 11%. The mean value of the cumulative NPV for Sharada-Babai is positive when the pure rate of time preference is low, and become negative when the pure rate of time preference is larger than 6%. The 95th percentile of the cumulative NPV for Ilisu becomes negative when the pure rate of time preference is larger than 8%.



Bakun



Sharada-Babai



Ilisu

Figure 3 Mean cumulative NPV against pure rate of time preference

Conclusion

This study examines the possible outcome of three highly controversial dam projects in Malaysia, Nepal and Turkey. The CBA model, developed in Morimoto and Hope (2001; 2002) has been applied to the case studies on Three Gorges dam in China (Morimoto and Hope 2002) and Upper Kotmale dam in Sri Lanka (Morimoto and Hope 2001). It is further improved in this study. The result for the Bakun dam in Malaysia shows expected huge losses due to the inundation of the dense rainforest and the fertile agricultural lands, and the significant negative impacts on downstream fishery. The benefit of 2.4 GW electricity supply and facilitated economic growth might outweigh these massive losses. However, this is unlikely to occur during any feasible planning horizon, as can be seen from the 5th percentile and the mean of the cumulative NPV being negative even at t = 100.

The result obtained for the Sharada-Babai hydro project in Nepal seems reasonable; as expected there are large benefits from an increased power supply increasing economic growth as the country is at present seriously short of electricity, large revenues from electricity sales, and the benefits of clean hydro power, in exchange for a large construction cost and unrecoverable loss of submerging fertile agricultural land and forest. This study confirms that the improvement of hydropower development in Nepal seems to be necessary and crucial.

The main finding for the Turkish Ilisu hydro project is the enormous impact of the loss of unique archaeological sites, some of which date back at least 2,700 years. The losses are not only the value of these cultural heritages and artifacts to be submerged, but also the significant number of tourists and pilgrims visiting the sites. Both the 5th percentile and the mean of the cumulative NPV depict that the proposed project benefits will not outweigh the large costs of the project.

Since huge costs are involved in each project discussed above, an increase in electricity prices might not be avoidable. However, this may not be the case for the Sharada-Babai Project, as the benefit is likely to outweigh the cost soon after the construction.

The model in the paper calculates clearly the means and the ranges of present values for each impact of the proposed dams, both positive and negative. Thus, it identifies the most significant impacts with a support of numerical justification. The findings of the model such as each impact and NPV are shown by year. Thus, the model developed herein has a potential to help policy makers in their decision-making, as it provides a whole picture of a project at a glance, and it is visually very clear to see the annual movements of each impact.

The beauty of the model developed here is its flexibility; developers could choose from an array of variables that most closely fit the constraints and conditions of their individual case. Some of the available variables are either included or excluded in order to serve the differences in each project. From these case studies with diverse individual concerns, it shows that the generalised model can be a highly practical tool, with the great advantage of its simplicity and a capability to cater for almost any kind of hydro project assessment under uncertainty.

The limitations of the model are such that some impacts could be much larger than the impacts included in the above model, though may not be quantifiable. For example, the scale of the resettlement for the Bakun project is enormous and the resettlement impact is therefore expected to be huge, though this impact seems to be not fully reflected in our results. This suggests that current estimates of the resettlement cost might be too low, and that alternative approaches such as 'willingness to pay' or 'willingness to accept' might better estimate the true resettlement cost. Furthermore, some evaluations in the model might be over-simplified. There would be other possible impacts for each project not considered; some of these could be major. For example, increased malaria infection; health problem caused by reduced water quality; negative impacts on biodiversity in the area and so on. Displaced people are further impoverished economically, and suffer cultural decline, high rates of sickness, malnutrition, deaths, and great psychological stress in nearly every case[8]. Some of the dam sites, such as Bakun, are home to many unique species of fauna and flora, which may disappear due to the project's impact. The Bakun dam site is located in dense forest; therefore the CO_2 release from the reservoir might not be negligible. These impacts are omitted from the current analysis due to lack of data and the difficulty of quantifications. Including every single impact is not possible, therefore the variables entered into the model are prioritised in each project assessment in this research. They could, however, be included in the future analysis, if relevant, with sufficient background information.

