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Measuring and Apportioning Rents from Hydroelectric Power Developments

Mitchell Rothman

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Measuring and Apportioning Rents from Hydroelectric Power Developments

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FOREWORD

Hydro resources are provided by nature. The exploitation of such resources can generate significant economic rent to the owners. In the past, governments have usually claimed ownership of hydroelectric resources and passed on the rents to their state-owned utilities, which have used them to expand their systems or provide lower tariffs to their consumers. With the restructuring of the electric power sector in many countries, a more explicit consideration of hydroelectric rents is required. Moreover, hydropower resources are often owned by more than one party, or at least require cooperation between parties to develop them.. In this context, the measurement and apportionment of hydropower rents between cooperating parties becomes important.

This paper addresses some of the issues involved in cooperative development of water resources, especially for hydroelectric generation. It promotes a better understanding of the sources of the benefits and attempts to derive an analytical basis for discussions between cooperating parties.

It is hoped that the analytical approaches developed and the exposition of practical examples will help form a basis for cooperative resource development.

James Bond
Chairman
Energy, Mining and Telecommunications Sector Board

ABSTRACT

This paper deals with economic rents arising from the development of hydroelectric generation on international watercourses.

The paper briefly defines the concept of economic rent and its application to hydroelectric developments. It explores two areas of precedents that can help us understand how the concept could be applied in developments on international watercourses. First, it looks at international law on the ownership and rights of use of such watercourses. Then it looks at past instances of international watercourse development that have used the idea of rent, or rent-like concepts, to determine how to share the benefits from the development.

The paper notes that international convention and practice on this topic expect that riparian countries will negotiate the sharing of benefits from international developments. What the paper then seeks is a guide to such negotiations.

The paper also devotes some attention to methods for quantifying the rents generated by projects in various situations: where a competitive market exists for the project's output; where no market exists; or where the hydroelectric development is part of a multipurpose project.

Following the precedent areas, the paper develops a theoretical approach to the measurement and sharing of the rents arising from international developments. Where possible, the paper recommends an analytical approach to the sharing of the rent. In general, the paper notes, the total benefit from a cooperative development of an international watercourse is greater than the benefits from separate independent developments. The basic principle derived for rent sharing derived from this observation is that each participant should get from the cooperative development at least as much rent as it could have obtained from an independent development. This principle is applied to several kinds of potential developments.

Finally, the paper generalizes to some principles for the sharing of rents in hydroelectric projects.

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1. INTRODUCTION

Nature provides valuable resources that, when exploited, can generate significant economic rent—a surplus return over and above the value of the capital, labor, materials and other factors of production employed to exploit the resource. Hydroelectric power generation, for example, relies on Nature's provision of precipitation and water seepage at sites where the forces of water flow can be harnessed.

Capturing economic rent from resource developers and delivering it back to the resource owners (the public) is common practice in the oil and gas, mining, forestry and fishing sectors. It is rare, however, in the hydroelectric power sector, where governments typically regulate tariffs such that the resulting rent flows to electricity consumers in the form of lower tariffs.

When hydro developments are international in scope, measuring and apportioning the hydro rent is a more important issue. In these cases, apportioning the rent between the co-owners of the water resources often requires explicit mechanisms, since there is no guarantee that embodying hydro rent into the electricity price will lead to an equitable division of the rent.

Very little has been written either on how to measure economic rent from hydroelectric developments or on how to apportion hydro rent between co-owners of the water resources being exploited. This paper addresses these two issues.

Chapter 2 of the paper introduces the concept of economic rent, while the next chapter examines rent within the context of the hydroelectric power sector. This includes a review of some studies that explicitly measure the economic rent arising from water resources. Chapter 4 introduces international law on the ownership of water in transboundary watercourses. Chapter 5 reports on some case studies where rents have been allocated or a rent-like approach has been taken to benefit calculation and apportionment for transboundary watercourse development. The theoretical development occurs in Chapter 6, in deriving some principles for allocating rent among riparians on international watercourses. These themes are drawn together in a final chapter dealing with the principles for sharing benefits.

2. THEORY OF ECONOMIC RENT

DEFINITIONS

> Rent is "that portion of the produce of the earth which is paid to the landlord for the use of the original and indestructible powers of the soil.... When in the progress of society, land of the second degree of fertility is taken into cultivation, rent immediately commences on that of the first quality, and the amount of that rent will depend on the difference in quality of these two portions of land."[1]

The concept of rent has evolved considerably since David Ricardo's classic examination in his *Principles of Political Economy and Taxation*, first published in 1817. Building on the work of the late seventeenth-century mercantilists, the physiocrats, Adam Smith, David Hume and others, Ricardo espoused a notion of land rent that has been expanded and refined into the modern concept of economic rent.[2]

Economic rent is the surplus return (earnings or profit) that some factors of production generate when they vary in quality and are limited in supply. Surplus means that the return is more than what the factor could earn in its next best occupation. In other words, the return is greater than needed to keep the factor in that use or a reward in excess of that required to bring forth a desired effort or function. If all factors of production were of the same quality, none could earn a surplus return since factors could be interchanged. Furthermore, if the factors were available in limitless quantities, they would earn no return at all.

Rent is a unique form of return in that it will not be dissipated by free market competition. Under the economic model of perfect competition, any profit in excess of the return that a factor is able to generate in its next best alternative will be competed away, at least in the long run. In contrast, the existence of rent is a long-run equilibrium condition. Since resources are scarce and have inherent differences in quality that cannot be recreated, rent will continue to accrue to whoever holds the right to exploit those

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1 David Ricardo (1971), *Principles of Political Economy and Taxation*, London: Pelican Books.

2 Kula, E. (1998), *History of Environmental Economic Thought*, New York: Routledge. Keiper, J., E. Kurnow, C. Clark and H. Segal (1961), *Theory and Measurement of Rent*, New York: Chilton Company.

resources. Competition is restricted because the nature of the resource prevents market entry.[3]

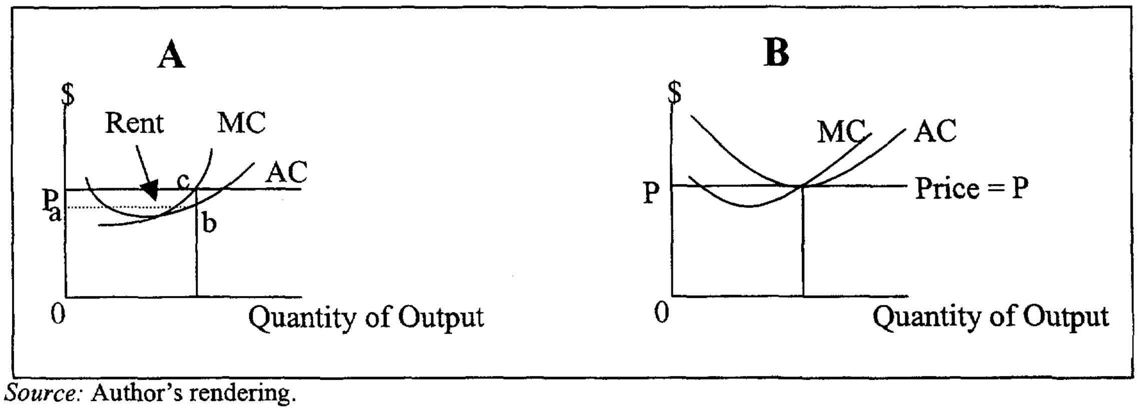
As suggested by the above explanation, economic rent arises from two main sources—differences in quality of factors of production and scarcity—and has been further classified along these lines: differential rent and scarcity rent, respectively.

DIFFERENTIAL RENT

Differential rent—often called Ricardian rent since that is the type of rent discussed in David Ricardo's classic treatment of the subject—arises when the fulfillment of demand requires simultaneously bringing into service resources of different qualities. In the case of land, sources of differential rent include soil fertility and proximity to markets.

Figure 1 illustrates differential rent when there are two producers with access to resources that differ in quality. Producer A has access to high-quality resources that allow production at costs lower than Producer B. Since both producers earn the same price for their output and operate where marginal cost (MC) equals the output price, Producer A earns differential rent of *Pabc*. Producer B operates on the margin and earns no differential rent.

FIGURE 1: DIFFERENTIAL RENT



Source: Author's rendering.

The figure also illustrates that the level of differential rent is limited by the output price as determined by the marginal cost of the marginal producer. If the output price

[3] Efforts to gain the right to exploit such resources are called rent-seeking. Rent-seeking is considered to be a major source of economic inefficiency and a large body of literature examines the behavior and its policy implications. For an introduction, see C. Rowley, R. Tollison and G. Tullock (1988), *The Political Economy of Rent-Seeking*, Boston: Kluwer Academic Publishers.

changes over time due to technological advances that alter marginal cost or due to shifts in demand, then the level of differential rent will also change.

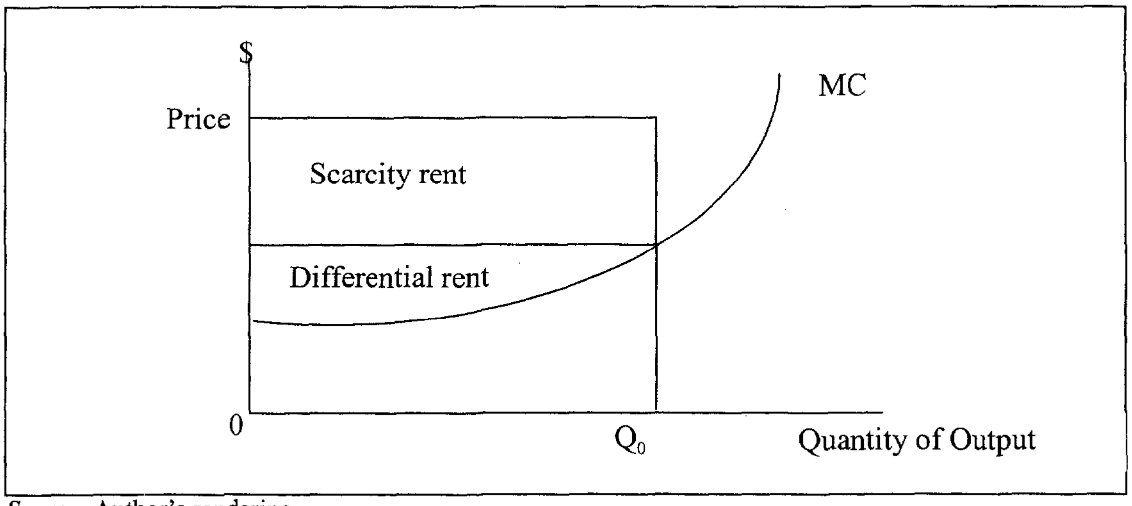
The specific sources of differential rent depend on the resource being used. Resource extraction activities, such as mining and oil and gas production, can generate differential rent from differences in the grade of ore, petroleum or gas, proximity to the surface (ease of extraction), the need for environmental mitigation measures, etc. Land resources can have different qualities, which produce differential returns. For example, land used for forestry resources will differ in terms of rainfall, distance from markets, kind of trees that can be grown, etc.

SCARCITY RENT

Beyond differences in resource quality, economic rent also arises due to scarcity. Scarcity rent—called absolute rent by Karl Marx—is rent that a landowner could earn on land that generated no differential rent. Scarcity rent occurs when limits on the supply of a resource allow producers to charge prices greater than their marginal costs.

Figure 2 illustrates the difference between differential and scarcity rent. When the flow of goods or services from the resource is limited to Q_0 due to scarcity constraints, price will exceed marginal cost and allow the producer to earn scarcity rent as indicated.

FIGURE 2: DIFFERENTIAL AND SCARCITY RENT



Source: Author's rendering.

RENT OWNERSHIP AND CAPTURE

Ownership of most factors of production determines the entitlement to the return on the use of the factor. For example, the entitlement of owners of capital equipment to a competitive rate of return on the use of the capital is widely acknowledged.

Economic rent arises when exploiting a resource that Nature has endowed with a value that is independent of any labor, capital or entrepreneurial effort applied to the resource. Resource developers, therefore, do not "earn" rent as they do normal profits (i.e., return to capital and entrepreneurship). Rather, rent is a windfall created by exploiting the bounty of Nature. The owner of the natural resource is the owner of the rent. Typically, the natural resource is an attribute of a particular piece of land that has minerals under it, or water falling over it, or some other attribute that produces rent.

