Comparing benefits of hydropower development in two boundary systems in the Mekong

Seemanta Sharma Bhagabati[a], Akiyuki Kawasaki[a,b]

[a] Regional Network Office for Urban Safety, Asian Institute of Technology, Thailand. E-mail: seemanta0605@gmail.com
[b] Institute of Industrial Sciences, The University of Tokyo, Japan

Abstract

Hydropower seems to be a very promising source of energy, although it has huge economic, social and environment impacts at a local, national, and trans-national level which may result to transboundary conflicts among the riparian countries. Past literature has suggested that these conflicts may be approached through benefit sharing. Selecting different sets of riparians (such as countries (Political boundary) and river sub-basins (Natural boundary)) within the same study area may lead to different benefit sharing system. While a lot of research has been done in the country aspect (political boundary), the natural boundary aspect has been left simply untouched. This study shows promising results of the natural boundary approach. The study attempts to investigate the difference in benefit sharing in the transboundary sub-basin, the Sesan and Srepok sub basin, covering areas of Cambodia and Vietnam in the Mekong River Basin using a game theory approach. Two sets are defined, based on Political boundary (National boundaries) and based on Natural boundary (Sub-basin boundaries). A wide range of parameters such as energy production, irrigational benefits, flood control socio-economic costs etc. have been incorporated to define models and methodologies. This study then compares these two sets using the game theory concepts, such as core stability and incentive compatibility. Here we show that depending on the type of riparians chosen, the extent of benefit sharing changes. The results of the study will provide a basis for local policy decisions and regional planning in the Mekong River and beyond.

Keywords: Mekong River Basin, sub-basin, Hydropower development, Game Theory, Natural boundary, Political boundary, Optimization

Introduction

Rivers are one of the main sources of fresh water. They play a dominant role in sustaining ecosystems. Rivers have always played a vital role in the economic development of mankind. A healthy river is typically one with protected watersheds, conserved wetlands, protected aquatic and riverine terrestrial biodiversity and controlled water abstraction and wastewater discharge (Sadoff et al., 2002).

There are hundreds of rivers in the world, of which 261 rivers are shared by two or more countries, hence the name International rivers (Wolf et al., 1999). Proper water resources allocation is an important issue and there have been many critical debates and conflicts throughout the world in the history of mankind (Falkenmark and Lundqvist, 1995; Postel, 2000; Tarlock, 2001). Many multilateral agreements on transboundary cooperation of international rivers have been drafted in the 20th century (Beach et al, 2000), yet it is unclear how the interactions among the riparian states will proceed in the near future (Ward, 2002).

Watersheds have their own natural boundaries. These boundaries have nothing to do with the political boundaries such as national boundaries and provincial boundaries, etc. In case of international rivers; it is often found that that river watershed is shared between two or more countries. Each country has its own policies and agreements about the watershed. A number of multilateral agreements on such transboundary watershed cooperation has been established. Although, a lot of research has been performed in the country extent (political boundary), the watershed extent (natural boundary) has been simple left untouched. There exist very little to no history on such research.

This paper tries to include the natural boundary extent for policy implementations. It tries to show how natural boundary extent can also be used in case of transboundary scenarios. The Sesan and Srepok sub-basins of the Mekong are selected as the study area. A number of parameters were selected to form a model to optimize the benefits from hydropower development. Optimization is performed for both country-wise (political boundary) and sub-basin wise (natural boundary). The study tries to provide a new basis for local policy makers.

Game Theory

Game theory models strategic situations, or games, in which an individual's success in making choices depends on the choices of others (Myerson, 1991). According to Langlois (1996), Game Theory can be described as the science of strategy or that of conflict resolution; at its core, it has the characteristics of a mathematical construct: a set of concepts and assumptions, fundamental theorems, and applications to real world issues.

Core stability and incentive compatibility

For a scenario to be successful, it must provide a non-empty core. Core, here, refers to the benefit arising out of cooperation among the three countries. The larger the size of the core, the greater is the amount of benefit.

