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Benefit Sharing on Transboundary Rivers: Case Study and Theoretical Exploration

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Abstract: Benefit sharing on transboundary rivers is an approach to address equitable and reasonable development and utilization of transboundary water resources (TWR). Through analyzing a few typical benefit sharing cases, this paper provides a systematic discussion of the theory of TWR benefits sharing. TWR features a kind of common pool resources (CPRs). Its benefit sharing subjects are the riparian countries. The shared benefits usually include flood prevention, power generation, navigation, irrigation, contributions to society and culture, etc. The benefit sharing modes mainly include shared benefits and responsibilities, reciprocal rights and obligations, equal benefit distribution, cost proportion-based benefit sharing, and demand-based benefit sharing. The first step in the realization process of benefit sharing is the sharing of data and information. Second is the benefit identification and evaluation. Third is the establishment of a mechanism to guarantee the benefit sharing. The conditions for realizing benefit sharing depends on, first, if the riparian countries are willing to cooperate with each other; second, whether the cooperation can bring incremental benefit or cost reduction in comparison with unilateral operation; and third, if the benefit distribution is equitable and reasonable and can stand the test of time.

Key words: transboundary water resources; benefit sharing; mode; realization process; realization conditions

1 Introduction

The world has a total of 286 transboundary rivers involving 151 countries and 40% of the world's population, with their gross water resources accounting for 60% of the global fresh water resources. With the economic development of human society, global changes and population growth, the fresh water resource crisis has been sharpened in recent years. The water crisis will be the top global risk in the upcoming decade, and transboundary water disputes will be of the greatest concern (He et al., 2016; UNEP, 2016; World Economic Forum, 2015). The inconsistency between the borders of transboundary river drainage basins and the administrative borders of the countries involved easily causes conflicts between the riparian countries in terms of the allocation, utilization and conservation of water resources. In the face of the global water crisis, transboundary water resources (TWR) increasingly arouses the wide concern of

countries and international societies worldwide. In fact, the theme of the 2009 World Water Day was “*Transboundary Waters-Shared Waters, Shared Opportunities*”. UNESCO called on countries sharing transboundary water resources to strengthen communications and cooperation, as well as carry out scientific management and joint exploration on TWR. 2013 was defined by the UN as the International Year of Water Cooperation. TWR cooperation is considered to be the general course of development.

TWR dispute solutions gradually turn to benefit sharing from water allocation (a zero-sum game). In 2000, the World Commission on Dams (WCD) brought forward the idea of benefit sharing of hydroelectric power for the first time, defining stakeholders as the subjects for sharing the benefits (WCD, 2000). In 2002, the World Bank's experts completed a benefit sharing study for dam projects, including the theoretical basis of benefit sharing, types of benefit

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sharing mechanisms, processes and practicalities involved with the implementation of benefit sharing mechanisms and others (Dominique et al., 2002). Since then, hydropower experts have carried out many theoretical studies on benefit sharing of water resources development (Daoudy, 2007; Tafesse, 2009; Hensengerth et al., 2012). Sadoff and Grey (2002) defined benefit-sharing as a kind of behavior to redistribute the costs and benefits through cooperation. They classified the benefits into the following four categories: 1) increasing benefits to the river (environmental): sustainable improvement of river basin's ecology; 2) increasing benefits from the river (direct economic impact): benefits from water resource application, such as irrigation, hydropower, flood prevention and navigation; 3) reducing costs because of the river (political): the countries turn from river-related conflicts to cooperative development, avoiding or reducing costs of conflicts; and 4) increasing benefits beyond the river (indirect economic impact): benefits from the rivers (the catalytic river), such as complete regional infrastructures, markets and trade (Sadoff and Grey, 2002). Phillips and colleagues divided benefits into three categories, i.e. security, economic development, and the environment (Phillips et al., 2006). Up to now, most scholars have mainly discussed economic benefit sharing, and calculated the economic benefit gained from cooperation with traditional hydrological and economic models (Arjoon et al., 2014; Jeuland et al., 2014; Tilmant and Kinzelbach, 2012).