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[8] http://www.caa.org.au/campaigns/adb/fact_sheets/dams.html

Appendix

A-I Model

The brief summary of the equations used in the model is as follows[9]:

EG = (proportion of time during which an alternative generation technology is unavailable)*(quantity of electricity)*(increased economic output due to increased electricity supply)

PG = (quantity of electricity)*(price of electricity)

CP = (proportion of time during which an alternative generation technology is available)*(benefit of avoiding air pollution due to reduced thermal power use)

IN = economic value of lost land

AS = valuation proxies for lost cultural resources

CC = annual construction cost

FI = annual lost profit from fishery due to the dam

LT = annual lost tourism revenue with absence of the dam

OM = annual operation & maintenance cost

RE = annual resettlement cost

IF = annual infrastructure relocation cost

AC = (number of deaths/injuries during construction, O&M, and under special circumstances)*(economic valuation of death/injury) + (annual economic damage cost of dam collapsing)

NPVt = $(1 + \text{discount rate})^{-t}$*(EGt+PGt+CPt-INt-ASt-CCt-FIt-LTt-OMt-REt-IFt-ACt)

[9] The complete set of equations are presented in details in Morimoto (2002).

A-II Data

Table A-1. Parameters and descriptions for Bakun [BHP] ($1= 3.8 Ringgit Central Bank of Malaysia)

(min, most likely, max)	Description of each value
GC (0.5, 0.7, 2.4)	Original plan is 2.4GW, but might be scaled down to 0.5-0.7GW (www.earthisland.org).
EO (380, 760, 1500)	In China, each kWh of power shortage results in a loss of economic output of $0.38-1.5 (MOF 1990)
TCC (0.7, 0.8, 32)	The planned figure is $4 billion (www.idsnet.org). If we consider the possibility of GC being scaled down as above, the min and most likely should be reduced to $0.083 and 0.1 billion. Since the BHP is financially highly uncertain project, set the worst case like the latest India's Narmada dam cost estimate being more than 8 times of the original figure for all the min, most likely and max (McCully 1996).
φ (0.01, 0.04, 0.05)	The planned installed capacity in Malaysia will grow at 11% per annum on average up to 2007, while power demand is expected to grow by 8-10%, or in reality the demand has registered an even slower growth of 6-7% (Shabat Alam Malaysia Press Release; www.surforever.com/sam/pressrelease/lipis.htm).
P0 (0.33, 0.5, 0.66)	Malaysia consumes 1/3 of electricity consumption in Singapore (www.mint.gov.my/policy/nuc_energy/metp95_asli.htm). Thus, they may need to increase their electricity supply by 2/3 to bring their economic development to the Singapore level. The min value is assumed to be ½ of this value, taking into account the possibility of electricity over-supply they have experienced before. The most likely is valued at ½, assuming equal possibility of over-supply and demand growth.

FP (0.005, 0.3, 0.6)	US Fish and Wildlife Service studies show Savage Rapids Dam in Oregon has destroyed at least $5 million/year in fisheries benefits (The Pacific Coast Federation of Fisherman's Associations 'From Fisherman's News May 1998). 'The National Marine Fisheries Service estimated the losses of Salmon fishery due to dams in the Colombia basin to be $6.5 billion in 1960-80 alone' (McCulley 1997). The max value is assuming twice as much as the most likely value. These are also used for SBHP.
Tc (12.5, 13.5, 17.5)	The min is the original plan (www.idsnet.org). The WCD Survey (2000) shows about 40% of the delayed projects shows 1-year delay, and 5% shows 5 years delay.
PEo (30, 50, 80)	These are min, average and max TNB tariff rates in 1999 respectively (www.tnb.com.my/newtnb/custom/tr/et1.html).
α (0.1, 0.2, 0.5)	Generally, the distribution of CC skewed to the left due to large costs at an initial stage. These are also used for IHP.
β (0.6, 0.8, 0.9)	The distribution is likely to be skewed to the right, as the resettlement process often delays. These are used for IHP
a (0.001, 0.02, 0.03)	The average annual loss rate of active storage due to sedimentation in WCD Survey is 0.1% (WCD 2000). Some experts say the dam will not last for more than 50 years, i.e., 2% (www.earthisland.org). The max rate in WCD Survey is 3%. A relatively high rate is set in order to challenge project optimism
EL (0.6, 0.7, 0.9)	70000ha of affected rainforests including rich agricultural lands are valued based on the following studies. Projected economic value of the Peruvian Amazon if intact forest is sustainably harvested for fruits, latex, and timber is $6820/ha/year with the 5% discount rate based on the annual yield in the region (Peters 1989). Constanza (1997) placed a value of $1660/ha/year on the 'ecological services' provided by rainforests excluding any rewards from harvesting forests for food or raw materials[10]. The most likely and max are 20% and 50% higher, as there should be other benefits from the forest which are not valued.