Formally the core is defined as the set of all benefit allocation vectors $\underset{x}{\rightarrow} \in R^N$ which satisfy two conditions:

Efficiency:

$$\sum_{j \in N} x_j = v(N)$$

Coalition rationality:

$$\sum_{j \in c} x_j \geq v(c) \quad \forall c \subseteq N$$

where N is the grand coalition that includes all players j, and v is the characteristic function value, or the total benefits to the members of the coalition. Efficiency states that the sum of benefits to each player is equal to the value of the grand coalition. Coalitional rationality states that players are not incentivized to leave the grand coalition for a subset coalition (i.e. individual action or partial coalitions).

Study Area

The Sesan and Sre Pok sub-basin

The Mekong River, the longest international river of Asia, is the ninth largest river in the world, spanning 4,909 km and draining an area of 795,000 km^2, discharging 475 km^3 of water annually. The river basin is thickly populated with over 72 million inhabitants (Campbell 2009).

The Sesan and Sre Pok sub-basins, is a large tributary system of the Mekong River, with a total area of 56,085 km^2 covering the border areas of the “Indochina Junction” in Cambodia and Vietnam. It is shared among the two countries, Cambodia (25,975 km^2; 46.3%) and Vietnam (30,110 km^2; 53.7%).

Hydropower scenario of the sub-basins

Hydropower potential of these sub-basins has attracted attention for more than 50 years. The total number of HEPs already constructed, under construction or in the designing or master planning stage amount to 21, as of April 2009 (Asian Development Bank (ADB, 2009)). These HEPs are grouped into 4 groups, viz. Group 1 – under operation HEPs, Group 2 – HEPs under construction, Group 3 – HEPs in the design stage and Group 4 – HEPs in the master plan stage. These plants are shown in the Figure 1 based on their group. The total number of HEPs in each group and the total annual production of each country are shown in table 1(MRC, 2009).