The key to benefit sharing is the allocation of benefits. While guaranteeing benefit maximization, how to guarantee the equitable benefit allocation and the common understanding among riparian countries has been a key issue studied by scholars. Several different theories, including game theory (Jafarzadegan et al., 2013; Abed-Elmdoust and Kerachian, 2012) and bankruptcy theory (Sechi and Zucca, 2015; Mianabadi et al., 2015; Madani et al., 2014; Ansink and Weikard, 2012) have been applied to this issue, and many achievements have been realized. Some have even proposed building a system (Arjoon et al., 2016) to widely involve stakeholders, turn the common understanding into benefit sharing rules, and then combine it with hydrological and economic models to produce a reasonable plan via model analysis, guaranteeing the maximization of cooperation benefits and realizing the equitable sharing of benefits.

In 2009, the World Bank publicized its new hydropower policy to promote a new round of hydropower development and investment through comprehensive environmental governance and benefit sharing (The World Bank Group, 2009). In its directive paper on benefit sharing launched in 2011, the Mekong River Commission (MRC) pointed out that "*benefit sharing is an integral element of sustainable form of hydropower consistent with IWRM principles. Today, benefit sharing is widely seen as a powerful, practical tool to advance cooperation on sustainable water infrastructure*

development and management in river basins" (MRC, 2011). Currently, there are many published studies on the types of benefit sharing and allocation of transboundary rivers. However, the discussion on benefit sharing theory still lacks a systematic foundation. Based on the analysis of typical benefit sharing cases, this paper will provide systematic discussions on the subjects, objects, modes, realization processes and conditions of benefit sharing.

2 Typical TWR benefit sharing cases

2.1 Practice of the benefit sharing of the Columbia River

The Columbia River, the biggest transboundary river between the US and Canada, features a 2000 km-long main stream, 66.9 km² drainage area, and an annual average runoff of 221.9 thousand million m³. Its trunk stream flows from Canada to the US. Some tributaries cross the US-Canada border several times, building the upper and lower reaches relationship between the two countries and creating great challenges for the TWR management. In 1948, the destructive spring flood of the Columbia River devastated the 30000-inhabitant Vanport City, Oregon and drowned 50 people. After the flood, an International Joint Commission of the two countries was dedicated to handle the TWR issues, focusing mainly on flood prevention and energy development for the Columbia River. In 1961, after coordination and negotiation for over ten years, both sides signed *the Treaty between Canada and the United States of America, relating to Cooperative Development of the Water Resources of The Columbia River Basin* (below shortened to *Columbia River Treaty*, CRT). The treaty came into effect in 1964 (with validity for 60 years).

In accordance with CRT, Canada built three dams (Mica, flood prevention capacity of about 8.64 thousand million m³; Keenleyside, flood prevention capacity of about 8.76 thousand million m³; and Duncan, flood prevention capacity of about 1.7 thousand million m³) to provide 19.1 thousand million m³ of storage usable for improving the runoff of the Columbia River. The three dams are mainly used for the flood prevention in the middle and lower reaches and hydropower generation in both countries. The increased flood prevention and hydropower benefits to the US in the lower reach have been shared by both countries. Meanwhile, the US received approval to build the Libby Dam in the Kootenai River, which runs according to the rules defined by both parties. However, the new hydropower benefits to Canada in its lower reach could not be shared with the US. As a trade, Canada agreed to allow the Libby Dam's backwater to flow into Canada.

According to the treaty, a Permanent Engineering Board was established for mediating the possible technical or administrative disputes between the executives of both parties. The treaty was implemented by the Northwestern Division

of the United States Army Corps of Engineers (USACE), the Bonneville Power Administration of United States, and the Water Resource and Power Administration of British Columbia of Canada. The Hydrometeorology Committee and Operation & Dispatch Committee, both organized by entities from both countries, carry out the rights and obligations described in the treaty.