Ownership of the land and of the rights to its rents differ with the nature of the resource and with local law. In some cases, the owner of the land may also own outright all the rights to it. In many cases, governments own the land or the rights to its attributes that produce the rents. Governments, in the name of the public that owns the resources, then typically try to "capture" the rent through royalties, stumpage fees, competitive auctions, development license fees and other mechanisms. A very large body of literature examines the efficiency and effectiveness of rent-capture mechanisms.[4]

Rent capture has been the motivation for attempts to measure economic rent. Because any productive resource commands a return, simply measuring the total returns to a resource expected to produce rent will not measure the amount of rent. Normal economic returns to the use of the resource must be accounted for, since rent is defined as the returns to the resource which are in excess of normal returns. The difficulty of explicit measurement of economic rent arises from these conditions of use of the resource.

MEASURING ECONOMIC RENT

In theory, the measurement of economic rent is straightforward. Both Figure 1 and Figure 2 illustrate the general approach. Economic rent is calculated as the difference between output price and the marginal cost of production, where the cost of production includes a normal rate of return to all factors of production, including capital.[5]

Unfortunately, behind this simple formulation are many assumptions that do not always hold in practice. Most important are the assumptions of perfect competition in factor markets and output markets. These assumptions must hold for the difference between output price and the marginal production cost to be an accurate measure of economic rent.

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4 For example, see Amundsen, E., C. Andersen and J. Sannarnes (1992), "Rent Taxes on Norwegian Hydropower Generation" in *The Energy Journal* 13:1, pp. 97-116; Grafton, R.Q. (1995), "Rent Capture in a Rights-Based Fishery" in *Journal of Environmental Economics and Management* 28:1 (January):48-67; and Zhang, L. (1997), "Neutrality and Efficiency of Petroleum Revenue Tax: A Theoretical Assessment" in *The Economic Journal*, 107 (July):1106-1120.

5 Mathematically, economic rent is measured by the integral of price minus the cost curve calculated over the range of output produced. For simplicity, this review of the basic theory of economic rent does not present the algebraic formulation of rent.

- **Competitive Factor Markets**: The marginal cost of production will only reflect the true social value of the factors of production if the factors are paid their marginal opportunity cost. This occurs when factor markets are perfectly competitive. For example, if a natural resource is exploited using subsidized capital, then the observed marginal production cost will be lower than the social cost and rent will be overestimated.

- **Competitive Output Markets**: Market prices for output will only reflect the true social value of the output if prices are set in competitive markets. If, for example, the price of the output is regulated such that it is below what competitive markets would set, then rent will be underestimated.

In market economies, these assumptions of competitive markets are likely to hold for many rent-generating resources, including oil, minerals, metals and forest products. However, as discussed in more detail below, the electricity sector is rarely competitive in either factor markets or output markets. For example, public electric utilities often pay less than the social value for capital, are given special tax treatment and are not required to earn a market rate of return, so their costs do not reflect true economic costs. They also are often regulated monopolies, so that their prices are also not competitive prices.

Identifying and quantifying rents in noncompetitive markets can be difficult in any case. In noncompetitive markets, by definition, firms can use their market power to sustain prices above the competitive level and therefore sustain profits above a normal rate of return. Such profits are returns to market power, not rents, but they can be quite hard to distinguish from rents in markets where both kinds of excess returns may be present. The presence of market power therefore makes measurement of rents very difficult.

3. HYDROELECTRIC POWER AND RENT

This chapter discusses rent as the concept is applied to single-purpose hydroelectric sites. It develops the theory of rent for hydroelectric developments, indicates the factors which produce and influence the amount of rent from such developments, and finally reviews some studies that attempt to measure hydroelectric rent. The studies generally refer to aggregates, rather than measurements of hydroelectric rents at specific sites.

DIFFERENTIAL AND SCARCITY RENT AT HYDRO SITES

Hydroelectric generation relies on the exploitation of Nature's resources and, therefore, can be expected to give rise to economic rent. Rent at hydroelectric sites can result from the limited number of sites that are suitable for hydroelectric development, as well as the ability of some hydroelectric sites to generate electricity at lower cost than other alternative generation technologies. This implies that hydro rent can include both differential rent and scarcity rent.

Differential rent arises since hydro is often a low-cost option for power generation. Just as the highest-cost mine regulates the differential rent that can be earned at lower-cost mines, the marginal production cost of alternative sources of electricity limits the differential rent that can be earned on hydro sites.

Scarcity rent also accrues from hydro sites, although the rationale is perhaps less intuitive than the rationale for differential rent. Hydro sites produce an output (electricity) for which there are abundant opportunities to produce using nonhydro production methods (gas, oil, coal, nuclear, geothermal and solar among them). Scarcity rent will arise if the marginal generation source can produce only limited quantities of electricity (i.e., is subject to scarcity limitations itself). Scarcity rent also arises from the seasonal limitations on the amount of water contained in a dam. Within any given season, one would expect the limited water to be managed and consumed according to its "water value" inclusive of a scarcity rent.[6]

Figure 3 illustrates rents arising from alternative electricity generation technologies. Total economic rent from any given source of electricity generation is the difference between the marginal cost of production (denoted C) and the price for

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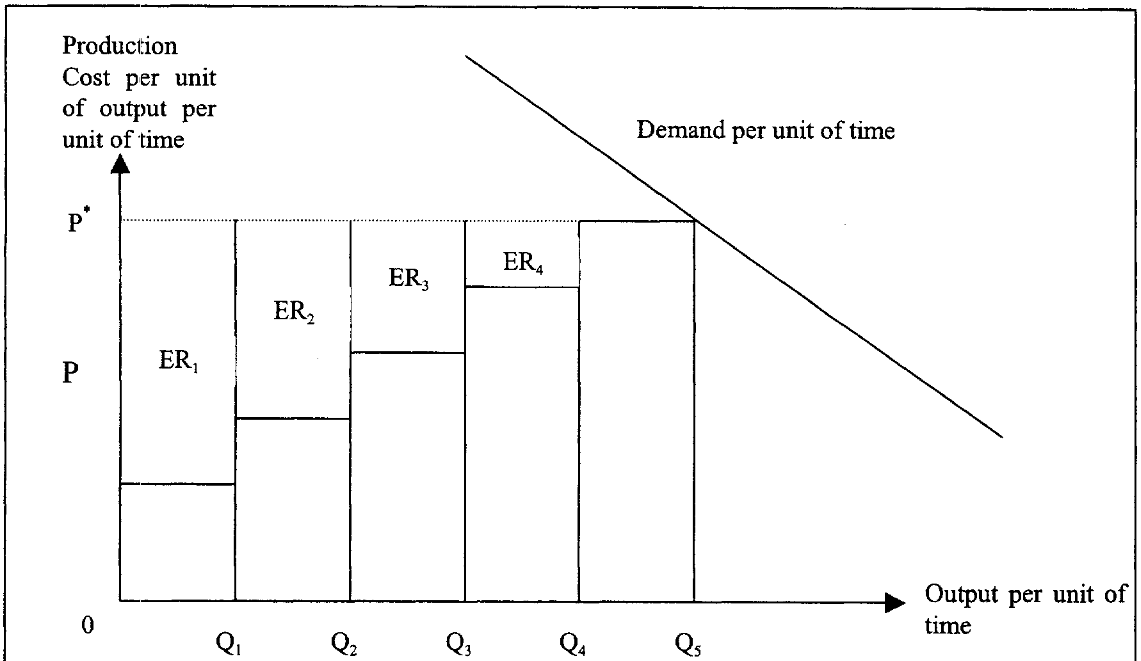
[6] Amundsen, E., C. Andersen and J. Sannarnes (1992), "Rent Taxes on Norwegian Hydropower Generation" in *The Energy Journal*, 13:1, pp. 97-116.

electricity that would obtain in a fully competitive market for electricity (P*). Competitive markets would establish electricity prices at the marginal production cost of the marginal source used in an efficient electricity generation system.

Assuming there are five sources of electricity (Q_i), economic rent (ER_i) arises from each with the exception of the marginal source. The rent will depend on the time of production, since demand and therefore value of the electricity fluctuates according to the load duration curve. Each hydro site could be classified as a different source of electricity and generate its own level of rent depending on the site-specific marginal production cost.

FIGURE 3: ECONOMIC RENT AT HYDROELECTRIC DEVELOPMENTS



Source: Taken from Zuker and Jenkins (1984), *Blue Gold: Hydroelectric Development in Canada*, Ottawa: Supply and Services Canada.

SOURCES OF DIFFERENTIAL RENT

Many factors determine the differential rent available from a given hydro site. Such factors can be classified as factors that affect generation and transmission costs at the hydro site (site-specific factors) and factors that affect the selection of the least-cost alternative and its associated generation and transmission costs. While a complete list of such factors would clearly be quite lengthy, Box 1 lists some of the most important. The list shows that hydro rent is site-specific and will change over time.

BOX 1: SELECTED FACTORS INFLUENCING HYDRO RENTS

Site-Specific Factors	• *Generation capacity (head, flow volume, storage capacity)*: affects the total revenues that can be obtained from the site's output • *Flow timing*: affects when electricity can be generated and, therefore, how much it is worth • *Proximity to consumers*: affects transmission infrastructure costs and transmission losses • *Proximity to construction materials*: affects construction costs • *Topographical and geological conditions*: affects the design and cost of building the generation and (if required) storage infrastructure
Factors Affecting the Least-Cost Alternative	• *Power demand characteristics*: the least cost alternative will vary depending on the load and timing (peak versus base) of the electricity it must generate to replace the hydro site • *World prices for energy resources*: oil, gas, coal and uranium prices affect variable costs of alternative electricity sources[7] • *User cost of capital*: affects relative costs of alternative sources, since alternatives differ in relative split between capital and operating costs • *Extent of the power market*: interconnections between power grids increase hydro rent by letting locked-in power get to market or decrease rent by letting cheaper power into the market

Source: Author's compilation.

MEASURING HYDRO RENTS

As with other forms of rent, measuring hydro rent is, conceptually, straightforward. As shown in Figure 3, hydro rent is the competitively determined electricity price minus the marginal cost of producing the hydroelectric power.

Unfortunately, neither of these values is readily observable in jurisdictions with public utilities and regulated tariffs. Regulated electricity tariffs, typically set at the utility's average cost, remain the norm in most countries. If the utility explicitly paid water rentals or other royalties to recognize rent, then the prices would reflect rent. The utilities pay water royalties which are sometimes zero, and usually lower than the value of the rents. In such cases, regulated tariffs pass the hydro rent on to electricity consumers, because they pay less than full economic cost including rent. Although the resource developer (the utility) is not capturing the rent, this situation does raise questions of equity. Since the rent is transferred to electricity consumers, those who consume more electricity will get more of the rent. Further, if the electricity is then used to produce goods for export, the exported goods embody some of the rent, which is then captured

7 For example, one theoretical paper examined the effects on rent and royalty revenues of introducing natural gas power production into an electricity sector based on hydropower. See Amundsen, E. (1997), "Gas Power Production, Surplus Concepts and the Transformation of Hydroelectric Rent into Resource Rent" in *Resource and Energy Economics* 19, pp. 241-259.

either by the foreign customers or by the producer of the goods, depending on pricing conditions in the exported goods market.

At the same time, public utilities' costs often do not reflect the marginal opportunity cost of factors of production. For example, capital may be subsidized by borrowing at the government's preferred rate of interest. Governments may offer utilities preferential tax treatment. Labor may be paid higher than normal wages due to inefficiencies or, in developing countries especially, the fulfillment of other public objectives. A final difficulty in observing the values needed to calculate economic rent lies in the accounting systems of public utilities. Often, they are simply not set up to track actual costs. Such was the case in Norway, where the country's move to competitive electricity markets involved a special Parliamentary Proposition to require utilities to adopt new accounting systems that reflect real costs.[8]

Inability to observe competitive electricity tariffs and the social (opportunity) cost of hydroelectric production does not prohibit estimation of hydro rent, although the task is made more difficult. The typical approach involves four general steps:

1. Adjusting the recorded financial costs of hydroelectric generation and transmission to reflect the full opportunity cost of the factors of production employed;

2. Identifying the least-cost alternative source of electricity that could replace the electricity generated at the hydro site(s);

3. Estimating the full opportunity cost of the factors of production employed to generate and transmit electricity produced using the least-cost alternative; and

4. Calculating rent as the cost of generating electricity using the least-cost alternative minus the cost of the hydroelectric generation and transmission.