[10] The 'ecosystem' refers to climate/disturbance/water regulations, water suplí, erosion control, soil formation, nutrient cycling, waster treatment, genetic resources, recreation and cultural services. His estimation is based on past studies and a few original calculations (mostly, willingnesss to pay of individuals for ecosystem services).

f20 (-0.001, 0.001, 0.02)	The attempt by TNB to raise tariff was not successful in 2001, so assume very tiny deviations for the min and most likely. These are also used for the following periods (max will be reduced by 20% every period). The tariff rate was increased by 8% in 1997, i.e., 8%/4=2% (TNB Annual Report 2001).
σ (0.1, 0.5, 0.8)	For the min, assuming the peak of the distribution is at the beginning while completing fundamental work; for the most likely, in the middle period during complicated and large-scale work; for the max, at the end of the period. These are used for SBHP & IHP
TRE (0.08, 0.16, 0.32)	The planned figure is 0.08 (www.earthisland.org). Assume the cost overrun of 2-4 times (McCully 1996).
C1 (660, 730, 880)	The most likely is calculated with the same procedure in Morimoto and Hope (2002). The min and max are 10% lower and 20% higher than the most likely.
C2 (13, 14, 17)	Ibid.
CM1 (14.5,15.7, 19.3)	The same values in Morimoto and Hope (2002). These are also used for IHP.
CM2 (414, 60, 552)	Ibid.
OMC (20, 28, 39)	The min is the calculated value by Battelle (1998 Table 5.11). Cost overrun of 40% is assumed (WCD 2000).
VD (0.4, 0.8, 6.7)	The same values in Morimoto and Hope (2002). These are also used in SBHP and IHP.
VM (0.0001, 0.0004, 0.04)	Ibid.
DCR (0.3, 0.8, 1.9)	Ibid.
MCR (170, 310, 340)	Ibid.
DCR’ (0.32, 0.57, 0.63)	Ibid.
MCR’ (7, 12, 13)	Ibid.
DCR’’ (6750, 12150, 13500)	Same in Morimoto and Hope (2002). These are also used in IHP, but excluded for SBHP, as the scale is small.

MCR'' (34750, 62550, 69500)	Ibid.
ECL (2, 3.6, 5.1)	See Morimoto and Hope (2001). Cost overrun of 40% is assumed for max (WCD 2000). These are used also for IHP.
π (0.06, 0.2, 0.6)	The min and the most likely are 1/10 & 1/3 of the max. The removal of the Marmot and Little Sandy dams which generate 22 MW is estimated to be $22 million. Based on this, the Bakun needs 2.4 GW / (mean TCC = 4) = 0.6.
TDC (50, 75, 100)	The expected life of a dam is 50 years. About 5000 large dams in the world are now more than 50 years old (McCully 1997; Wade 1999). Assume 50% more than the min for the most likely. The max is the final year of the analysis.
$P = 10^{-4}$; $P' = 10^{-5}$; $P'' = 10^{-5}$	The same values in Morimoto and Hope (2002). These are also used for IHP.

Note: PERT distribution (a special form of Beta distribution) is used for all the parameters apart from EO, f20, DCR, MCR, DCR', MCR', DCR'', MCR'' for which Triangular distribution is used instead. The same distributions are used for SBHP and IHP.

Table A-2. Parameters and descriptions for Sharada-Babai [SBHP] ($1=NRS76 Central Bank of Nepal 2001).