The calculation and allocation of the TWR's benefits has been the most difficult part in benefit sharing. For the purpose of feasibility, the US and Canada shared equally the benefits of flood prevention and power generation brought by the implementation of the treaty. In terms of the calculation of flood prevention benefits, both countries applied the multi-year average flood loss method proposed by USACE after years of research. The flood prevention benefit equaled the flood loss reduction brought by the treaty. The US agreed to pay \$64.40 million in a lump sum to Canada in 1964 as compensation for the flood prevention benefits gained from Canada's efforts of building three reservoirs within 60 years as reserved flood prevention capacity. For the calculation of increased power generation benefits, both sides agreed that it was based on the power balance between using and not using the Canadian storage. After negotiations, the US decided to purchase Canada's entitlement to downstream power benefits generated in the first 30 years at a price of \$254.4 million, and made the advanced payment in 1964. With these advances, Canada built the three projects agreed to in the treaty. The 30-year power purchase validity for the three projects expired in 1998, 1999 and 2003, respectively, when the power would be returned to British Columbia of Canada. In terms of the return method, entities of both sides signed the Agreement on Disposals of the Canadian Entitlement within the United States for April 1, 1998 through September 15, 2024 between the Bonneville Power Administration, Acting on Behalf of the U.S. Entity and the Province of British Columbia ("British Columbia") in 1999.

2.2 Practice of the benefit sharing of the Senegal River

The Senegal River, the second longest river in western Africa, flows through Guinea, Mali, Senegal and Mauritania to the Atlantic Ocean. It measures 1800 km in length, 4.3×10^5 km² in basin area, and 24 thousand million m³ in annual average runoff. It passes through several different climate zones from the upper to the lower reaches. The upper reach features plentiful rainfall with an annual average rainfall of 700–2000 mm, while the middle and lower reaches are arid and drought-prone with an annual average rainfall of 150–300 mm.

Between the 1960s and the 1980s, the basin area suffered severe aridity, leading to enormous losses in agriculture and ecology, and other problems of salt water erosion and groundwater recession. These developments enabled the riparian countries of the Senegal River Basin to realize that

joint efforts were necessary to alleviate the disastrous effects of the severe drought. In July 1963, Guinea, Mali, Mauritania and Senegal signed the *Bamako Convention for the development of the Senegal River* and established the Interstate Committee to discuss regional development. In March 1968, to further boost the political and economic development of the basin, the four riparian countries founded the Organization of the Boundary States of the Senegal River (OERS, Organisation des Etats Riverains du Sénégal). On March 11, 1972, the Organization for the Development of the Senegal River (OMVS) was founded, aimed at realizing the self-sufficient grain supply within the basin, reducing the influence of climate change and external factors to the vulnerable economy, speeding up economic development, and securing and improving the people's income through cooperation. In December 1975, three institutions within OMVS, namely, Conference of Heads of States and Government, Council of Ministers and Technical Commission, were reorganized.

In order to push forward the construction of Manantali and Diama dams proposed in 1972, members of OMVS signed the conventions on the legal status and financing of the common works in December 1978 and March 1982, respectively. The conventions defined that all projects were common and indivisible property. Member states owned their own shares and the rights for joint management of the common property. The allocation of investment and operation costs was based on the member state's benefit share from the joint infrastructures. The member states were responsible for paying back the dam construction loans from OMVS. Two entities were established to manage the joint infrastructures of OMVS' members. In addition, the convention signed in 1978 also defined the principles of equality and equity for benefit sharing. With construction started in September 1981 and completed in August 1986, the Diama Dam is mainly used for water supply, irrigation, shipping improvement and prevention of salt-water intrusion. On the other hand, the Manantali Dam, whose construction started in 1982 and ended in 1988, did not start power generation until 2001. In May 2003, the dam was at full capacity for power generation. The electricity generated would be distributed based on the three countries' investment proportions in the project. Thus, Mali, Mauritania and Senegal received 52%, 15% and 33% of the power generated, respectively. In terms of other benefits, the benefit focus also varied due to the number of countries involved. For instance, Mali concentrated more on the shipping of the Atlantic Ocean and power generation while Mauritania and Senegal focused more on irrigation and power generation. Thus, the benefit allocation was relatively complex.

At the request of OMVS' Council of Ministers in 1977, through several years' effort, Utah State University developed the allocation method for the construction costs and benefits of the Manantali and Diama reservoirs, i.e. the

adjusted separable cost remaining benefit (ASCRB). The project's total cost was divided into separable costs (SC) and joint costs (JC). SC referred to the costs related with certain service functions, for example, generation units are only related with power generation. JC, in contrast with SC, referred to the costs which are joint costs for multiple service functions and cannot be defined for a single service function. For example, the costs for the concrete dam of the reservoirs belong to JC. JC was proportional to the remaining benefit (RB) of each service function. RB equaled the lesser of benefits or alternative costs (AC, or the cost of providing a service using a single-purpose infrastructure) minus SC. The total cost equaled the sum of SC and JC.