In other words, the task involves estimating the cost savings—from a full-cost perspective—from including the hydro site within an electricity generation system.

The literature on hydro rents is extremely small. No more than a handful of attempts to measure hydro rent appear to exist, although this may change as more jurisdictions introduce competition into electricity markets and move to tax hydro rents on a basis equal to that used for other resource sectors.

Four empirical studies of hydro rent were identified and are reviewed below. Key methodological issues that emerge from these studies are as follows.

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8 See Amundsen, E., C. Andersen and J. Sannarnes (1992), "Rent Taxes on Norwegian Hydropower Generation" in *The Energy Journal*, 13:1, pp. 97-116.

- **Effects on Electricity Tariffs and Demand**: Forgoing the use of the hydro sites and relying on the next best alternative may increase the system generating costs to such an extent that tariffs must increase. In turn, tariff increases might shift the market-clearing quantity of electricity. This is unlikely to occur from forgoing the use of a single hydro site. It is, however, more likely if all hydro sites are included in the rent calculation, the hydro sites account for a large percentage of total electricity generation and the tariff increase that would be needed if hydro sites were forgone is large. Whether effects on electricity tariffs and demand should be taken into account when calculating hydro rents is a function of the sensitivity of electricity demand to tariff increases.

- **Selection of the Least-Cost Alternative**: The alternative selected as the next best to hydroelectric generation must provide the same services as the hydro site. Therefore, the least-cost alternative will depend not only on the total electricity generated, but also whether the power is supplied as peak or baseload, what season the electricity is supplied, the transmission infrastructure that is available, hydro reliability (variability of rainfall), etc. A further complicating issue is that hydroelectric developments may also provide social benefits unrelated to electricity production, such as flood control and irrigation, navigation and recreation opportunities. The opportunity cost of forgoing the hydroelectric development may also mean forgoing these social benefits or providing them through other means at additional cost. Finally, the least-cost alternative may be constrained by the current configuration of the power system. The least-cost alternative may not involve simply replacing the hydro electricity with another source, but rather require a complete reconfiguration of the system. As we shall see below, some attempts to measure hydro rents have selected a least-cost alternative unconstrained by the current system, while others have chosen a constrained least-cost alternative.

- **Imported Electricity as the Least-Cost Alternative**: If imports and exports of electricity are possible in the jurisdiction for which hydro rent is to be calculated, then it may be appropriate to take electricity prices in the foreign market(s) as the competitive market price for electricity in the rent calculation.

- **Current Cost of the Least-Cost Alternative**: It is important that the cost of the least-cost alternative be based on today's costs of new facilities, not the historical costs for similar units. Historical costs do not reflect technological advances (efficiency improvements) and, therefore, will underestimate rent.

- **Transformation, Distribution and Administrative Costs**: Costs related to generation and transmission are clearly different for alternatives, but costs related to transformation, distribution and administration may also vary. Whether or not these are taken into account should depend on their expected relative magnitude and feasibility of developing accurate estimates.

With that as a summary of some of the major methodological issues, we now summarize how hydro rents have been measured in practice.

Hydroelectric Rent in Canada (Bernard, Bridges and Scott, 1982)[9]

Canada's federal-provincial Equalization Program contributes to the country's regional equity goals by redistributing funds from wealthy provinces to less wealthy provinces. World oil price increases in the 1970s significantly raised the value of Canada's oil and gas reserves and resulted in substantially higher tax revenues to oil-producing provinces. Under the equalization formula, the federal government would have been required to make large additional equalization grants to many other provinces without oil production. Consequently, the federal government introduced measures designed to limit equalization grants arising from natural resource revenues.

Most natural resources produce benefits that appear in provincial financial accounts as government revenues. This includes, for example, stumpage fees paid by loggers of public forests and bonus payments from developers of public oil and gas. These revenues are inputs to the calculation of equalization grant entitlements. Benefits from low-cost hydro sites are not readily apparent, however, since they are usually passed on to consumers in the form of lower electricity tariffs. This inconsistency resulted in several studies exploring ways to measure hydro rent for incorporation into the Equalization Program.

Bernard, Bridges and Scott (1982) was the first study to estimate hydro rent in Canada. Their purpose was to develop a hypothetical tax base analogous to the tax bases calculated for other natural resources. Therefore, their approach involved estimating "the cost savings or rent arising from the use of a site or deposit compared to the costs of inferior ways of satisfying demand." More specifically, rents were measured as the value of the electricity derived from the hydro site (measured as alternative-method cost) minus all long-run and short-run costs to produce the electricity discounted to a present value.

Important methodological parameters of their approach included the following.

General

- Costs of generating equipment, transmission lines and transformers were developed for the rent estimation. Costs related to transformation, distribution and administration are assumed to be the same for all alternatives.

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9 Bernard, J.-T., G. Bridges and A. Scott (1982), "An Evaluation of Potential Canadian Hydroelectric Rents," Resources Paper No. 78, Program in Natural Resource Economics, University of British Columbia, Vancouver.

- Rent was estimated for four provinces in which hydro plays a major role in the provincial power systems. The provinces account for over 90 percent of hydroelectric power generation in Canada.[10]

- The assumption was made that there are no external costs or benefits from any power projects. For example, this assumes that environmental standards eliminate externalities from the air emissions from thermal generation and that no timber, fish or recreational losses or irrigation, flood control, navigation or recreational benefits arise from hydro projects.

- Each provincial system's reserve margin was increased by an additional 5 to 8 percent of capacity to reflect lower reliability of the alternatives to hydro.

Cost of Hydro

- Assume cost of hydro power is represented by historical costs and simply adjust for inflation and proper discounting.

- Private hydro facilities were excluded due to lack of data.

- Hydro production was averaged over a number of years.

Cost of Alternative

- US electricity prices were rejected as the opportunity cost of hydro, since international trade is constrained by government regulation.

- A load duration curve was plotted, and the contribution of hydro power to base, intermediate and peak power was estimated.

- Costs of thermal (oil, coal and gas) and nuclear generation were calculated based on current cost estimates.

- Least-cost alternatives were identified for each province and type of power (base, intermediate and peak).

- The costs of alternatives ignored future efficiency gains in thermal and nuclear (i.e., assumed current thermal and nuclear costs will remain constant into the future).

The estimates resulting from this approach are presented in Table 1.

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10 Rent was also calculated for the Churchill Falls hydro site, developed with Quebec and Newfoundland.

TABLE 1: ESTIMATES OF POTENTIAL HYDROELECTRIC RENTS, 1979

	Quebec /a	Ontario	Manitoba	British Columbia /a
		(millions of 1979 Canadian dollars)		
Total Hydro Rent	$879.75	$214.92	$108.35	$502.60
Adjusted for demand elasticity	$785.80	$214.92	$100.40	$430.40
		(kilowatt hours x 10^6)		
Hydro Production	88,506	42,224	20,443	40,928
		(1979 Canadian dollars)		
Rent per kWh	$0.00994	$.00509	$.00530	$.01228
Rent per Capita	$139	$25	$105	$186

/a Excludes energy purchased from Churchill Falls.

/b Rent estimated on the assumption that nuclear power is available.

Source: Bernard, J.-T., G. Bridges and A. Scott (1982), "An Evaluation of Potential Canadian Hydroelectric Rents," Resources Paper No. 78, Program in Natural Resource Economics, University of British Columbia, Vancouver, Table 6.

Hydroelectric Rent in Canada (Zuker and Jenkins, 1984)[11]

This study continued the exploration begun by Bernard, Scott and Bridges (1982) on an appropriate means to calculate hydro rents for inclusion in Canada's Equalization Program. The study estimated hydroelectric rents as the difference between hydroelectric production costs and the marginal opportunity cost of hydroelectric production. Two approaches were suggested for calculating the marginal opportunity cost:

1. Viewing electricity broadly as energy and calculating the least-cost approach of providing users with some quantity of energy, measured in British thermal units or joules. The weakness of this approach is that it does not recognize that different uses of electricity have different least-cost alternatives.

2. Find the least-cost alternative for replacing the electricity produced at hydro sites. This approach has two merits. First, it measures the least-cost approach to producing an identical service (i.e., a perfect substitute for hydroelectric power). Second, it would be more likely to measure accurately the least-cost alternative because it could take into account economies of scale arising from centralized generation and delivery of electricity.

The study selected the second approach. Theoretically, the ideal method for implementing the approach would be to compare the least-cost power systems with and without hydro generation. Hydro rent would be the difference between the two least-cost systems.

[11] Zuker, R. and G. Jenkins (1984), *Blue Gold: Hydroelectric Rent in Canada*, Ottawa: Supply and Services Canada.

Unfortunately, the study's models were incapable of estimating the least-cost system with hydro and so the study calculated rent as the difference in total cost of the current system with hydro and the least-cost system without hydro. The method used by Bernard, Scott and Bridges (1982)—calculating rent as the incremental costs of building new thermal plants to replace hydro electric generation, while holding the rest of the system constant—was rejected, since it would include in the rent estimate some costs associated with current system inefficiencies.

Having selected the approach, the study:

- Developed a model to identify and estimate the costs of the most efficient system without hydro;
- Calculated the *economic* costs of the current system. This involved adjusting the observed *financial* costs to reflect full social opportunity costs; and
- Estimated hydro rents in total dollars and on a mills per kilowatt-hour basis.

The model was applied to four provinces accounting for 93 percent of hydroelectricity generated in Canada during 1993. Table 2 summarizes the results. Note that the estimates presented for Quebec are not comparable to those of Bernard, Scott and Bridges (1982) presented above, since Zuker and Jenkins included the portion of Churchill Falls' output bought by Hydro-Quebec.

TABLE 2: ELECTRICITY COSTS, REVENUES AND HYDRO RENTS, 1979

	Quebec /a	**Ontario**	**Manitoba**	**British Columbia**
	(millions of Canadian dollars)			
Cost of Energy Sold:				
Current system	$2,630	$4,093	$672	$1,419
All-thermal system	$4,505	$4,845	$1,194	$2,238
Difference (Rent)	$1,874	$753	$523	$819
	(megawatt hours)			
Energy Sold:				
Hydro	97,812,791	36,907,860	17,753,065	24,626,965
All	100,525,446	105,056,065	18,101,301	29,324,924
	(mills per kilowatt hour)			
Hydro rent relative to hydro energy sold	19.163	20.398	29.385	33.259
Revenue from energy sold	19.601	26.371	22.170	24.848

/a Includes energy purchased from Churchill Falls. Churchill Falls energy accounts for about 31 percent of rent estimated for Quebec.

Source: Zuker, R. and G. Jenkins (1984), *Blue Gold: Hydroelectric Rent in Canada*, Ottawa: Supply and Services Canada.

Hydroelectric Rent in Norway (Bye and Johnsen, 1991)[12]

About 99 percent of Norway's electricity generation comes from hydropower. The hydro rent on this electricity has been estimated at NKr 9-10 billion annually, or about NKr 2,000 per capita.[13]

Hydroelectric Rents in Sweden (Hartman and Lindblom, 1988)[14]

In what appears to be a unique rent capture tool, Sweden imposed a tax on electricity produced at old hydro sites as a means for the government to capture the portion of differential rent arising from increases in electricity prices since the hydro sites were built. The tax was imposed in 1983. The intent is not to measure and capture all hydro rents, but only to tax the windfall as increasing world energy prices pushed the price of electricity beyond the level at which the hydro sites were economically viable (as exhibited by the original decision to develop the sites). The tax is differentiated by age of plant.