(min, most likely, max)	Description
EO (110, 280, 1300)	The min and the most likely are estimated losses to the Sri Lankan economy for energy not served in 1990 prices & 1998 prices respectively (CEB 1994). The max is a loss of economic output per kWh of power shortages in China (MOF 1990).
P0 (0.1, 0.75, 0.9)	The min and max are same as the ones in Morimoto and Hope (2001). About ¾ of the yearly precipitation in the subcontinent of South Asia falls within just 3 months (Lincoln 1989).
GC (0.06, 0.08, 0.093)	The energy output of Victoria Dam in Sri Lanka is about 31% lower than the planned figure (WCD 2000). The WCD Survey shows that the most likely case is 10% below the target (WCD 2000). The max is the current planned installed capacity (WRC and SILT 2001).
Tc (5, 6, 10)	The original plan is 5 years (WRC and SILT 2001). According to the WCD Survey, about 40% of delayed projects show a 1-year delay; 5% shows 5-year delay (WCD 2000).
f20 (-0.013, 0.01 0.026)	The electricity price is increased by 1% in 1999-2001 (NEA 2000)[11] The same values in Morimoto and Hope (2001) for the min and max[12].
φ (0.077, 0.08, 0.09)	The number of electricity consumers increased by 0.09% (1998), 0.08% (1999), and 0.077% (2000) annually.
PEo (69, 77, 92)	Average electricity price in 2000 is 5850 NRs (NEA). Assume 10% lower than the most likely value for the min and 20% higher than the most likely for the max.
TCC (0.13, 0.17, 0.18)	The min is the planned figure (WRS). 70 hydropower projects commissioned in 1915-1986 financed by the World Bank show average cost overruns of 30% (Bacon and Besant-Jones 1998). Average cost overruns excluding extreme cases are 40% (WCD 2000).

[11] See also www.nea.org.np/tariffrate.htm.
[12] The same minimum and maximum values are used for every period. The most likely value is assumed to decrease by 20% every period.

α (0.2, 0.7, 0.8)	The peak is likely to be at the end of the construction period. See Morimoto & Hope (2001).
β (0.2, 0.3, 0.5)	The peak is more likely to come near the beginning of the construction period. See Morimoto and Hope (2001).
BD (0.01, 0.018, 0.019)	The min is the damage caused by particulates CO_2 (CEB 1994). The most likely is the total damage caused by air pollution (SO_2, NOx, particulates, & CO_2) emitted by diesel (CEB 1994). The max is 10% higher than most likely.
IN (0.004, 0.005, 0.006)	The min is the estimated losses (WRC and SILT 2001)[13]. The same cost overrun rates as for TCC, 30% & 40%.
IF (0.0008, 0.0011, 0.0012)	The min value is the estimated cost (WRC and SILT 2001)[14]. The same cost overrun rates as for TCC, 30% & 40%.
TRE (0.0026, 0.0036, 0.0039)	The min is the planned figure (WRC and SILT 2001). The actual number of resettled people is 35% higher than the estimated figure according to the WCD Survey (WCD 2000). The actual number is 47% higher than the estimated figure among the projects financed by the World Bank (World Bank 1996).
OMC (0.0018, 0.0023, 0.0026)	The min is the planned figure (WRC). The same cost overrun rate as for TCC are used, 30% & 40%.
a (0.0005, 0.001, 0.002)	The most likely is same as the min for BHP. This issue involves huge uncertainty. Assume the min and max are ½ and twice of the most likely.
π (0.07, 0.23, 0.7)	The max is calculated in the same manner as in Morimoto and Hope (2001). The min and the most likely values value are 1/10 and 1/3 of the max value respectively. The removal of the Marmot and Little Sandy dams which generate 22 MW is estimated to be $22 million. Based on this figure, the SBHP needs 0.093GW / (TCC = 0.13)
TDC (50, 75, 100)	Same as in Morimoto and Hope (2001)

[13] Land acquisition [Agricultural land (268ha) and Forest land (33ha)] = 0.311 GNRs

[14] 2 suspension bridges = 5,000,000Rs; 2 temples = 40,000 Rs; 1 school = 1,400,000 Rs; 5 roads = 50,000,000 Rs; 5 foot trails = 500,000 Rs; 6 irrigation schemes = 6,000,000 Rs; 1 health post = 100,000 Rs; 1 post office = 80,000 Rs; 1 police office = 1,300,000 Rs; 3 water mills = 150,000 Rs; 1 telephone office = 50,000 Rs.