The first step for calculating these costs and benefits is to estimate the earnings of irrigation, power generation and navigation. Earnings of irrigation were calculated based on the three countries' irrigation acreage and the crops planned to be planted. Power generation earnings were calculated based on heating and power prices and power generation volume was based on historical average flows. Shipping earnings were reckoned through alternatives, i.e. the earnings of equal goods transported through highways and railroads of the same period were the shipping benefits of the project.

Then, the formula AC-SC was used to work out the RB values of irrigation, power generation and shipping. The JC was allocated to irrigation, power generation and shipping proportionally according to the RB. JC and SC made up of the total costs of irrigation, power generation and shipping which accounted for 22.37%, 30.78% and 46.85% of the total, respectively. Finally, a cost allocation was made based on the benefits member states gained from irrigation, power generation and shipping. Thus, the allocated cost percentages for Mali, Mauritania and Senegal were 35.3%, 22.6% and 42.1%, respectively (Table 1).

The above table indicates that Mali gained the greatest shipping benefit, Senegal gained the greatest irrigation benefit and both countries shouldered higher allocated costs accordingly.

2.3 Benefit sharing of Lesotho Highlands Water Project (LHWP)

Orange River is an important river in Southern Africa. It originates from Lesotho Highlands, runs westward through central South Africa and the borders between South Africa and Namibia, and then turns south to join the Atlantic Ocean. The river measures 1860 km long and forms a drainage ba-

sin with an area of $9.7 \times 10^5 \text{ km}^2$, and an annual average run-off of $15.4 \times 10^9 \text{ m}^3$. Surrounded by South Africa, the Kingdom of Lesotho is rich in water resources and its annual precipitation is 700–1000 mm. In contrast, the average annual precipitation in South Africa is only about 500 mm, and water resources are scarce. LHWP aims to divert water from Orange River to Gauteng province, the industrial and economic center of South Africa. In 1978, South Africa and Lesotho agreed to jointly conduct a feasibility study of LHWP. Following 10 years of negotiation and argumentation, the two countries agreed that the best solution was to build a dam on Orange River in Lesotho and divert water through a tunnel to the water-deficient area of South Africa by gravity flow. Then the two governments signed the *Lesotho Highlands Water Project Treaty* in October 1986. The whole project mainly included building five dams, a 200 km mountain tunnel and 72 MW Muela hydropower Station in the territory of Lesotho. After the project was completed, it could supply hydroelectric power for Lesotho and $70 \text{ m}^3/\text{s}$ water to South Africa. The project was divided into four phases, and Phase I has been completed and the designed flow is $28 \text{ m}^3/\text{s}$.

According to the Treaty, South Africa is liable for the water diversion construction costs (main works, roads, and resident resettlement, etc.) and water diversion maintenance costs, while Lesotho is liable for the hydropower station construction as well as its operating and maintenance costs. The Treaty specified that 56% of the net benefits of LHWP belong to Lesotho and the remaining 44% to South Africa. Here the net benefits refer to the differences between LHWP and the alternative Orange-Vaal Transfer Scheme (OVTS) in terms of project construction as well as operating and maintenance costs. The OVTS cost differences mainly consist of three parts: the difference in the project construction costs, the difference in costs of consumed electricity by the pumping station, and the difference in other operating and maintenance costs. For the first part, the net benefits from the project construction are relatively fixed, while the remaining two will change with the volume of diverted water. Lesotho charges the three net benefits in the form of royalties.

According to the Treaty, the two governments established Lesotho Highlands Water Commission (LHWC), Lesotho Highlands Development Authority (LHDA), Trans-Caledon Tunnel Authority (TCTA), and other agencies to manage the early stage preparations, design, construction and operation of the project.

Table 1 Benefits and costs allocation of Mali, Mauritania and Senegal in Senegal River Basin

(unit: %)

Countries	Item			
	Irrigation benefits (Diamana+Manantali)	Power generation benefits (Manantali)	Shipping benefits (Manantali)	Allocation of total costs
Mali	11	52	82	35.3
Mauritania	31	15	12	22.6
Senegal	58	33	6	42.1

Lesotho and South Africa signed the Phase II Project Agreement in 2011. Based on experiences and lessons from LHWP Phase I, more provisions were added to this agreement. For example, a Technical Sub-committee (TSC) was established to provide suggestions and help for addressing the technical, engineering, environmental and social issues in the process of Phase II construction. In addition, a Project Management Unit (PMU) was established to take charge of the daily management of various activities under the leadership of LHDA.