For plants which started up before 1973, the tax was set at SKr 0.02 per kWh.[15] The tax was half that for plants starting up between 1973 and 1977. There was no tax on plants started up after 1977.[16]

Water Rents in Hawaii (Bowen, Moncur and Pollock, 1991)[17]

Note: Although this study does not measure hydroelectric rents per se, it does estimate rent from water resources and is relevant as an example of how to measure rent on the basis of the reservation prices competing stakeholders would be willing to pay for water resource.

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[12] Bye, T. and T.A. Johnsen (1991), "Effektivisering av kraftforbruk" (Rationalization in the market for electric power), Center for Research in Economics and Business Administration, Bergen-Sandviken, Norway, Working Paper 19/1991.

[13] One Norwegian Krone is worth about US$0.16.

[14] Hartman, T. and T. Lindblom (1988), *Vattenkraftiskatt i Sverige* (Taxes on Hydropower in Sweden), Stockholm: Energiverk.

[15] At an exchange rate of US$0.12 per Swedish Krona (approximate value at end-1998), this amounts to about US$2.40 per MWh.

[16] Brubaker, Elizabeth, "Water Charges to Hydroelectricity Producers: An International Survey," *Energy Probe*, Toronto, Ontario, November 1992.

[17] Bowen, R., J. Moncur and R. Pollock (1991), "Rent Seeking, Wealth Transfers and Water Rights: The Hawaii Case" in *Journal of Natural Resources* 31:3 (Winter):429-448. For an earlier application of their approach, see Moncur, J. and R. Pollock (1988), "Scarcity Rents for Water: A Valuation and Pricing Model" in *Land Economics* 64:1 (February):62-72.

By 1991, the island of Oahu, home to three fourths of Hawaii's population, had nearly exhausted its annual capacity for fresh water. Irrigation accounted for the largest share of water use. However, demand was increasing rapidly due to urban growth. The only major alternatives to meet urban demand were transferring water use from irrigation and desalination.

Transferring water use from irrigation to urban uses would have major implications for the distribution of water rents. A series of court cases attempted to sort out the confusing history of water rights and, therefore, claims to the rents. This study estimated the value of irrigation water in its next best alternative (i.e., the willingness to pay of urban users) as the cost of the backstop technology (desalination) minus the cost of extracting the groundwater. The study further estimated the water's scarcity value to current agricultural users by means of a willingness to accept compensation approach. The study reasoned that if today's rate of water demand increases by one unit, urban users will incur sooner the higher costs of supramarginal wells. The resulting increase in the present value of future costs is the scarcity value attached to the marginal well. Knowing that urban users face higher water costs as urban demand grows, current agricultural users would not accept less than the scarcity value plus the extraction costs.

Using these approaches, the study estimated that a recognition of current agricultural users right to current water use and subsequent market transactions for the water would result in payments of US$55-200 million for the rights to 75 million gallons per day of water. This amounted to roughly $700 to $2,500 per housing unit to be served by the transferred water.

CAPTURING HYDROELECTRIC RENTS THROUGH ROYALTIES

Because exact measurement of hydroelectric rents is difficult, there are several examples of instances where tax or royalty regimes have been used to attempt to capture some of the rent, without explicitly measuring it. These instances include some involving shared resources and other forms of development.

Many resource development projects include provision for some tax or royalty. The royalty is frequently an ad valorem royalty, assessed without reference to the profitability of the project. Taxes are often profits taxes, assessed on accounting, not economic, profits. These are often attempts to extract some of the rent inherent in the resource; if the developer is willing to pay the royalty and taxes, it is an indication that the developer expects the project has at least that much rent.

Another way to extract rent from hydroelectric projects is to impose a charge on the water. The charge can be expressed as a rental, royalty, or simply a charge for the use of the water. Such charges can be stated as ad valorem charges, as fixed charges per unit of water used or unit of electricity generated. Again, if the developer is willing to pay the charges, it indicates that the project has that much return in excess of normal profits. That amount might not be rent, in the sense that it is defined here. It might only represent the return to a monopoly or other market imperfection. To determine the rent still requires a comparison of the costs of the project against its alternatives.

The Nam Theun 2 Development (Lao PDR/Thailand)

Nam Theun 2 is a development located in Lao PDR.[18] The project is designed to export electricity to Thailand. It is being built by a project-specific corporation. A consortium of international private companies with the Thai government (75 percent) and the Laotian government (25 percent) will own the corporation. The Concession Agreement provides for a Concession duration of 25 years.

Under the Concession Agreement, tax and royalty rates will be fixed for the Concession period. The royalty is an escalating percentage of the gross revenue of the project, assessed without reference to costs of the project. It starts at 5 percent for the first 15 years, moves to 15 percent for the next 5 years, and finishes at 30 percent for the last 5 years.

The tax is called a resource levy/profits tax, and it is levied on the net income of the project corporation. The net income will be calculated after all recognized expenditures, including depreciation, for the project. The tax structure starts with a five-year tax holiday from the start of commercial operations. After the first five years, the tax is set at 5 percent of profits for 7 years, then moves to 15 percent of profits for 6 years, and ends at 30 percent of profits for the last 7 years.

These measures do not attempt to estimate the rent value of the hydroelectric resource directly. They are effectively taxes placed on the resource developer, on the assumption that there are enough rents in the project to support the taxes. The royalty is a typical ad valorem royalty, which is payable whether or not the development is returning a profit. The resource levy/profits tax is based on an accounting, not an economic, definition of profits, and therefore could be leveled even if the project is not making economic profits; accounting profits are not necessarily equivalent to economic rent.

If the developers agree to these provisions, it is reasonable to conclude that the available rents are at least as high as the tax and royalty take. The definition of rent is that it is an excess return; if the imposition of these taxes does not affect the developers' willingness to undertake the project, they must expect at least that much excess return.

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[18] Mangesh Hoskote (1996), "Royalty Arrangements in Hydroelectric Power Projects," World Bank, China and Mongolia Department. Prepared for Government of China - World Bank Seminar: Mobilizing Domestic Resources for Infrastructure Financing, Beijing, November 1996.

Water Payments

Examples of payment regimes for the use of water for hydroelectric generation are given below.[19]

- **Brazil**. Brazil instituted in 1989 a charge of 6 percent of revenues from hydroelectric generation, except for small producers and for industries generating their own power.

- **China**. China has a charge for hydroelectric production. It varies from city to city and province to province. In 1991, Shandong charged 1.2 fen per kWh. Beijing charged from 1 to 1.5 fen per kWh. Other cities in China based charges on the value of the electricity generated.

- **Colombia**. Colombia imposes a tax on the value of the energy produced. In 1991, the tax was set at 4 percent of the value of the electricity. Of that, half was used for electrification of local areas near the hydroelectric facility, and half was used for more general environmental protection.

[19] Information for Brazil, China and Colombia is from Elizabeth Brubaker, op. cit.

4. OWNERSHIP OF WATER RESOURCES

Many, if not most, water resources in the world are shared by more than one jurisdiction. Even if the water resource—lake or watercourse—lies entirely within a single country, subnational parties, especially in federal states, often share it. Establishing ownership of the resource is the first step both in developing it and in determining the use of any rents. Many water resources also allow multiple uses, often from a single development. Some uses may be consumptive, like water for irrigation or domestic use, while others are not, like hydroelectric generation or recreational boating and fishing.

There is no body of international law or established practice relating to the sharing of water rentals. Chapter 6 will discuss the actual practices we have found, in relation to existing international arrangements for sharing of water rents. To start to formulate a theory, it is useful to address first the issue of who has the rights to the natural resource that generates the rents. That is then the first step in establishing how the rents themselves could be shared.

As noted in Chapter 3, the nature of the resource encompasses more than water. Hydroelectric generation requires that the water fall an appreciable distance; building a dam requires the right topography on the watercourse; building a major dam requires adequate geophysical characteristics to allow the bedrock to hold the dam. This study will deal later with evaluating and apportioning rents flowing from these characteristics. However, since flowing water is central to the ability to generate electricity, the study will start by reviewing rights to the water.

A water resource (river, lake, underground aquifer) that is entirely within one legal jurisdiction (typically, a country) is owned by that country. It is then called a national water resource. Many water resources are national resources.[20] Any rents accruing from such a water resource clearly belong to the country owning it, and it can dispose of them as it likes.

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[20] In federal states, a national water resource may be shared by several states or provinces, each of which may have various rights to it. One way to resolve these rights would be to apply international law; there is no evidence that such application has frequently been made. In general, rights of the local governments depend on local practice.

INTERNATIONAL WATERCOURSES

The existing law and practice on the ownership and sharing of international watercourses relates primarily to ownership of the water itself; that is, to its application in consumptive uses. This practice can, in some cases, be extended to inform the discussion for nonconsumptive uses.

There are in the world over 240[21] international river basins. An international watercourse is now defined as "'international watercourse' means a watercourse, parts of which are situated in different states."[22] International watercourses can be *successive*, passing through the territories of two or more riparian countries in succession, or *contiguous*, forming the border between two riparian countries. The international law does not make a distinction between the two kinds of watercourses, although there is a clear difference between them in the possibility of usage and disruption.

Successive watercourses inherently create an asymmetry between upstream and downstream states. While an upstream state's use of the watercourse may affect the potential and actual use by the downstream state, the downstream state's use (with a few exceptions, such as creating dams that flood upstream) cannot affect the upstream state.

Contiguous international watercourses do not create such inherent asymmetries. Both riparians are affected by actions taken by either one which would, for example, pollute the waterway. Asymmetries may be created by the particulars of the waterway (as, for example, the degree of flooding from a dam if the bank is steep on one side and shallow on the other) or by the patterns of settlement and use along the waterway, or other factors.

Riparians on contiguous watercourses can face what has been called the "tragedy of the commons." The watercourse constitutes a resource that is common to the riparians. Each riparian acting only in its own interest will use the common resource, without regard to damage to the interests of the other riparian, up to the point where further use would damage its own interests beyond the marginal value of the use. If each riparian does that, the resource could be irreparably damaged. Each riparian therefore has an incentive to make its use early, perhaps preventing the other riparian from such use.

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[21] Caponera, Dante A., "Shared Waters and International Law", in Gerald H. Blake, William J. Hildesley, Martin A. Pratt, Rebecca J. Ridley and Clive H. Schofield, eds. (1995), *The Peaceful Management of Transboundary Resources*, Graham and Trattman, p. 121.

[22] Convention on the Law of the Nonnavigational Uses of International Watercourses, Draft, Official Records of the General Assembly, forty-ninth Session, Supplement . At one time, only navigable watercourses were considered "international." The definition has now changed so that the UN Convention cited includes the entire watercourse system, including groundwaters.

The tragedy of the commons occurs when there are many such users, each of which does only small damage to the common resource. However, in the case of contiguous watercourses, there are only two claimants to the common resource, and each can readily see the costs of both its own and the other's use. In consequence, most uses of contiguous watercourses have been the subject of international discussions, if not always resolutions.

International Law on International Watercourses

The question of the ownership of rights to international watercourses has been addressed by law and diplomacy since at least the start of the 19th century, and indeed earlier than that. The rights addressed include both nonconsumptive uses (navigation, recreation, hydroelectric generation) and consumptive uses (irrigation, domestic use, industrial use).

International law depends on four sources:

- International conventions, or treaty law;
- International custom, or the practice of States;
- General principles of law; and
- Judicial decisions in international cases.[23]

Early practice depended on the second of these sources, the practice of states, and following the evolution of doctrines delineating rights of the riparian nations. These developed in a wide range.

An early doctrine, known as the Harmon doctrine after a nineteenth-century US Secretary of State, asserted that any country has absolute rights to do whatever it likes with the water resources located in its territory. In practice, this meant that downstream riparians in successive watercourses had no rights to the water; the upstream riparian could divert, pollute or otherwise use the water in any way it liked, without compensation to the downstream riparian. This is called the absolute sovereignty principle.

In direct opposition to this emerged the absolute territoriality principle. This principle asserts that the downstream riparian has an absolute right to the natural flow of the watercourse, in its full quantity and original quality. The upstream riparian has no right to do anything that would affect the downstream riparian.