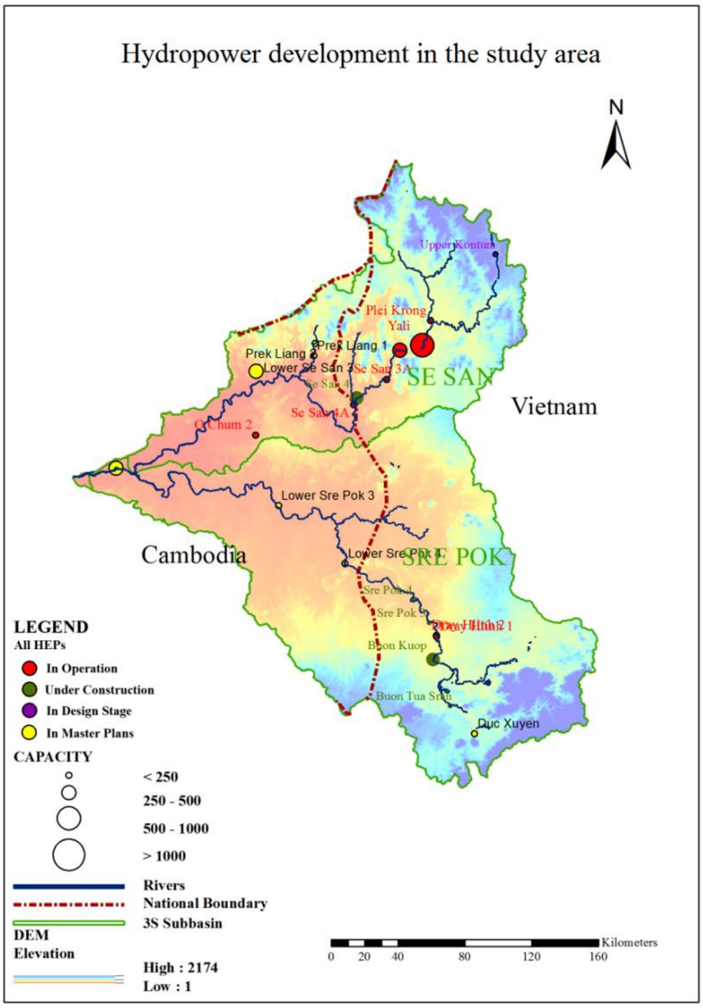

Figure 1: Hydropower development in the study area

Table 1: Hydropower data of the study area

	Land Area (km²)	Total Annual Production (Number of HEP), GWh					Total Reservoir Area
		Group 1 In Operation	Group 2 Under Construction	Group 3 In Design stage	Group 4 In Master Plan stage	Total	
Cambodia	25,975	3 (1)	0 (0)	0 (0)	6,538 (6)	6,541(7)	106,323
Vietnam	30,110	5,955 (7)	4,623 (5)	1,056 (1)	181 (1)	11,815(14)	94,335
Total	56,085	5,958 (8)	4,623 (5)	1,056 (1)	6,719 (7)	18,356(21)	241,141

Source: MRC, 2009

Parameters considered

There are two types of parameters; one provides the benefits while the other causes us losses. In the first category, parameters like energy production, irrigational benefits, benefits from fisheries and flood control are considered; while annual cost of project, cost of transmission lines, socio-economic costs, loss of fish, navigational loss and environmental losses fall into the second category.

The following paragraphs describe the parameters in detail.

Energy production

The estimation of benefits from energy production in a transboundary context, although seems very easy to calculate, it is not so. This is because the two countries have different cost of unit energy (Vietnam - $ 0.073 Million/ GWh and Cambodia - $ 0.213 Million/GWh). Hence for this study, the valuation method based on the concept of Replacement Cost has been used. It calculates benefits from alternative energy production to produce the equivalent amount of energy provided by a HEP (MRC, 2010a; Riecicky, 2011).

Irrigational benefits

MRC carried out an estimation of the annual net increase in benefit from irrigated crops in the study area (MRC, 2010b). This individual country benefit was the evenly distributed among the HEPs constructed for the purpose of Irrigation and can be represented as Bi (Million US$).

$$B_i = \frac{Total\ benefit\ from\ irrigated\ crops\ of\ each\ country}{Number\ of\ HEPs\ dedicated\ for\ irrigation}$$

Benefits from fisheries

For estimating the economic benefits, market prices of culture fish of the year 2010 were used (MRC, 2010b). Household surveys were done by MRC, which surveyed peoples' consumption of fish and other aquatic animals (MRC, 2010b). These benefits were then calculated for the sub-basin area based on the area distribution of the units. A linear relation between the catchment area and this benefit has been established for all the units, B_f (Million US$).

$$B_f = \frac{Benefit\ from\ fisheries}{Total\ catchment\ area} \times Catchment\ area\ of\ the\ HEP$$

Using this relation, the benefits for each HEPs has been calculated based on the catchment area of each HEP.

Flood control

The annual economic benefits of mitigating floods, due to hydropower activity, during the wet season due to the improved regulation of river flows has been estimated (MRC, 2010b). This total reduction of annual net economic damage due to flooding has been evenly divided among the HEPs constructed for the purpose of flood control, B_{fc} (Million US$).

$$B_{fc} = \frac{Total\ reduction\ of\ annual\ net\ economic\ damage\ due\ to\ flooding}{Number\ of\ HEPs\ dedicated\ for\ flood\ control}$$

Annual cost of project

The annual cost of the project is the amortized annual value of the investment cost calculated using the Capital Recovery Factor (CRF). CRF is the ratio of a fixed annuity to the current value of receiving the annuity for a given period of time.