3 Comprehensive analysis of TWR benefit sharing cases

From the above cases, we can see that the TWR benefit sharing is realized through cooperation. Riparian countries of Columbia River, Senegal River and LHWP have signed cooperation agreements which defined their respective rights and obligations. For example, the *Columbia River Treaty* stipulated that Canada should build three dams in its territory to provide 19.1 thousand million m³ live storage for the downstream of the river as well as improve the flood control capability and hydropower generation of the middle and lower reaches by optimum scheduling. The United States can fully make use of the storage to distribute the flood control benefits and 50 percent of the increase in power generation to Canada.

The focus on TWR benefit sharing is not on the water volume, but on the resulting benefits. For example, what is shared from the Columbia River is the benefits from flood control and hydropower generation. What is shared from the Senegal River is benefits from hydropower generation, irrigation and shipping. Benefits shared from LHWP are from the differences between the two water diversion schemes in terms of project construction and operating maintenance costs caused by the differences in water intake positions, since LHWP is in Lesotho, and the alternative is completely located in the territory of South Africa. The benefits shared by the two countries are not only related to the project location, but also the water diversion volume.

It normally takes a long time (even decades) to reach a consensus on the benefit sharing plans. The United States and Canada started to discuss the Columbia River benefit sharing plan in 1944, and they signed the *Columbia River Treaty* in 1961 after nearly 20 years of negotiation. Riparian countries of the Senegal River commenced cooperation since the 1960s and officially established OMVS in 1972 to promote construction of the Manantali and Diama projects. In 1985, the countries reached a consensus on the benefit sharing and costs apportionment. The two projects were completed in 1986 and 1988, respectively, but Manantali did not officially start power generation until 2001. The feasibility study for LHWP was carried out in the 1950s, but it took until 1986 for South Africa and Lesotho to sign the agreement, and Phase I was completed in 2004.

Different drainage basins have different characteristics, consequently the way of determining and distributing water resource benefits should be different. The United States and Canada agreed to share the benefits of flood control and hydropower generation at the proportion of 50:50. The benefits of flood control are calculated with the multi-year annual average loss method while the power benefit is determined as the difference between the 1961 US Base Hydro System with and without Canadian treaty storage. Three categories of benefits in the Senegal River are shared: irrigation, hydropower generation and shipping. The calculations of these benefits are relatively simple. For example, the irrigation benefits are calculated by the irrigation area and crops to be planted in each country and the hydropower generation benefits are calculated according to the electric energy production while the shipping benefits are calculated with the substitution method. However, how to share construction costs became the major difficulty for the three countries. In 1985, OMVS Council of Ministers reached a consensus and agreed to adopt the adjusted separable residual income method developed by Utah State University, realizing the benefit sharing and costs apportionment of state members of OMVS. LHWP's net benefits are distributed at the proportion of 56:44 between Lesotho and South Africa. The net benefits are calculated through differences in the construction costs, pumping station operation costs, electric power consumption and operating maintenance costs between the two water diversion schemes. The construction costs are relatively fixed while the electric energy consumption and operating maintenance costs are related to the water diversion volume.

A joint organization is necessary to effectively ensure implementation of the benefit sharing plans. According to *Columbia River Treaty*, the United States and Canada established a Permanent Engineering Board, which serves as a permanent body for implementation of the treaty. The joint organization for Senegal River drainage area was developed from an Interstate Committee, OERS to OMVS, which has three bodies, Conference of Heads of States, Council of Ministers and Technical Commission, to be responsible for promoting benefit sharing of the Senegal River basin. According to LHWP Treaty, South Africa and Lesotho established the LHWC, which manages the project on behalf of the two governments. LHDA is responsible for implementation, operation and maintenance of the project within Lesotho; while TCTA is responsible for implementation, operation and maintenance of the project within the territory of South Africa and fund raising of the water diversion project.