Another practice which has been relevant in the past, and which is still important in practice, is that of prior appropriation. This is essentially a "first-come, first served"

[23] Caponera, op. cit.

doctrine. It was adopted, for example, for internal uses in the United States in the nineteenth century, to encourage private development at a time when governments did not have enough capital to develop the water resources themselves.[24] Using prior appropriation for new projects now would be essentially to take unilateral action, which is unlikely in the current international context. However, there is a strong tendency to recognize as fact any existing uses, so that in terms of the existing actual uses, the rule still is that the user that got there first did get the rights to the water. This has led to situations such as downstream riparians having to pay the upstream riparians to stop doing something that harms their use of the water (for example, to get them to stop polluting the waterway).[25]

More recently, neither of these extreme doctrines continues to be widely applied. Virtually all riparian states on international watercourses recognize that they do not have absolute rights, and must negotiate with other riparians for whatever use they plan to make of the water. The agreements are then codified into an international treaty, which is a way of making clear and binding international agreements.

In the case of international watercourses, a vast body of such treaties has emerged. Most of them are bilateral treaties, dealing with a wide range of uses and a wide range of situations. There are also a few multilateral treaties, which tend to be specific to the watercourses involved. These treaties now form the body of international practice that informs international law, under the first of the sources. Recent treaties, in turn, follow the principles that have emerged both from the practice and from the considerations of multinational bodies.

These can be stated as two general principles:

- The principle that one state should not do appreciable harm to another through its use (or abuse, like pollution) of a shared watercourse; and

- The principle that each riparian has the right to a "reasonable and equitable" share in the use of the waterway.[26]

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[24] Zilberman, David and Douglas Parker, "Internal Water Disputes: Causes and Solutions," in Richard Just and Siniaia Netanyahu, eds.(1998), *Conflict and Cooperation on Transboundary Water Resources*, Kluwer.

[25] Gerald H. Blake, William J. Hildesley, Martin A. Pratt, Rebecca J. Ridley and Clive H. Schofield, eds. (1995), *The Peaceful Management of Transboundary Resources,* Graham and Trattman, p. 154.

[26] Goldberg, David, "World Bank Policy on Projects on International Waterways in the Context of Emerging International Law and the Work of the International Law Commission," in Gerald H. Blake, William J. Hildesley, Martin A. Pratt, Rebecca J. Ridley and Clive H. Schofield, eds. (1995), *The Peaceful Management of Transboundary Resources,* Graham and Trattman, p. 154.

The UN Convention has further definition of the considerations in deciding on what a reasonable and equitable share would be:

> Utilization of an international watercourse in an equitable and reasonable manner ... requires taking into account all relevant factors and circumstances, including:
>
> (a) Geographic, hydrographic, hydrological, climatic, ecological and other factors of a natural character;
>
> (b) The social and economic needs of the watercourse States concerned;
>
> (c) The population dependent on the watercourse in each watercourse State;
>
> (d) The effects of the use or uses of the watercourses in one watercourse state on other watercourse States;
>
> (e) Existing and potential uses of the watercourse;
>
> (f) Conservation, protection, development and economy use of the water resources or the watercourse and the costs of measures taken to that effect;
>
> (g) The availability of alternatives, of comparable value, to a particular planned or existing use.

In other words, there is no ready rule of thumb for sharing of the water or the benefits, even for a contiguous watercourse. The actual sharing depends both on the physical characteristics of the watercourse and on the relative need of each of the riparian states. These principles clearly imply that the actual sharing of the water for any use will require negotiations among the parties to determine a reasonable and equitable share.

These principles elaborate the practice that had in any case emerged: unilateral action is not accepted in international law; the parties must negotiate an agreement acceptable to both.

Law and Practice on Watercourses in Federal States

Many states are unitary, where the governments, down to the local governments, are creatures of the national government. Others are federal states, where subnational governments of states and provinces have certain sovereignty rights. In such cases, the treatment of watercourses that either cross or form the border between two subnational entities depends on the national law and practice.

Under the US Constitution, the states have rights to control natural resources. However, the federal government (in the Supreme Court) has jurisdiction in all matters between states, including those involving water. In addition, the Congress clearly has the power to legislate in the area of apportionment of interstate waters.[27] In fact, the Supreme Court has held that Congress could order the interstate transfer of water even when the source is not an interstate watercourse. Congress has acted with respect to water, in particular in the West with respect to the Colorado River.

In the western part of the United States, the general rule on water rights has been that of prior appropriation. In cases that have come before the Supreme Court, it has tried to use the doctrine of fair apportionment, viewing interstate disputes as being between co-equal sovereign entities. Many interstate water matters have been addressed through the creation of interstate compacts, in effect treaties of a sort between states. These are given some attributes of federal law through the requirement that they be ratified by Congress. Compacts dealing with water resources cover a wide range of issues, from water quality and bridges to interstate allocations of water.

In Australia, the states each have jurisdiction over water use in their territories, and the federal government has no constitutional responsibility. However, in practical applications, the scarcity and importance of water in the country have led the Commonwealth government to become involved in cooperative federalism with respect to water resource development.[28]

HYDROELECTRIC DEVELOPMENTS IN SHARED WATERCOURSES

In relation specifically to hydroelectric projects on contiguous watercourses, there had emerged a rough rule of thumb that was widely applied: there should be an even (50/50) division between the parties. The division could be of the water itself (as it is between the United States and Canada for water taken out of the Niagara River above Niagara Falls) or of the electricity generated.

An equal split was negotiated in the Treaty between (then) Czechoslovakia and Hungary regarding the Gabíkovo-Nagymaros system of projects on the Danube. That system included works to improve navigation, provide flood control, improve the water flow, and produce hydroelectric power. The costs and the energy produced were to be

[27] Cairo, Richard A., "Dealing with Interstate Water Issues: the Federal Interstate Compact Experience," in Richard Just and Siniaia Netanyahu, eds. (1998), *Conflict and Cooperation on Transboundary Water Resources*, Kluwer.

[28] Pigram, John. J and Warren F. Musgrave, "Sharing the Waters of the Murray-Darling Basin: Cooperative Federalism under Test in Australia," in Richard Just and Siniaia Netanyahu, eds. (1998), *Conflict and Cooperation on Transboundary Water Resources*, Kluwer.

evenly shared between the two parties, regardless of where the generation facilities were located.[29]

Within Canada, a similar split occurs between Ontario and Quebec for electricity generated on the Ottawa River where it forms the border between the two provinces.

IDENTIFYING BENEFITS IN MULTIPURPOSE PROJECTS

Many water projects have more than one purpose. Determining hydroelectric rents in such projects can be difficult. The rent is the return to the hydroelectric resource above its normal rate. With common costs, the return is often calculated for the project as a whole, not for any component. To determine the return to one component, first a cost must be assigned, so that the return can be computed.

One way to assign costs to particular components of multipurpose projects is the separable costs-remaining benefits method. This method allows allocation of the overall benefits from a project to its components. Since the method relies on costs, it does not necessarily compute the rents available from the project, but it does provide a start on the problem of apportioning rents from multipurpose projects.

The exposition here largely follows that in Alvin Goodman's Principles of Water Resource Planning.[30] The separable costs-remaining benefits approach starts by assigning a separable cost to each purpose of the project. The separable cost is defined as the difference between the cost of the project as built with all components and the cost if the component were left out. That cost is therefore directly identified as the cost that is incurred only and specifically for the individual purpose.

Project costs remaining once all the separable costs have been identified are the total joint costs of the project. These costs must then be allocated among the purposes to obtain an estimate of the total costs for each of the components. The basis on which the joint costs will be allocated is its share of the total costs.

The allocation is best described with the aid of an example, shown in Table 3 below. The example is taken from Goodman.[31] It describes a project with a total cost of $350 million and four purposes.

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[29] Liska, Miroslav B., "Development of the Slovak-Hungarian Section of the Danube," in Gerald H. Blake, William J. Hildesley, Martin A. Pratt, Rebecca J. Ridley and Clive H. Schofield, eds. (1995), *The Peaceful Management of Transboundary Resources*, Graham and Trattman, p. 154.

[30] Goodman, Alvin S. (1984), *Principles of Water Resource Planning*, Prentice-Hall, Ch. 8.

[31] Ibid., p. 231.

TABLE 3: ILLUSTRATION OF SEPARABLE COSTS-REMAINING BENEFITS CALCULATION

Item	Description	Purpose A	B	C	D	Total
1	Benefits	140	100	150	100	490
2	Adjusted Cost	100	120	100	130	450
3	Justifiable Costs /a	100	100	100	100	400
4	Separable Costs	80	50	20	0	150
5	Remaining Benefits /b	20	50	80	100	250
6	Allocated Joint Costs	16	40	64	80	200
7	Total Allocated Costs /c	96	90	84	80	350

/a Lesser of Lines 1 and 2.
/b Line 3 - Line 4.
/c Line 4 + Line 6.

Source: Derived from Goodman, ibid., p. 231.

Line 1 in the table shows the benefits of each project component, computed as discounted net present value (NPV) of the benefits. Line 2 shows the cost of the next least-cost alternative to achieve the same result. Line 3 has the "justifiable costs" (also called "adjusted benefits"), which are the lesser of lines 1 and 2. If an alternative would cost less than the benefits of the component, the benefits cannot be more than that alternative cost.

Line 4 shows the separable costs, which are derived as indicated from consideration of the reduction in project cost if that component is omitted entirely. The remaining benefits, on line 5, are simply the justifiable costs less the separable costs. The justifiable costs indicate the benefit from that component; subtracting its separable cost leaves the amount of benefit remaining for that component. The total of remaining benefits will equal total project justifiable costs less total project separable costs.

The allocation of the joint costs is shown on line 6. The total of line 6 is the total project cost ($350 million, not shown on the table) less the total of the separable costs ($150 million), or $200 million. This is the amount to be allocated among the purposes. The allocation is in proportion to each purpose's share of the total remaining benefits. For example, purpose B has one fifth (50/250) of the total remaining benefits, so it is allocated one fifth ($40 million) of the allocated joint costs.

The total cost for each purpose is shown on line 7 as the sum of its separable costs and its allocation of the joint costs. The amount on line 7 can then be compared to the justifiable cost to compute a benefit/cost ratio or other test to determine whether the project is economic.

This methodology offers an analytical way to apportion the common costs of a project. The apportionment remains somewhat arbitrary; it assumes that the components share in the common costs in proportion to their share of the remaining benefits. This assumption at least provides an analytical basis for the allocation of the costs.

For multipurpose projects with hydroelectric developments, the separable cost remaining benefit methodology offers a way to identify the rent attributable to the hydroelectric portion. This analysis would therefore be the first step in apportioning hydroelectric rent to the owners of multipurpose projects.

This step does not eliminate the problem, in identifying rent, of finding the true least-cost alternative to the development. Finding the separable benefit requires estimates of the total value of the electricity generated and the incremental costs of the electricity component. These are the amounts on lines 1 and 2 in the table. To apply this methodology, all of these values must be discounted to present value at the same rate as for the rest of the project, implying that all have the same risk factors.

One principle underlying this methodology will be applied later to the apportionment of hydroelectric rents in multiple jurisdictions. That principle is that the first assignment of economic responsibility (in this case, costs; in the case of the rents, benefits) for multipurpose (multijurisdictional) projects should be that amount that can be directly identified with one purpose or owner. Such amounts can be separated from the common costs or benefits and assigned to that purpose or owner. Then the remaining costs or benefits from the joint project must be apportioned on some reasonable basis.

5. SHARING WATER RENTS—PRACTICE

There are relatively few examples of actual calculation of or reference to the rents from a hydroelectric or other water development. In part, this reflects the difficulty of computing rents when a true market value of the output is not available. In part, it reflects the practice of charging a royalty or other payment that usually does not depend on the economic returns to the project.[32] This is similar to the practice of assessment of royalty in the resource extraction industries, where royalties are frequently computed on either the market value or the volume of the resource extracted, without reference to the overall profitability of the project and therefore the amount of rent it earns.

Below are some examples of explicit calculation of rents associated with a project, and the explicit sharing of the rents among different owners.

EXPLICIT CALCULATION OF RENTS

The Lesotho Highlands Water Project

Lesotho is a small southern African kingdom, completely surrounded by South Africa. The country consists of a high plateau in the western part of the country, along the Caledon River which there forms the border with South Africa. Most of the population is located in this western portion. In the east, Lesotho is mountainous (the Maloti Mountains) and sparsely settled, but well watered. The major river draining this portion of the country is the Senqu, which flows out of Lesotho into South Africa where it is called the Orange.