CRF is calculated as:

Capital Recovery Factor = $\frac{[(1+r)^L]*r}{[(1+r)^L]-1}$

where, r = discount rate

L = time period

In context of hydropower development, estimated project life, L is considered as 50 years with an 'r' of 10%. This cost also includes the annual operating cost. In hydroelectric projects operation and maintenance costs are typically around 1% to 2.5% of the total investment (IRENA, 2012). For this analysis, 2.5% of the total investment cost has been added as an estimation of annual operating and maintenance cost.

Hence, the annual cost of the project, C_i, has been calculated by the following formula:

C_i = Total Investment Cost × (CRF + 0.025)

For the simplicity of calculation, it has been assumed that the country where the project is located bears the entire construction costs.

Cost of transmission lines

The cost of construction has been calculated based on the distance of the destination grid of the country from the dam site. Using GIS, the shortest route for the transmission lines were found out. The cost of the "Na Bong-Udon Thani Power Transmission Project" has been used as a reference to calculate the average unit cost of transmission lines (ADB, project approved in 2007, project started in 2010). Using the average cost of transmission lines per kilometre (US$ 28,150), the total cost of transmission lines has been calculated. It was assumed that the hydropower importing country bears this cost.

Socio-economic costs

The socio-economic loss includes resettlement of local communities and compensation measures used such as livelihood programs, water quality monitoring, wildlife programs, public training and watershed management. These costs for the Nam Theun 2 (NT2) dam, with an active storage of 3680 million cubic meters, have been estimated to be around US$ 88 million (ADB, 2004). Using these data, a linear relationship between the socio-economic loss and the active storage of NT2 HEP has been estimated as

$$C_{se} = \frac{88}{3680} A(i)$$

where $C_{se}(i)$ is the total socio-economic cost of HEP *i* in millions USD and *A(i)* is the active storage of HEP *i* in million cubic meters.

Annual socio-economic costs, $aC_{se}(i) = C_{se}(i) \times$ CRF.

Loss of Fish

Construction of dams on the river course restricts the migration of fish which hampers fish productivity. This loss of fish due to hydropower development has been extensively studied by MRC for the three countries (MRC, 2010b). The loss of fish per unit catchment area has been calculated, taking into account the total catchment area of the HEPs. From this relation, the individual annual net loss of fish has been calculated.

Navigational loss

Construction of dams across the river affects the system. It ceases the extensive use of inland navigation by the local communities. This loss has been calculated for each of the two countries based on the sub-basin area they share. This individual country loss is then assigned equally among all the HEPs of the countries.

Environmental loss

The loss to wetlands due to hydro-power activities for the sub-basin has been estimated by MRC (MRC, 2010c). A linear relationship between the total loss to wetlands and the total active storage of HEPs has been formed. The annual loss was then assigned to each HEP based on its active storage, C_e (Million US$).

$$C_e = \frac{Total\ \ wetland\ \ loss}{Total\ \ active\ \ storage} \times Active\ storage\ of\ HEP$$

Estimation of investment funds available

To optimize the different scenarios, the investment funds of each unit (country or sub-basin) have been used as a constraint. It has been calculated based on two factors, viz. (a) past construction activity and (b) future projects. In calculating the average cost of past HEPs, Group 1 and Group 2 HEPs are considered, while for future projects, Group 3 and Group 4 HEPs are considered. The maximum of the two costs is rounded-off and fixed as the unit's hydropower construction investment funds. The funds for Cambodia, Vietnam, Sesan and Srepok were assumed as US$ 1000, 300, 900 and 200 Million respectively.

Optimization model and scenarios considered

A very simple model has been in this study. Each country or sub-basin (unit) is a player having two options: to build or not to build additional damns. The objective is to maximize the net total annual benefits in the sub-basin. The grand coalition case seeks to maximize total benefit.