4 Theoretical exploration of TWR benefit sharing

The TWR benefit sharing is an approach for equitable and reasonable utilization of water sources. It mainly focuses on the values accompanying cooperative water development

and utilization in different aspects, including economic, environmental, social and political values. Riparian countries have paid a great deal of attention to the benefits from optimized water utilization instead of viewing it as a zero-sum game of water allocation.

4.1 Jurisprudential foundation of TWR benefit sharing

The TWR has the features of the common pool resources (CPRs). A country's use of the water resources may have impacts on the other countries. In 1990, Elinor Ostrom put forward the CPRs concept (McKean, 2000) and summarized eight principles for the autonomous governance of the CPRs (Wang et al., 2012), including definition of CPR boundaries, bodies that have the right to use the CPR, institutional arrangement and supervision, and conflict settlement. In 1966, Article 4 of the *Helsinki Rules* stated: "Each basin state is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin." In 1997, Article 5 of the *Convention on the Law of the Non-Navigational Uses of International Watercourses* declared: "Watercourse States shall in their respective territories utilize an international watercourse in an equitable and reasonable manner." The transboundary river mobility makes the use of water resources by riparian countries closely linked. A country's use will cause externalities to another country; and if those externalities cannot be internalized, the overall benefits of the water resource will be reduced.

4.2 Subjects and objects of TWR benefit sharing

Benefit sharing subjects refer to the subjects with right and obligations. Transboundary water resources are shared by the riparian states, attached to the territory of the corresponding country and closely linked with the country's sovereignty. Therefore, the riparian countries are the subjects of TWR benefit sharing and should equitably share benefits by the principle of equality of rights and obligations among them (Zeng et al., 2012).

The benefit sharing objects refer to the objects needed by the subjects. Scholars have expressed different opinions on classification of the benefit sharing objects. Some are visible, that is, material and tangible benefits such as power generation, irrigation, flood control, water supply, shipping, and ecological environment; while others are invisible, that is, spiritual and intangible benefits such as cultural and social values, and ethics. Some benefits can be quantified such as irrigation, hydropower generation, water supply, flood control and shipping, and others are difficult to quantify, for example the cultural, social and political benefits.

4.3 Core of TWR benefit sharing

The mobility of TWR often makes it difficult to determine the TWR sharing quota. A country cannot execute the TWR right in the territory of another country. Therefore, the TWR

is a unique "jointly owned resource" based on sovereignty and the natural properties of the transboundary rivers. The core of TWR is that riparian countries must undertake the obligations of "common protection" while "sharing" the benefits of the transboundary water resources (Zeng et al., 2012).

4.4 Modes of TWR benefit sharing

Benefit sharing modes can be classified into the following four categories:

(1) Benefits and responsibilities shared together. Riparian countries undertake the water resource development, utilization and protection responsibilities together while sharing the benefits of development. For example, Mali, Mauritania and Senegal in the Senegal River basin agreed to jointly construct Manantali and Diama Dams, and share the development responsibilities and benefits from irrigation, hydropower generation and shipping of the two dams.

(2) Equity of rights and obligations as well as equal distribution of benefits. While enjoying certain rights, the riparian countries must undertake certain obligations. For example, the *Columbia River Treaty* specified that Canada has the obligation to provide 19.1 thousand million m³ of effective storage to regulate the runoff of Columbia River; meanwhile the United States runs and maintains any additional hydropower facilities built on the mainstream and should maximize benefits from the storage adjustment of Canada. The United States and Canada both have the right to equally share the benefits from flood control and hydroelectricity increased by the Canadian treaty storage.

(3) Costs apportioned and benefits shared in proportion. The riparian countries of Senegal River started cooperation in the 1960s, and promoted the economic development of the basin by building Manantali and Diama Dams in the 1970s. They divided the construction costs into SC and JC. First, they shared the hydropower generation costs according to the benefits they enjoyed, and apportioned the joint costs to the shipping and irrigation functions according to the ASCRB. Then these countries apportioned the construction costs according to the shipping and irrigation benefits obtained in proportion.

(4) Each takes what one needs and share benefits fairly. Gauteng province is economically developed, but short of water resources while Lesotho is abundant in water resources but economically underdeveloped. LHWP diverts the water resources from Orange River in Lesotho to Vaal River in South Africa to meet the water needs of Gauteng province for economic development. With the project, Lesotho has developed its economy and South Africa has a guaranteed water supply for its economic development. In the end, the benefits from LHWP are equally distributed between the two countries.