The water flowing from the Senqu River therefore, if not used consumptively by Lesotho, will come to South Africa. The Orange River flows westward across much of South Africa, eventually forming the border between South Africa and Namibia.[33]

The Lesotho Highlands Water Project (LHWP) is a water transfer and hydroelectric scheme being built in the mountains of Lesotho. The conditions of the

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[32] In some cases, the amount of the royalty may be based on an informal assessment of the likely economic returns to the project in question.

[33] Namibia is therefore a downstream riparian for the Orange/Senqu system. However, relative to the Orange at that point, the water transfer to the Vaal system is mostly nonconsumptive. The Vaal flows into the Orange, and most of the water to be used will ultimately be treated and returned to the Vaal. The most important consumptive use is watering lawns and gardens.

project are governed by a treaty between Lesotho and South Africa.[34] The provisions of the treaty give an example of the explicit consideration of the rent available from a water project.

In this case, the resource that generates the rent is not the water itself. The water ultimately belongs to South Africa; Lesotho has no reasonable possibility of significant consumptive use of the water. The area where the Senqu flows is mostly mountainous and sparsely populated, leaving little demand for water for domestic or industrial use. There is also little arable land that could be successfully irrigated. Lands that could benefit from irrigation are in the western part of the country, much closer to the Caledon.

South Africa has its highest-value use for the water in the Vaal River system, which provides domestic and industrial water to the Johannesburg and Pretoria areas. These lie to the north and west of Lesotho and the Orange River system. South Africa could, therefore, simply wait for the water to flow out of the mountains and construct a series of works entirely within South Africa to transfer it to the Vaal system. However, if the water is captured in the Maloti Mountains in the Senqu system, much of it can flow into the Vaal system by gravity, through a much shorter and less complex series of works than would be required to transfer it from the Orange River.

The resource that generates the rent therefore is the location of the water, far enough up in the mountains to allow the transfer of some of it entirely by gravity, through a shorter and less complex set of works.

Following the discussion of Chapter 3, therefore, the rent should be seen as the difference in cost, due to the unique physical nature of the resource, between the resource generating the rent and the next cheapest alternative. In this case, that would be the difference between the cost of a system in Lesotho and the alternative system entirely in South Africa, each optimally designed to produce the same result in terms of water transfer.

That is precisely the way that the treaty defines the basis for the payment of royalties from South Africa to Lesotho. In this case, the royalties cannot be seen as payment for the water itself, since that would come to South Africa in any case. The royalty is to be seen as payment for the use of the water in its higher elevation in Lesotho.

The treaty bases the royalty payment on the difference in cost between two entirely hypothetical systems. Each of them is designed to deliver 70 cubic meters per second (cumecs) of water to the Vaal River system. The first system, which forms the

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[34] Treaty on the Lesotho Highlands Water Project between the Government of the Kingdom of Lesotho and the Government of the Republic of South Africa *"The Treaty"* (1987), Ministry of Water, Energy and Mining, Government of Lesotho.

basis for the alternative-cost calculation, is the Least-Cost Orange Vaal Transfer Scheme. It is a system of canals, tunnels, siphons, and other works that would move that much water from the Orange River to a tributary of the Vaal. The other system, whose cost forms the basis of the royalty payments, is called the least-cost Lesotho Highlands Water Project Initial Development. It is a system of dams, tunnels and pumping facilities that will also deliver 70 cumecs to a tributary of the Vaal. This system is one optimally designed for that purpose.

The royalty to be paid to Lesotho has three components: an investment element, an operation element for pumping cost differences, and an operation and maintenance cost element. These are the elements of the cost differences between the Orange Vaal transfer scheme and the LHWP. The royalty payment is then calculated as 56 percent of the cost differences.[35]

Under the terms of the treaty, South Africa essentially is responsible for all the construction costs of the LHWP as it is being built. The works are being financed by a variety of international aid agencies and multilateral lending institutions, including the World Bank, but payment for the loans is entirely the responsibility of South Africa. The returns to the costs of the works themselves, therefore, are also entirely South Africa's, in the form of the water. The royalty is a split of the savings South Africa makes between what it could do by itself and what it can do in cooperation with Lesotho. In that sense, the royalty calculation base is close to a true definition of the economic rent available from a cooperative solution.

It is worth noting that neither of the projects on which the royalty calculation is based will ever be built. The optimal LHWP scheme is for water transfer only, and assumes that the entire 70 cumecs are ultimately delivered. The scheme that is actually being built is determined by the treaty, which only firmly commits to the first two phases of the project, which together are able to deliver only about 38 cumecs.

The project that is being built also has hydroelectric generation at the outfall from the first set of transfer tunnels. The electricity generation facilities are being built entirely by Lesotho, which also is entitled to all the electricity.

The design of the project actually being built is affected by these two conditions. For example, the main water transfer tunnel is designed to handle only the water committed in the first phase. Later phases, which will require pumping from dams farther down the Senqu system, would require building an additional tunnel. In the optimized single system, however, all the water transfer would be in a single tunnel.

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[35] The *Treaty*, Article 12.

The concept of rent-sharing is carried over to the treaty's provisions for royalties in the event that the entire project is not built. If the cancellation of later phases is a unilateral South African decision, the royalty will be based on the difference in cost between two projects (an Orange Vaal Transfer Scheme and a version of the LHWP) each optimally designed to deliver the amount of water actually available from the system as built. In other words, the royalty is based on the true rent for whatever part of the whole project is actually completed.

If subsequent phases are canceled by mutual agreement, however, the royalty is based on the difference in cost between two alternative projects that would accomplish the original aim of delivering 70 cumecs of water to the Vaal River system. One project would be the original optimal Orange Vaal Transfer Scheme, designed to deliver the full 70 cumecs. The other would be a combination of the LHWP at whatever capacity it was built and a project called the Follow-On Orange Vaal Transfer Scheme, designed optimally to deliver whatever volume of water was needed to make up the total of 70 cumecs. This royalty is again based on rents, but this time the rent is defined relative to the full target volume, not to whatever is actually delivered. It is clear that the rents from this calculation will be lower than those from the first, since there are likely to be significant economies of scale (and loss of them for the Follow-on Scheme) in the construction of the Orange Vaal Transfer Scheme.

In summary, then, the provisions of the treaty for the LHWP are an excellent example of the definition of the rent available from the project, looking carefully at what constitutes the resource generating the rent.

The apportionment of the rent between the parties was clearly a matter for negotiation. There does not appear to be a readily available method of rent apportionment, and the 56 percent agreed upon appears to be a result favoring Lesotho slightly over what might have been a baseline 50/50 split of the rental. In part, this favoring Lesotho could reflect the fact that, relative to South Africa, Lesotho is a small and poor country. The water in the Maloti Mountains can be seen to be its only significant natural resource, and the revenue from its transfer under the treaty provisions can become a significant source of revenue.

Lower Churchill Falls Hydroelectric Development

The Canadian province of Newfoundland and Labrador consists of the island of Newfoundland, some other islands in the Atlantic, and the mainland area of Labrador. Its main population and activity centers are on the island of Newfoundland. Labrador is generally sparsely settled. The province of Quebec lies west of Labrador, and is geographically closer to many parts of Labrador than is the island of Newfoundland. To get from Labrador to the United States efficiently, it is essential to cross the province of Quebec.

The Churchill River is located in Labrador, and flows into Labrador Bay, on the Atlantic Ocean. It has significant hydroelectric generation potential. Some of that potential is already taken up, with the Churchill Falls dam and generation complex. That complex was built in the 1960s, by a joint venture of Newfoundland and Labrador Hydro and Hydro Quebec, the Crown-owned electricity generation and distribution companies in the two provinces. The ownership ratio is roughly two thirds Newfoundland and Labrador Hydro, one third Hydro Quebec. The power is sold to Hydro Quebec under a long-term fixed-price contract, at a price that was fixed in money terms at the time the contract was signed, and now produces significant profits for Hydro Quebec, which exports most of the power to the United States.

Recently, Quebec and Newfoundland have signed a preliminary agreement to develop further hydroelectric generation at the Gull Island site on the Lower Churchill River. This agreement addresses some of the problems of the earlier site, and brings closer the exploitation of the most economic large-scale hydroelectric generation site in Canada.

Under terms of the agreement, the generating station at Gull Island will be built by a limited partnership between Newfoundland and Labrador Hydro and Hydro Quebec, with ownership in the same ratio as for the existing Churchill Falls generating station. Additional generating capacity will also be built at the existing Churchill Falls site, utilizing water to be transferred from Quebec into the Churchill River system.

Newfoundland and Labrador Hydro will buy 1,000 megawatts (MW) of the planned 2,264 MW, and 7.5 terawatt-hours (TWh) of the expected 13 TWh annual production, for use in Newfoundland. It will build a new transmission line to the island of Newfoundland to carry this power. The price for this power will be based on cost, including a "fair and reasonable" rate of return to the partnership.[36] The remainder will be purchased by Hydro Quebec under a market netback arrangement, with the market price based on a border export price or other market price at the time of the sale, and the returns to the partnership calculated net of the transmission charges and a 2.8 percent marketing fee to Hydro Quebec.

The Province of Newfoundland and Labrador will also receive a royalty from the project. The royalty regime is being negotiated. However, it will constitute a fraction (not to exceed 50 percent) of the profits of the partnership above a level specified as providing a "fair and reasonable return on equity" to the partnership. The royalty is therefore an explicit share of the economic rent. The market value of the electricity is established as its

[36] Churchill River Power Projects (1998), "Framework for Churchill River Hydro Developments," Fact Sheet.

price in the competitive Northeast markets, and the amount subject to royalty will be defined as the amount above a normal economic return for the investment in the project.

This is another case of a clear definition of the economic rent as being the above-normal return to the entity, based on a market price for the resource product. The formula for sharing this rent, in the form of the royalty to the Province, has yet to be determined, but it is clear that there is a sense of sharing it with the partners owning the productive capacity, who in turn are creatures of their respective provincial governments.

The resource producing the rent is taken to be the physical nature of the falls at Gull Island, including the water flow, the height, and the ability to dam the river for hydroelectric production. This project is interjurisdictional because cooperation from the province of Quebec is essential to the success of the project; without transmission lines to and across Quebec's territory, the power would find no market. Under the terms of the project as announced, however, Quebec gets no direct rent. It does get a share of the rent from its share of the residual excess profit, if any, of the joint venture building the Gull Island project. There is no announced provision for any rents to be paid to Quebec for the use of its territory for the transmission lines.

EXPLICIT SHARING OF BENEFITS: THE COLUMBIA RIVER TREATY

The Columbia is an important river in the western part of North America. It rises in the Canadian province of British Columbia and the mainstem flows from there into the US state of Washington and into the Atlantic. It has important tributaries in Canada and in the United States. A large fraction of the total water in the river comes from snow melt in the mountains, so that the flow is highly seasonal. The river has therefore been subject to severe flooding, mostly in the United States. In general, Canada is the upstream riparian and the United States the downstream riparian with respect to the Columbia and its tributaries, but some rivers flow north into Canada from the United States before turning around and flowing south again, or emptying into a river that eventually flows south.

The British Columbia River has large hydroelectric potential. It has been heavily developed in the United States. At the time of the negotiation of the Columbia River Treaty, 1,121 of the 1,288-foot drop from the Canadian border to the mouth of the river were either developed, under construction, or under active consideration for electricity generation, often in multipurpose projects including flood control and recreation. There were also developments on the US tributaries. By contrast, none of the mainstem of the Columbia river had been developed in British Columbia.[37]

[37] John V. Krutilla (1967), *The Columbia River Treaty: The Economics of an International River Basin Development*. Resources for the Future, p. 23.

The United States had two objectives from cooperative development of the Columbia River in British Columbia: increased flood protection and increased generation at its existing hydroelectric stations, some of which were run-of-the-river and some of which did not have enough storage to allow full utilization of the total annual water flow.[38] British Columbia did not need flood protection, but could use some additional electricity to meet expected domestic needs.

