Chapter 1

Introduction

Water is essential for life. It can be used for household consumption, industrial production, agricultural irrigation and hydropower generation, etc. Though roughly 70 percent of the earth's surface is covered by water, only 3 percent of the water on earth is freshwater and about two-thirds of this is frozen in glaciers and polar ice caps. According to the United Nations Human Development Report 2006, around 700 million people in 43 countries suffer from water scarcity. The situation will be even worse by 2025 and two-thirds of the world's population could be living under water stressed conditions by then. Mark Twain once wrote, "Whisky is for drinking, water is for fighting over." The partition of British India in 1947 created a conflict over the waters of the Indus Basin. The newly formed states (India and Pakistan) were at odds over how to share and manage what was essentially a cohesive and unitary network of irrigation and finally went to war twice in 1965 and 1971.

The dispute over water resource allocation within a country can be properly solved by the legal system in a nation. Some governments can even allocate water resources among different river basins within a nation. For instance, the Chinese government leads the South-North Water Transfer project to channel 44.8 billion cubic meters of fresh water annually from the Yangtze River in Southern China to the more arid and industrialized north through three canal systems (Wang (2014)). However, there is no legal body over the dispute of trans-boundary river basins and absence of enforcement of the International Water Sharing Agreements. The limited water resources and lack of agreement enforcement in trans-boundary river basins have attracted economists to investigate water resource allocation problems.

Most river basins are trans-boundary. For instance, 14 countries share the Danube (another 5 have a marginal share in it), 11 the Nile and the Niger and 9 the Amazon (United Nations Human Development Report, 2006). International river basins cover almost half of Earth's land surface. An estimated 148 states have international basins within their territory, and 21 countries lie entirely within them (United Nations World Water Development Report, 2012).

Externality issues are often present in trans-boundary river basins. For instance, the construction of hydropower dam projects in Laos will hinder the fish migration route in the Lower Mekong River Basin, thus harming the fishery in Cambodia where the Tonle Sap Lake is located; in fear of largely changing the river flow pattern thus impacting

local livelihood, Egypt strongly objects the construction of the Grand Millennium Dam in Ethiopia located in the upstream of the Nile River. Potential economic gains from joint management in trans-boundary river basins are substantial. For instance, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan share the Syr Darya and Amu Darya basins in Central Asia. The huge Toktogul Reservoir in Kyrgyzstan is operated for water storage and control irrigation water in the wet and dry seasons. The current scenario of non-cooperation among these countries has forced each country to pursue suboptimal strategies for their own interests, with huge amount of economic losses. According to the estimates from the World Bank, Uzbekistan would gain 36 million USD and Kazakhstan 31 million USD from optimal operation of Toktogul Reservoir, while the incremental costs borne by Kyrgyzstan would amount to 35 million USD (United Nations Human Development Report, 2006). A simple cost-benefit analysis would indicate the potential gains from cooperation. In case of effective cooperation and that externality issues are properly addressed, all parties can benefit from cooperation. Thus, cooperation in water resource allocation in trans-boundary river basins is a "win-win" situation. Nevertheless, there exist several obstacles to trans-boundary water resource cooperations.

Firstly, countries vary in their dependence on shared trans-boundary river basins. For instance, one-fifth of the Mekong Basin lies in China, while the basin represents less than 2% of China's territory; another one-fifth of the Mekong River is in Cambodia, but the basin accounts for almost the whole country (more than 86%) and the Mekong is considered as the "Mother of Waters" for Cambodia. Moreover, in the same river basin, different countries may have different interests in water use, for example, in the Mekong River Basin, Laos heavily depends on hydropower from planned dams to reduce its poverty, while Cambodia relies on fishery to feed its people (Just and Netanyahu (1998)).