4.5 Realization process of TWR benefit sharing

The TWR benefit sharing practices show that it takes a long time to realize the benefit sharing. The first step in the

process is data and information sharing, including hydrologic data, social, economic and environmental information that may affect the benefit calculation. The second step is to reach a series of consensus agreements. These include determining the water resource development and utilization schemes as well as identifying the benefits that can be shared. They also include reaching a consensus on costs and benefits calculation methods and signing the cooperation agreement which considers differences in upstream and downstream concerns and interests, following the principles of equitable and reasonable utilization, mutual benefit and equal participation in line with the actual situation of the drainage basin. The third step is to establish the benefit sharing mechanism, clearly define the responsibilities of related agencies according to the agreement, and organize implementation of the planned project and shared benefits.

4.6 Realization conditions for TWR benefits sharing

Whether a benefit sharing agreement is signed for the transboundary rivers depends on many conditions. From the current transboundary rivers that have realized benefit sharing, it is clear that the following conditions can greatly increase the possibility of benefit sharing.

First, the riparian countries should be politically stable, and have the willingness for cooperation and an entry point for cooperation. Through cooperation, they can learn about each other's concerns and find out the common interests. This is the most basic condition to realize benefit sharing. For example, since the riparian countries in Senegal River Basin declared their independence successively in the 1950s and 1960s, they hoped to develop their basin economy as the common interests and realized the benefit sharing through cooperation in building the Manantali and Diama dams. Second, cooperation can bring incremental benefits, or lower costs than the unilateral actions. Only in this way can stakeholders be motivated to cooperate. For example in the Lesotho Highlands Water Project, South Africa and Lesotho shared the benefits incrementally gained from cooperation. Third, the distribution of benefits should be fair and reasonable and should stand the test of time. For example, the benefit sharing scheme of Columbia River has been executed for more than 50 years and the two countries have agreed to continue and improve it after expiry of the treaty, reflecting the strong vitality of the Columbia River benefit sharing scheme.

5 Conclusions

Benefit sharing is a good approach to address equitable and reasonable utilization of TWR. The focus is not the water volume allocation, but the benefit sharing from the cooperative water development and utilization. It will take a long time, many years or even decades, to reach consensus on benefit sharing because riparian countries need to complete a great deal of fundamental work to agree on the benefit distribution methods. The execution of the benefit sharing

should be guaranteed by signing an agreement and establishing effective implementation mechanisms.

The TWR has the property of CPR. The benefit sharing subjects are riparian countries which share a variety of benefits, mainly including flood control, hydropower generation, irrigation, shipping, environment and ecology, as well as social, cultural and political benefits. There are different benefit sharing modes, including benefits and responsibilities shared together; equity of rights and obligations as well as equal distribution of benefits; costs apportioned and benefits shared in proportion; and each takes what it needs and benefits are shared fairly. The process of benefit sharing starts with the sharing of data and information, then reaching a consensus on the benefit calculation and distribution, and then establishing a mechanism to ensure implementation of the benefit sharing. To reach the benefit sharing, the first condition is that riparian countries have the cooperation willingness, the second condition is that cooperation can generate incremental benefits, and the third condition is that the benefit sharing is equitable and reasonable and stands the test of time.

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跨界水利益共享：案例分析与理论探讨

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摘要：跨界水利益共享是解决跨界水资源公平合理利用的一种方法。本文通过跨界水利益共享典型案例分析，系统探讨了跨界水利益共享理论。跨界水具有公共池塘资源性质，跨界水利益共享的主体是流域国，共享的利益包括防洪、发电、航运、灌溉、社会、文化等。利益共享模式主要有利益共同享有，责任共同承担；权利义务对等，利益平等分配；成本分摊，利益按比例共享；各取所需，利益公平分配等。利益共享的实现过程首先是数据和信息的共享；其次是利益的识别和评估，并对利益计算方法和分配达成共识；第三是建立机制，保障利益共享。利益共享的实现条件，第一要看流域国家是否有合作意愿；第二要看合作能否带来利益的增量，或者比单方面行动带来成本的降低；第三要看利益的分配是否公平合理，是否经得起时间的考验。

关键词：跨界水；利益共享；模式；实现过程；实现条件