Table A-3. Parameters in the CBA model and descriptions for Ilisu [IHP] ($1= 1360000 TL Central Bank of Turkey 2002)

(min, most likely, max)	Description of each value
EO (380, 760, 1500)	Same as BHP above.
NT '0000 (13, 28, 103)	About 30,000 pilgrims visit Hasankeyf annually (www.khrp.org/publish/p1999/ilisuReport.htm). 1 million tourists are predicted to visit GAP region in 2005 (www.international.icomos.org/risk/turkey_2000.htm), and assume of which 10% and 25% for min and max.
TCC (1.52, 6.08, 9.12)	The original plan (www.rivernet.org/turquie/ilisu.htm); assumption of cost overrun of 4 & 6 times (2-4 times China TGP; 6 times Brazil Itaipu; McCully 1996).
GC (0.8, 1.1, 1.2)	The energy output of Victoria Dam in Sri Lanka is about 31% lower than the planned figure (WCD 2000 Report). The WCD Survey shows that the most likely case is 10% below the target. The max is the current planned installed capacity
φ (0.012, 0.026, 0.029)	The annual rates of decrease in the proportion of hydro and renewable planned installed capacity out of total capacity in Turkey are 0.012 (1997-2010), 0.026 (2010-2020), and 0.029 (2010-2020) (www.dolph.com.tr/energy.htm). The max is triple of the min.
P0 (0.52, 0.7, 0.75)	The domestic energy production can only meet 48% of the requirements (www.parliament.the-stationery-office.co.uk/pa/cm200001/cmselect/cmtrdind/360/36008.htm). The potential of hydropower in Turkey is presently < 30% developed (IEG 2001). The IHP is a peak power plant, so assume 75%.
FP (0.0025, 0.005, 0.3)	The most likely is same as the min for BHP above. The min is ½ of the most likely as fishery in this area is mainly for locals. The National Marine Fisheries Service estimated the losses of Salmon fishery due to dams in the Colombia basin to be $6.5 billion during 1960-80 alone' (McCulley 1997).

a (0.001, 0.02, 0.033)	The min is same as the min for IHP above. Experts foresee 30-50 years of functional life for the dam due to the high possibility of the dam being filled with rubble.
AL (0.5, 0.55, 0.75)	A four-foot bronze candelabrum dating to the Han Dynasty was sold for $2.5 million at the International Asian Art Fair in New York (www.archaeology.org/online/news/china.html). At least 200 or even some hundreds more sites would be inundated by Ilisu Dam (CHR et al 2001). The exact number of antiquities in the sites is unknown. Assume 10% (most likely) and 50% (max) as many antiquities exist in the area.
EL (0.008, 0.013, 0.016)	CEB (1994) estimated the value of land at 26-764 $/ha/year. Thus, assume the followings. The dam will submerge 7353ha of good agricultural land ($764/ha/yr), 4820ha of medium-low quality land ($500/ha/yr), 15675ha of land not suitable for growing crops ($26/ha/yr). The most likely and max are assumed to be 50% and 100% higher than the min.
ε (0.8, 0.9, 1)	Since Hasankeyf is the main attraction of both tourists and pilgrims, assume very high reduction rate of visitors.
RS (560, 620, 680)	The 1999 tourism recipient in Turkey is 620 (www.gso.org.tr/turkey.htm). 10% lower and higher for min and max.
Tc (7.5, 8.5, 12.5)	The min is the original plan (IEG 2001). The WCD Survey (2000) shows about 40% of the delayed projects shows 1-year delay; 5% shows 5 years delay.
PEo (72, 80, 88)	The most likely figure is the tariff rate effective from March 2002 (www.tedas.gov.tr). The min and max are 10% higher and lower than the tariff.
f20 (0, 0.001, 0.02)	An average rate of change in electricity tariff in Turkey is 0.02 from Oct to Nov 2001(Turkish electricity Distribution Corporation). The min and most likely assume small negative and no deviations in tariff rates.
TRE (0.57, 1.14, 2.28)	The planned figure is 0.57 (http://www.dsi.gov.tr/ilisu1.htm). Assume 2 & 4 times cost overrun (McCully 1996).
C1 (700, 780, 940)	The most likely is calculated in the same manner as in Morimoto and Hope (2002). The min and max are 10% lower and 20% higher than the most likely.
C2 (18, 20, 24)	Ibid.

OMC (20, 28, 39)	The min is the calculated value by Battelle (1998 Table 5.11). 40% cost overrun is assumed (WCD 2000).
π (0.079, 0.26, 0.79)	The removal of the Marmot and Little Sandy dams which generate 22 MW is estimated to be $22 million. Based on this figure, the IHP needs 1.2 GW / (TCC = 1.52). The min & the most likely are 1/10 & 1/3 of the max value respectively.
TDC (30, 50, 100)	The expected life of a dam is 30-50 years. The max value is the final year of the analysis.

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