Sets	I	HEPs identified by Project ID
	J	Countries – Cambodia, Vietnam Sub-basins – Sesan, Srepok
Parameters	$group_i$	1 – in operation, 2 – under construction, 3 – in design, 4 – in master plan
	$unit_i$	1 – Cambodia, 2 – Vietnam, 3 – Sesan, 4 - Srepok
	$budget_j$	unit hydropower investment fund
	$b_{i,j}$	benefits of HEP i on unit j
	$c_{i,j}$	costs of HEP i on unit j
Variables	$x_i = \{0,1\}$	HEP decision variable

Objective Function:

$$\text{Maximize} \sum_{j \in c} \left\{ \sum_{i \in I} x_i [b_{i,j} - c_{i,j}] \right\} \quad \forall\ c \in C$$

where C is a particular coalition status among the set of all the possible coalitions.

The constraints of this optimization models were the individual unit's investment funds and the benefit-cost ratio (b-c ratio) of individual HEPs, i.e., while optimizing, the first priority was to select HEPs within the available fund having the highest b-c ratio. Then the second best HEP in terms of b-c ratio was selected and so on.

A total of five different coalition scenarios were selected including joint and individual funds as well as partial coalitions for present and future scenarios. These are discussed below:

0 Status quo: The present hydropower situation. Only the existing HEPs in operation, group 1 HEPs, are selected.
1 Complete under-construction projects: The existing HEPs in operation (group 1) and the under construction HEPs (group 2) are considered.
2 Individual unit maximization: Each unit maximizes its benefits by constructing additional HEPs in group 3 and 4 within individual fund constraints; all groups.
3 Two units' simultaneous maximization (separate funds): Both the countries/sub-basins maximizes simultaneously but within their individual fund limits; all groups.
4 Two units' simultaneous maximization (joint funds): Both the countries/sub-basins combines their funds and then jointly maximize; all groups.

Results and discussion

The optimization has been performed in two steps; first for the two countries (political boundary) and second for the two sub-basins (natural boundary). The results of optimization are described in detail in the following sub-sections.

Optimization for two countries (political boundary)

Referring to table 2 (results of optimization – political boundary), Cambodia at present is in loss because of the construction and operation of HEPs in Vietnam. These HEPs are operating along the Cambodia-Vietnam border; hence almost all of the downstream costs of these HEPs were suffered by Cambodia. Currently, Cambodia is suffering a total of 4.1 Million US$ as downstream costs. Cambodia will also be suffering the downstream costs of the currently under construction HEPs (an additional 3.24 Million US$). Vietnam, on the other hand, is getting high benefits of 271.89 Million US$. The benefit will further increase by 199.13 Million US$ as the currently under construction HEPs are completed.

For individual maximization, highest benefit is achieved when Cambodia maximizes, (Max Cambodia) (346.59 Million US$). This is because of the fact that, Vietnam has already exploited its hydropower by building a number of HEPs and doesn't have much scope for further development, whereas Cambodia has just started to construct HEPs and has a lot of HEPs in the design and master plan stage (group 3 and 4).

When two countries maximizes together (Max Cambodia + Vietnam), a higher total net benefit is attained (618.42 Million US$). This benefit can be further increased by 13.1 Million US$ when they cooperate and maximize jointly with combined funds (Max j(Cambodia + Vietnam)). The highest net benefit of 631.52 Million US$ is reaped in this scenario (increase in net benefit of 363.73 Million US$).

Table 2: Results of optimization based on countries (political boundary)

Scenario		**Net Benefits (Million USD)**			**Change in Net Benefits (Million USD)**		
		Cambodia	**Vietnam**	**Total**	**Cambodia**	**Vietnam**	**Total**
Status Quo		-4.1	271.89	267.79	-	-	-
Complete current projects		-7.34	471.02	463.68	-3.24	199.13	195.89
Individual sub-basin maximization	**Max Cambodia**	**119.73**	**494.65**	**614.38**	**123.83**	**222.76**	**346.59**
	Max Vietnam	-7.34	475.06	467.72	-3.24	203.17	199.93
Two sub-basin Maximization	Max (Cambodia + Vietnam)	119.73	498.69	618.42	123.83	226.8	350.63
Two sub-basin Maximization (Join Funds)	**Max j(Cambodia + Vietnam)**	**132.83**	**498.69**	**631.52**	**136.93**	**226.8**	**363.73**

Optimization for two sub-basins (natural boundary)

Referring to table 3 (results of optimization – natural boundary), it can be seed from the results that no downstream costs were borne by Sesan sub-basin when any HEP is constructed in the Sre Pok sub-basin, and vice-versa. This is because of the fact that, downstream costs were suffered only along the downstream area of the same river basin.