Secondly, there is no consensus on property rights for international waters. Two most quoted principles in the International Water Law are the Absolute Territorial Sovereignty (hereafter, ATS) and Unlimited Territorial Integrity (hereafter, UTI). The former principle is also called the Harmon Doctrine. It implies that a country is free to use water from any system that flows through its territory, in a way that best suits it.[1] The latter principle states that a country has the right to demand the natural flow of an international river into its territory that is undiminished in quantity and unchanged in quality by the upstream countries.[2] The United Nations Human Development Report (page 218, 2006) states

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[1] In 1895, the Mexican government led a complaint against the US government about the excessive use of water from the river Rio Grande, which originates in the US and forms part of the border between the US and Mexico before owing into the Gulf of Mexico. The decision from the Attorney General of the US Department of Justice, Judson Harmon, is that "the United States is under no obligation to Mexico to refrain its use of the Rio Grande because its absolute sovereignty within its own territory entitles it to dispose of the water within that territory in any way it wishes, regardless of the consequences in Mexico" (McCaffrey (1996)). The US therefore declared it had no obligations towards Mexico. See also Moes (2013).

[2] Egyptian reliance on the Nile River over the millennia has led it to believe that it has natural and historical rights over those waters. This belief is reflected in the position taken by Egypt in international fora that "no country has the right to undertake any positive or negative measure that could have an impact on the river's flow in other countries," for instance in the Egypt Country Report at the 1981 Interregional Meeting of International River in Dakar. Hence, Egypt is particularly sensitive to any action toward the Nile River by the upstream countries and strongly opposed the 2010 agreement on

"in practice most governments accept that absolutist approaches to water rights are an unhelpful guide to policy design. After decades of consideration principles for sharing water were codified in the 1997 UN Convention for the Non-Navigational Use of Shared Watercourses, building on the 1966 Helsinki Rules. The core principles are 'equitable and reasonable utilisation', 'no significant harm' and 'prior notification of works'. The broad idea is that governance of international watercourses should be developed by taking into account the effects of use on other countries, the availability of alternative water sources, the size of the population affected, the social and economic needs of the watercourse states concerned, and the conservation, protection and development of the watercourse itself."

Thirdly, countries within a trans-boundary river basin differ in its country characteristics. Various countries might have different levels of population size, GDP per capita, military power, etc. This might reflect in its bargaining power in the International Water Sharing Agreements and in turn influence its benefits derived from the joint management of the trans-boundary river basins (Just and Netanyahu (1998) and Houba et al. (2014b)). Countries with a relatively weak bargaining position might refrain from joining the International Water Sharing Agreement even if its marginal contribution to the benefits of the joint management of the river basin is significant.

In this dissertation, we firstly address the following two puzzles,

1. In a trans-boundary river basin, how should we allocate water resources among all agents in terms of efficiency? Another relevant issue is how to distribute benefits among all agents from efficient allocation for a long-term sustainable development of the whole river basin. In order to answer these questions, we incorporate two principles from the International Water Law, i.e., ATS and UTI, to determine the reference point to distribute the total benefits. We generalize the line graph river geography (Kilgour and Dinar (2001) and Ambec and Sprumont (2002)), i.e., all agents are positioned on a line with upstream and downstream locations, by allowing two or more river branches to merge at a certain point.

2. Though in the International Environmental Agreement, the cooperation of all countries together often achieves the maximal amount of "pie", gradual coalition formation is often observed in the International Water Sharing Agreement (Rubio and Ulph (2007)), i.e., some countries within a trans-boundary river basin form a coalition and some other countries join the existing coalition at a later stage. We propose strategic timing of participation into the International Water Sharing Agreement to explain the above mentioned phenomenon and examine this approach in more detail in a "V" shape river basin (i.e., two upstream agents merge together at a third downstream agent).

In order to answer the question on how to distribute benefits among all agents as stated under 1, we apply two asymmetric Nash solutions: the bargaining and rationing solutions. The bargaining solution is applied to divide surpluses and the rationing solution is to compromise on incompatible demands. In the asymmetric Nash solutions, each agent gets their reference point plus a fraction of net surplus (the net surplus is calculated by the total benefits from cooperation minus the sum of all agents' reference points). The

sharing the Nile water signed in Entebbe by Ethiopia, Rwanda, Tanzania, Uganda and Burundi.

fraction of the net surplus is determined by the asymmetric weights that is exogenously related to the GDP, population sizes, political factors, military powers etc. In trans-boundary river basins, each agent's reference point is based on a common principle from the International Water Law. Two principles, i.e., ATS and UTI, are incorporated to determine the reference point in this dissertation. The results of this research have been published in *Strategic Behavior and the Environment*, see Houba et al. (2014b).