An International Joint Commission (IJC) was instrumental in the negotiations. It had two principles that were relevant for the sharing of the benefits: first, that the joint development should develop only those potential projects that are most economical, eliminating those that are mutually exclusive to the most economical, and that the most economical should be developed first; and, second, that the parties should not be worse off after a cooperative development than they could be independently.

The Treaty ultimately obliged Canada (an obligation transferred by the federal government to the Province of British Columbia) to provide a fixed amount of storage on the Columbia River system. In return, Canada gets an upfront fixed payment representing the discounted present value of the flood control benefits, plus the rights to half of the additional electricity generated because of the added storage.

This electricity (called the Downstream Benefits, or DSBs), was then sold by British Columbia to buyers in the United States on a 30-year contract for an upfront payment. The total of the upfront payments for flood control and electricity sales was sufficient to pay for all of the treaty projects in British Columbia, plus about half the cost of installing hydroelectric generation facilities at Mica, one of the treaty dams. The electricity from that facility is the sole property of British Columbia Hydro.

In keeping with the second IJC principle, British Columbia did determine the cost and benefits of a set of projects it could pursue independently that would provide a comparable amount of electricity to that available from its half of the benefits from the cooperative project. The independent project was seen to be more expensive and to produce less net electricity. Therefore, British Columbia concluded that it would be no worse off under the treaty than it could have been by itself.

On the other hand, Krutilla says that the United States could have accomplished the same flood control and electricity generation objectives at a cost to it lower by about a third of a billion dollars.[39] He also notes that the actual treaty projects may not have been

[38] Additional storage can increase annual generation because it can prevent spillage of water during periods of high flow. It can also increase the amount of water available to run-of-the-river plants during periods of low flow.

[39] Krutilla, op. cit., p. 184.

the most economic to achieve these goals. He especially notes that the one part of the treaty projects to be built in the United States, the Libby project on the Lower Kootenay River (a tributary that rises in British Columbia, flows south into the United States in Montana, then turns north into Idaho and flows back into British Columbia and ultimately into the Columbia) probably dissipates some of the advantage the United States could otherwise obtain.[40]

In summary, at least one analysis implies that a simple 50/50 sharing of the electricity in the Columbia River Treaty has overpaid the upstream riparian for its contribution to the joint project, and jeopardized the economic return for the downstream riparian.

40 The Libby project could not be built without international cooperation since its reservoir floods back into British Columbia.

6. PRINCIPLES OF SHARING WATER RENTS

Previous chapters have developed the theory of rents, its application to hydroelectric development, and the issue of the ownership of the resource. Where the resource belongs to a single owner and can be developed by that owner, sharing the rents from the development is not an issue. However, where a resource is shared between more than one owner, or where a resource can only be developed cooperatively, the parties to the development will need to negotiate an agreement that involves, among other things, the sharing of the net benefits, or rents, from the project.

Where possible, this chapter evolves some basic economic principles for such sharing. Where basic principles do not provide a basis for rent sharing, the chapter draws on the past practice described in Chapter 5.

THEORETICAL DEVELOPMENTS

Barrett[41] has proposed an approach to the sharing of a natural resource between two parties, a buyer and a seller, under conditions of uncertainty of the amount of the resource to be available and a single contract to be negotiated between a buyer and a seller.

Barrett proposes five potential contract arrangements, two of them symmetrical to each other. The first pair are that the seller or the buyer control absolutely the amount of the resource to be allocated to each party. The second pair is that the seller or the buyer control how much of the resource it keeps, and how much to offer to the other party, who then has the choice of taking all or some part of the offered resource at some price. The fifth alternative is a command solution that attempts to maximize total expected benefits. Under these conditions, Barrett concludes that the optimal contract occurs when the party with the highest expected net benefit is allowed to choose how much of the resource it wishes to keep.

While this work is interesting, it does not provide a guide to allocation of rents in the situations under study here. It relates to the allocation of the resource itself, not to the benefits, and therefore implies that the allocation of the resource is for a consumptive use.

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[41] Barrett, Richard, "The Efficient Sharing of an Uncertain Natural Resource: A Contract Theory Approach," in Gerald H. Blake, William J. Hildesley, Martin A. Pratt, Rebecca J. Ridley and Clive H. Schofield, eds. (1995), *The Peaceful Management of Transboundary Resources,* Graham and Trattman.

In the case of hydroelectric development, the use of the resource itself is nonconsumptive.

If the resource to be allocated is viewed as the electricity supply, however, this conclusion could offer some guidance in the determination of a "reasonable and equitable" allocation in that it addresses the allocation only of that portion of the total supply that is subject to risk. It suggests that under those conditions where one party has a higher expected value, and the two parties are equally risk-neutral, the electricity should be allocated first to the party with the higher expected value for it.

PRINCIPLES OF SHARING IN TRANSBORDER HYDROELECTRIC RESOURCES

To develop principles of sharing, it is necessary to quantify what is to be shared. As Chapter 5 of this report showed, in some cases what is shared is the resource itself, in the form of the water; in others, it is the resource product, in the form of electricity; in others, it is money. Explicit sharing of rents requires explicit statement of the rents available and a negotiated settlement to share that amount.

Where the rent is the difference in cost between two alternative methods of achieving the same result, all the inputs to that consideration must be quantified in the same terms. In this case, the terms will be monetary. All costs of a project, including environmental costs and others, must be quantified to allow proper rent calculation. Similarly, all the benefits must be understood on the same basis, which means that they also must be quantified in money terms.

Where there is a competitive market for the output of the project, the rent is readily defined as the excess of the return to the project over a normal risk-adjusted profit rate when the output is valued at the market value. The market allows a clear statement of the alternative cost of the same output.

Sharing a Successive Watercourse

Consider a successive watercourse that has sufficient water flow and sufficient head over some portion of it to allow hydroelectric generation, where the watercourse continues to drop as it crosses the boundary between the upstream and downstream riparians. How could the benefits (rents) from exploiting this resource be shared?

The problem requires first defining the nature of the resource creating the benefit. Start with the simplest case, that of a resource that can be a run-of-the-river hydroelectric generation site. This case is depicted in Diagram 1, where U is the upstream riparian, D is the downstream riparian, and B represents the boundary. In that case, the resource is the water and the drop. Electricity can be generated as a direct linear function of the head and the water flow, as:

$$kW.h = c \times H \times W$$

where kW.h is the output in kilowatt-hours, H is the height of the head, and W the volume of water. C will depend on the units of measurement. If H is in feet and W is in cubic feet per second, C will be 0.072, assuming 90 percent turbine and 94.5 percent generator efficiency.

Each of the parties in this case could conceivably act on their own. Country U could build a tunnel from the optimal point for it, the start of the steep drop, to a power plant or outfall at the border B. Similarly, country D could build a tunnel from the border to the point where the watercourse ceases to drop steeply. These potential tunnels are shown on Diagram 1.

Each of these individual projects could produce some level of economic rent, assuming that each would produce electricity at a price lower than the optimal alternatives available.[42]

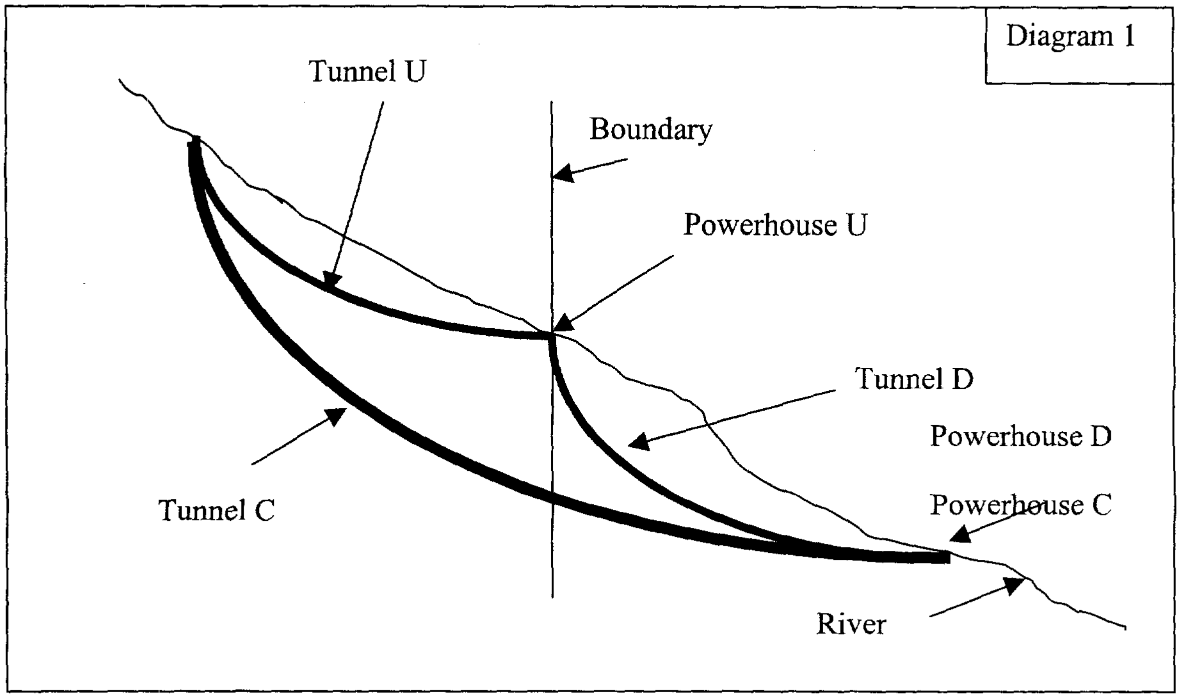
A cooperative project is also available. It would create a tunnel from the intake point in country U to the outfall in country D. It, too, could generate some amount of rent. Assuming that there are some economies of scale in tunnel and powerhouse construction, and in turbine design, it can be expected that the cost of the cooperative project would be lower than the combined cost of the two individual projects. The cooperative project, too, could generate some amount of rent. If its costs are lower than those of the combined individual projects, it would generate greater rent.

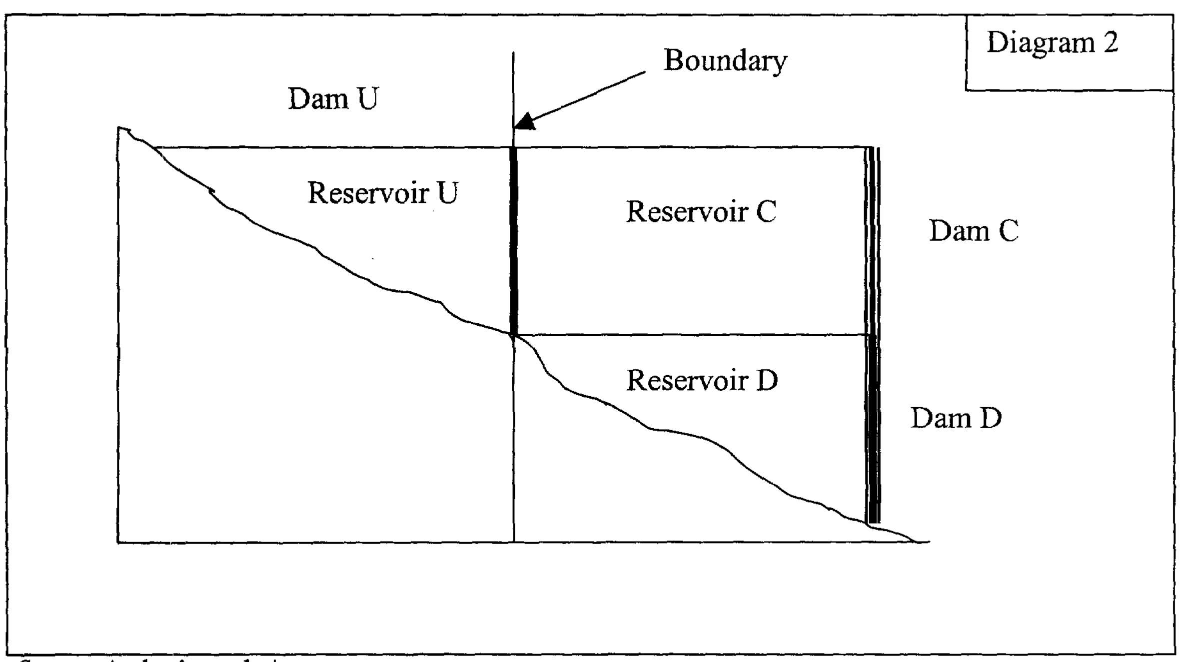
How is that rent to be apportioned between the two parties? As a first principle, each riparian should get at least as much rent as it could generate by its own independent project. That leaves each no worse off than it could do by itself.