At present, Sesan sub-basin has a very high benefit of 235.45 Million US$ compared to only 6.81 Million US$ of Srepok sub-basin. This is because a large number of HEPs (6 HEPs) are operating in the Sesan sub-basin compared to Srepok sub-basin (only 2 HEPs).

When the under-construction HEPs are completed, the net benefit for Sesan and Srepok sub-basins are increased by 53.41 and 119.6 Million US$ respectively with a total increase of 173.01 Million US$.

In case of individual maximization, highest benefit is achieved when Sesan maximizes (455.96 Million US$) (Max Sesan), a net increase of 213.69 Million US$. The reason behind this trend is that there are 7 HEPs in group 3 and 4 for Sesan sub-basin compared to only 1 HEP for Srepok sub-basin, i.e., there is not much scope for Srepok sub-basin to construct more HEPs.

For two sub-basin simultaneous maximization (separate funds) (Max (Sesan + Srepok), a slightly higher net benefit of 458.32 Million US$ is achieved. But when the two sub-basin maximize with joint funds (Max j(Sesan + Srepok), a much better net benefit is achieved (551.33 Million US$). This net benefit is the highest among all the scenarios considered (increase in net benefit of 309.07 Million US$).

Table 3: Results of optimization based on sub-basins (natural boundary)

Scenario		**Net Benefits (Million USD)**			**Change in Net Benefits (Million USD)**		
		Sesan	**Srepok**	**Total**	**Sesan**	**Srepok**	**Total**
Status Quo		235.45	6.81	242.26	-	-	-
Complete current projects		288.86	126.41	415.27	53.41	119.6	173.01
Individual sub-basin maximization	**Max Sesan**	**329.54**	**126.41**	**455.95**	**94.09**	**119.6**	**213.69**
	Max Srepok	288.86	128.78	417.64	53.41	121.97	175.38
Two sub-basin maximization	Max (Sesan + Srepok)	329.54	128.78	458.32	94.09	121.97	216.06
Two sub-basin maximization (Join Funds)	**Max j(Sesan + Srepok)**	**404.83**	**146.5**	**551.33**	**169.38**	**139.69**	**309.07**

Core stability and incentive compatibility

Figure 2 is plot of individual maximization and joint maximization for the two countries (political boundary). The benefit of Cambodia is plotted in the x-axis and the benefit of Vietnam is plotted along the y-axis. The values obtained in table are normalized w.r.t. the total net benefits of the two country maximization with joint funds.

The first line (at 19.9) shows the benefit achieved by Cambodia in individual maximization and the second line (at 24.5) shows the benefit Cambodia can achieve from joint cooperation (x-axis). Similarly, the first line (at 0.0) is the benefit to Vietnam from individual maximization and the second line (at 21.4) shows the benefit Vietnam can achieve from joint cooperation. The box thus formed by these intersecting lines is the core, which is non-empty.