The issues under 2 are studied by implementing the coalitional bargaining game (hereafter, CBG) to address strategic coalition formation. The CBG is a dynamic game that is played during a number of rounds and in which the set of players and the stage game changes over time. The game starts with a set of players, but over time the players form coalitions, always at most one at a time. At the beginning of each round, a collection of coalitions is present, i.e., a partition of the players being the coalitions formed in the preceding rounds called a coalition structure. Then this coalition structure forms the updated set of players that bargain among each other, so the set of players in each round is the set of coalitions in the coalition structure. In each round, a stage game is played. In a stage game, one of the players is selected randomly to be the proposer. He makes a proposal to other players to form a coalition and players that are proposed to respond the proposal by yes or no. When the grand coalition is formed, the game ends; otherwise it goes to the next round where the stage game restarts including the random selection of a new proposer (Gomes (2005)). The results of this research have been published in *Environmental and Resource Economics*, see Houba et al. (2015).

In trans-boundary river basins, dam projects are often built for water storage, flood control, hydropower generation, etc. For instance, Laos is considered as the "battery" of Southeast Asia because of its huge hydropower potential. Due to the high demand of electricity from neighboring countries, e.g., Thailand and Vietnam, Laos government has ambitious plans to build a number of dams in the Lower Mekong mainstream to benefit from these high demands. On the negative side, dams change the river flow pattern and endanger local or even basin-wide environment. For instance, dam construction in Laos might hinder the fish migratory route in the Lower Mekong, and largely damage the fishery in Cambodia. In this dissertation, we address the following puzzle,

3. Under the spirit of mutual management of trans-boundary river basins of the 1997 United Nations report, what will be the optimal plan of dam construction in the Mekong River Basin taken the externalities issues into account? What will be the reasonable compensation scheme in case some parties benefit from the dam construction and other parties bear losses from the dam plans?

Finally, as a separate project in this dissertation, we consider issues on the competition in two-sided market. With a large varieties of sellers covering as many customers' needs as possible, a local shopping mall might attract more consumers to visit. More consumers will reversely stimulate more sellers to gather in the shopping mall. Rochet and Tirole (2006) define that "two-sided (or, more generally, multi-sided) markets are roughly defined as markets in which one or several platforms enable interactions between end-users and try to get the two (or multiple) sides 'on board' by appropriately charging each side. That is, platforms court each side while attempting to make, or at least not lose, money overall."

Previous literature, e.g., Armstrong (2006) and Rochet and Tirole (2006), focuses on these so-called cross-group externalities. Though indeed cross-group externalities influence the price mechanism in a two-sided market context, within-group externalities might also play an important role. For instance, in the above example of a shopping mall, we also observe that more retailers in the mall will intensify the competition among similar product providers, so there may exist within-group externalities among the sellers. In this dissertation, we address the following puzzle,

4. We examine the price mechanism of a platform serving two sides of the market under three scenarios (i.e., monopoly, duopoly and competitive bottleneck) by adding within-group externalities.[3] What will be the differences compared with the price mechanism of a platform without taking into account within-group externalities?

This dissertation is organized in the following way. We first introduce some concepts in game theory in Chapter 2 that will be used later in the trans-boundary river sharing problems and then we proceed to answer the above four mentioned puzzles in chapters 3 to 6.

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[3]In the literature of two-sided market, competitive bottleneck represents the case that platforms compete aggressively to sign up one side agents (e.g., buyers), charging them less than the costs (or even subsidizing), and make the profits from another side of the market (e.g., sellers) who wants to reach their buyers and are forced to join the platform in order to reach the buyers (Armstrong (2006) and Armstrong and Wright (2007)).