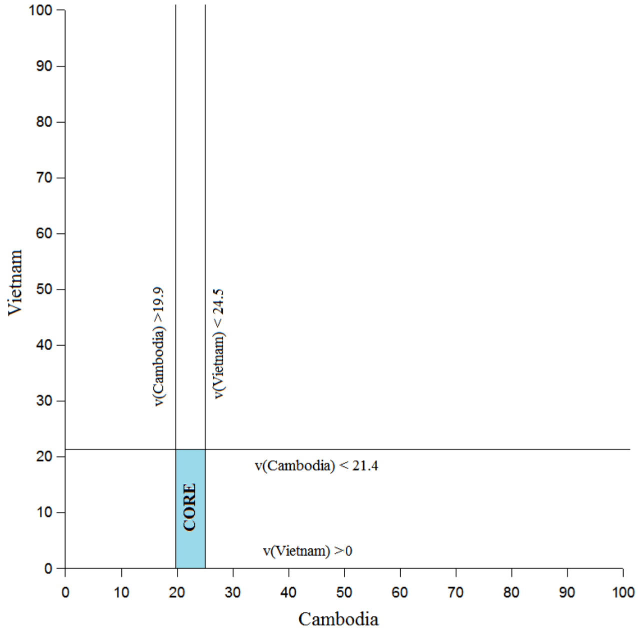

Figure 2: Graphical representation of the core for country optimization (normalized)

Similarly figure 3 is the plot of individual maximization and joint maximization for the two sub-basins (natural boundary). Here again the normalized values are used for plotting.

The benefits of Sesan sub-basin are plotted along the x-axis and that of Srepok sub-basin are plotted in the y-axis. The first line (at 59.8) shows the benefit achieved by Sesan sub-basin in individual maximization and the second line (at 77.1) shows the benefit that can be achieved from joint cooperation (x-axis). Similarly, the first line (at 52.4) is the benefit to Srepok sub-basin from individual maximization and the second line (at 76.6) shows the benefit that can be achieved from joint cooperation. The box thus formed by these intersecting lines is the core, which is non-empty as well.

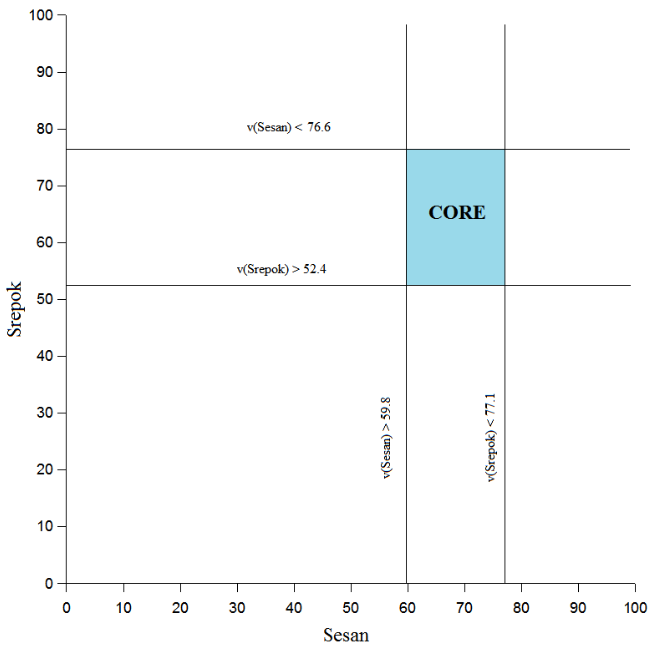

Figure 3: Graphical representation of the core for sub-basin optimization (normalized)

The existence of a core means that there exist several feasible allocations of benefits among the units (countries/sub-basins) where there are economic incentives for the units to cooperate.

The core in figure 3 is much bigger compared to the core in figure 2. This shows that the possibility of benefit sharing is higher in the case of sub-basins (natural boundary), which in turn means that the concept of optimization based on natural boundary is actually feasible.

Conclusions

Based on the optimization results (shown in table 2 and table 3), it can be seen that cooperation can lead to increased benefits from hydropower development. From table 2 it should be observed that Vietnam is getting the highest benefits (498.69 Million US$) in the two sub-basin maximization with separate funds (Max (Cambodia + Vietnam)) which is equal to the benefit it is getting in the case of joint funds (Max j(Cambodia + Vietnam)). Hence, if some incentives are not provided to Vietnam, it may not opt for joint fund cooperation. Hence, in order for the cooperation schemes to be successful, there must be economic incentives for individual players to stay in a particular coalition. The concepts of game theory, such as core stability and incentive compatibility, can be applied to show that there exists, in this case study, large benefits from full cooperation with joint budget planning. Benefit sharing is critical to achieving a distribution that will incentivize all players to cooperate, but the proof of the existence of a non-empty core points to the existence of several feasible benefit allocation schemes that are viable.

As mentioned earlier, from figure 2 and figure 3 it can be observed that the core for sub-basin (natural boundary) maximization was much bigger compared to the core of country (political boundary) maximization. This leads to the fact that the approach of optimizing based on natural boundary is acceptable and is in fact quite feasible.

Also, from the results of optimization, it should be noted that by changing the extent of optimization (country or sub-basin), the net benefits are changed although all the input parameters were the same.

References

Asian Development Bank (ADB) (2004) *Summary environmental and social impact assessment, Nam Theun 2 Hydroelectric project in Lao people's democratic republic*

Asian Development Bank (ADB) (2007) *Na Bong-Udon Thani Power Transmission Project Report: Lao People's Dem Rep*

Asian Development Bank (ADB) (2009) *Sesan, Sre Pok and Sekong River Basins Development Study in the Kingdom of Cambodia, Lao People's Democratic Republic and Socialist Republic of Viet Nam. Pilot testing IHA-SGAP in the 3Ss Basins Inception Report*

Beach, H et al (2000) *Transboundary freshwater dispute resolution: Theory, practice, and annotated references*. United Nations University Press, New York

Campbell, Ian C. (2009): 'Introduction". *The Mekong: Biophysical Environment of an International River Basin,* 1-11, Academic Press

Falkenmark, M, & Lundqvist, J (1995) 'Looming water crisis: new approaches are inevitable. L. Ohlsson (Ed.), Hydropolitics: Conflicts over water as a development constraint'. London: Zed Books, 178-212

IRENA (2012) *Renewable energy technologies: Cost analysis series, 2012*, Volume 1: Power Sector, Issue 3/5

Langlois, J P & Langlois, C (1996) 'Rationality in International Relations: A Game-Theoretic and Empirical Study of the U.S.-China Case'. *World Politics*, 48(3), 358-390

Mekong River Commission (MRC) (2009) *Hydropower Sector Review for the Joint Basin Planning Process, Basin Development Plan Programme, Phase 2*

Mekong River Commission (MRC) (2010a) *Power Benefits. Technical Note 6 of Assessment of basin-wide development scenarios. Basin Development Plan Programme Phase 2, Work in Progress*

Mekong River Commission (MRC) (2010b) *Economic Benefits and Costs, Technical Note 13 of basin-wide development scenarios, Basin Development Plan Programme Phase 2, Work in Progress*

Mekong River Commission (MRC) (2010c) *Social Assessment, Technical Note 12 of Assessment of basin-wide development scenarios, Basin Development Plan Programme Phase 2, Work in Progress*

Myerson Roger, B (1991) *Game theory: analysis of conflict*. Harvard University Press

Postel, S (2000) 'Entering an era of water scarcity: the challenges ahead'. *Ecological Applications*, 10(4), 941-948

Riecicky, V (2011) *Case Study: Replacement Cost Based Approach to Risk Management of Knowledge Assets. System Sciences (HICSS)*, 2011 44th Hawaii International Conference on , pp.1-10, 4-7 Jan. 2011. doi: 10.1109/HICSS.2011.95 http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5718751&isnumber=5718420

Sadoff, C W & Grey, D (2002) ‘Beyond the river: the benefits of cooperation on international rivers’. *Water Policy*, 4(5), 389–403

Tarlock, A (2001) ‘The changing environment of international water management law’. *Water Law*, 12(6), 351-357

Ward, D R (2002) *Water wars: Drought, flood, folly, and the politics of thirst*. Riverhead Books, New York.

Wolf, A T et al (1999) ‘International River basins of the world’. *International Journal of Water Resources Development*, 15(4), 387-427