Assuming that additional rents are available, how are they apportioned? One rule might be to apportion them relative to the ownership of the resource, which in this case would be the height of the drop. This rule has a certain appeal, in that it assigns rents to owners in relation to their ownership of the scarce resource producing the rent. It does not relate well to the criteria in the UN Convention; a division according to the relative possession of height of drop may not be seen to be reasonable and equitable. However, this division does at least create a starting point, based not on political or equity considerations but on the physical nature of the resource.

[42] As the examples of Chapter 3 showed, the definition of the optimal alternatives and the calculation of the economic rent available are not trivial problems. The amount of rent will depend on, among other things, the nature of the next best available resource and the load characteristics of the electricity system.

FIGURE 4: DIAGRAMS FOR DEVELOPMENT OF A SUCCESSIVE WATERCOURSE





Source: Author's rendering.

A simple extension of this first principle can be made for a similar project, but one where the water flow is seasonal enough, or the electricity demand is seasonal enough, to warrant storage. This situation is illustrated in Diagram 2. Again, the upstream country, U, could conceivably build a project on its own, with a dam on the border and the dam height reaching the point where the watercourse begins to slope downward, so that the reservoir will extend back to that point. Similarly, country D could build its own dam, with the reservoir extending to the border, which would be the foot of the dam of country U.

Each of these individual projects could create an amount of rent, which would depend on the nature of the alternatives available for electricity generation, the seasonality of the water flow and the consequent value of storage, and the seasonality of the electricity demand.[43]

Again, a cooperative solution is available, with the construction of a dam on the territory of D and the reservoir reaching back to the same point in U. This cooperative project could generate some amount of rent. That amount will be greater than the total of the rents from the individual projects for two reasons. First, economies of scale available in construction will give the joint project lower cost. Second, it will have a significant advantage over the single projects: it will afford significantly increased storage, of the amount shown on the diagram as Reservoir C. Storage has value, so that the rent from the cooperative project can be expected to be much larger than the sum of the rents from the two independent projects.

How is this rent to be apportioned between the two countries? The first principle from the simpler example still holds: each country should get at least the rent available to it from the noncooperative project. In this case, ensuring this principle requires explicit agreement between the parties. The dam and generating facilities are on the territory of the downstream riparian. Ensuring returns to the upstream riparian therefore likely requires some transfer of funds from the downstream to the upstream riparian.

The principle stated here provides a minimum for that transfer: it should represent at least the return that the upstream riparian could have achieved by building its own dam U and selling the output in the best available market.

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[43] This is one of the few cases where the downstream riparian may have a stronger bargaining position than the upstream riparian. The downstream riparian could unilaterally build the larger dam, which would make the upstream riparian's dam worthless by leaving it with no head. However, if the upstream riparian has already built the dam, it will hold back water whenever the downstream riparian starts to draw water down in its reservoir.

Similarly, the returns accruing to the downstream riparian from dam C, after payment to the upstream riparian, should at least be equal to the return that it could have obtained by building its own dam D.

In this case, there is likely to be considerable additional rent available after these principles are met, because the additional storage could have considerable value. It is more difficult in this case to apportion this additional rent on the basis of physical attributes. Each country contributes some physical attributes to the size of the additional reservoir C. The downstream riparian contributes its length, while the upstream contributes its height, in some sense. Each contributes the width of the reservoir in its territory.

Since the volume of storage is the product of the three dimensions, assigning a value to any one or two of them is difficult. If any of the three dimensions is zero, the storage is zero. In a sense, then, each country can be said to have contributed all of the value of the additional storage, since it could not have arisen without a contribution from each country.

In the absence of a physical basis for allocating the rent, the default position, as on contiguous waterways, is an even (50/50) split of the rent added by Reservoir C. That value is still calculated as net of the incremental costs; the builder of the dam and other works is first entitled to a normal rate of return on the investment in the works. Beyond that, the rents should be explicitly divided.

The ultimate disposition of the rents from the project will in any case be a matter of negotiation between the two jurisdictions. The proposition here can only form a starting point for the discussion of a reasonable and equitable distribution of the benefits. This basis for division is consistent with the UN convention, which includes as the first of the factors to be considered in reaching an equitable and reasonable division the natural character of the resource. It allows these factors to be quantified and the division better understood.

The addition of storage to the project further complicates the situation in other ways. First, additional storage will have other benefits than improving the load meeting characteristics of the cooperative as opposed to the unitary project. Most of these other benefits occur downstream of the project, and therefore benefit country D or another downstream riparian. These benefits are mostly in the form of improved hydroelectric generation at downstream facilities, and better flood control from the increased storage.[44]

[44] The larger reservoir could also increase the value of the project for consumptive uses, like irrigation. This could be treated in the same way as the value of the electricity rents.

The Columbia River Treaty, discussed in Chapter 5, is an example of the sharing of benefits from a successive watercourse, where the benefits to be shared consisted entirely of the value of additional storage. The treaty obligates Canada to provide a certain amount of storage, not any other product or service. The storage itself provides the value.

Similarly, any project that increases storage has the potential to increase downstream benefits. This may complicate the negotiations over the allocation of the benefits by producing benefits entirely on the territory of country D or those downstream of it. For example, the additional storage can increase the value of electricity production at hydroelectric developments downstream of country D. As Krutilla[45] shows, the storage value can be calculated, taking into account both the flood control benefits (which must be valued on an expected value basis) and electricity generation benefits. This value must be added to the value of the storage in generating electricity at the site itself.

This project also creates additional costs. Its costs are the costs of the lost land due to flooding, including any resettlement required, and the environmental damage cost of the flooding. Set against these costs are the potential benefits from increased recreation and improved transportation on the river, at least on that portion upstream of the cooperative dam C. These costs and benefits can also be calculated. The costs become part of the costs of the project, to be treated just like other costs such as out-of-pocket costs for construction of the dam. They are then subtracted from the benefits to obtain the net amount of rent available for allocation between the countries involved.

Sharing a Contiguous Watercourse

The first principle for sharing in a successive watercourse, that neither participant should collect less benefit from a cooperative project than it could realize on its own, cannot readily be implemented in a contiguous watercourse.

Either both riparians can act unilaterally or neither can. For example, in the case of the Niagara River, which forms the border between the United States and Canada, there is enough reliable water for either side to extract water unilaterally and build run-of-the-river generation facilities.

On the other hand, the Ottawa River between the Canadian provinces of Ontario and Quebec does not afford a place where run-of-the-river generation would be economic, though it does have several places where a dam could create an economic hydroelectric site. However, neither riparian could act alone. The dam requires that part

[45] Krutilla, John V. (1967), *The Columbia River Treaty: The Economics of an International River Basic Development*, Resources for the Future.

of the works be on the territory of each riparian, even if the border is declared to be on one bank or the other.

As discussed in Chapter 4, there is a problem of the commons in contiguous systems, where each riparian has some incentive to make preemptive use of the resource. A cooperative project is likely to produce lower benefits to one riparian than it could achieve by preemptive action, if that is available. On the other hand, where preemptive action is not possible, the resource can be exploited only by a cooperative project.

The problem of defining and sharing rents in this case is defining who owns the features of the resource that create the rent. Since the resource for hydroelectric generation is the water, its drop and volume, neither riparian can be said to own that resource. It is inherently shared. It is this inherently shared ownership that has led to the use of the common rule of thumb, noted in Chapter 4, that the benefits are shared equally. Beyond that sharing, the objectives of the UN Convention can be invoked.

Cooperative Development of a River Basin

The example derived above is a special case of a more general observation. Cooperative approaches to development of a river basin, which allow optimal development at all points along the basin, will in general produce greater benefits (lower costs, higher rents) than will a series of unitary developments. The downstream riparians can benefit from regulation and flood control upstream, as they could not do by themselves. The upstream riparians can benefit if they can share the increased value their cooperation creates downstream.

7. PRINCIPLES FOR SHARING BENEFITS

PRINCIPLES DERIVED FROM THE THEORY OF RENTS

Rents accrue to unique resources that are in naturally limited supply and can produce a good more cheaply than alternative resources. Rents are returns above the normal rate of return, and represent the unique value of the particular resource. Rents accrue to the owner of the resource that generates them. In the case of natural resource-based rents, the owner is usually the government of the country where the resource is located. The resource is taken to be a gift of Nature to the country, and the government is the steward of that gift on behalf of the people.

In the case of resources that can produce hydroelectricity, the basic resource is defined by the generation equation: the head and the water flow. An additional resource is the potential for storage. In the case of international watercourses, rents cannot be collected and assigned to an owner until the ownership has been defined.

The principle derived in Chapter 6 for the allocation of rents from cooperative development of hydroelectric power on international watercourses is that, where independent action is possible and noncompetitive, countries participating in cooperative developments should be able to obtain at least as much rent as they could through independent action.

This principle can be broadened to include the benefits available from the integrated development of an entire river basin. Coordinating development can produce a much lower cost for all of the benefits, therefore increasing the rents available. By extension from the solution for an immediate cross-border development, the participants in a cooperative development of an entire river basin should not be worse off than they would be if they had acted independently. There are significant benefits available for such cooperation along a successive river, assuming that there are no portions where partners on a contiguous section have incentives to act alone and reduce their partners' ability to use the river.

This principle does not hold as well in development of a contiguous river, when each partner may have an incentive to preempt any use by the other. For hydroelectric development in such cases, it may still be true that the cooperative solution is preferred to any set of independent actions. Then the usual practice has been to make an equal division of the benefits, perhaps because of the difficulty of ascertaining that either party owns more than half of the shared watercourse, which constitutes the resource.

PRINCIPLES OF CALCULATION OF HYDROELECTRIC RENTS

To have explicit sharing of hydroelectric rents, the amount of the rent must be calculated. In theory, this amount is readily understood: it is the amount by which the total cost of the hydroelectric generation lies below the cost of the least-cost alternative method of getting the same result, which is typically the same amount of electricity.

The cost of the hydroelectric generation will be affected by the physical nature of the resource, including water flow, head, factors affecting construction cost like soil conditions, the cost of transmission, and other costs including environmental and resettlement costs. The value of the hydroelectric generation will be affected by anything that changes the value of electricity, such as improvements or deterioration of cost or productivity in the alternative electricity supply, transmission capacity elsewhere in the network, and other factors.

Rents from hydroelectric generation are therefore difficult to calculate explicitly. The usual practice is therefore not to do so. In many countries, the rents are simply transferred to electricity consumers in the form of lower, cost-based prices. In others, the rents may effectively be captured by companies or others who are given the rights to exploit resources that could produce rents.

The difficulty of calculating the rents varies with the circumstances of the project. A progression of cases can be stated and analyzed.

Single-Purpose Projects

Where a Competitive Market Exists

If a competitive market exists for the output of a single-purpose project, calculation of the rent is theoretically straightforward. This is the case, for example, of the proposed Gull Island project in Labrador, Canada. There is some economic rate of return the project should earn. The return is calculated using the market price, which represents the cost of any alternative supply (on the assumption that the project is not so large that it influences the market price). The return should be adjusted for the risk of the project. Any long-term returns to the project above that risk-adjusted return to the investment constitute rent.

Even though this theoretical definition is straightforward, its practical application requires definition of a number of factors. In the case of the Gull Island development, for example, significant issues have arisen in determining exactly what the base will be for the calculation of the proposed "profit-sensitive royalty."

Where No Competitive Market Exists

In the absence of a competitive market, the rent is the difference between the cost of the project and the cost of the next most economic alternative that will accomplish the same result. This calculation is still relatively straightforward theoretically. Applying this approach is more difficult than in a market environment. The result of the project must be clearly defined, in order to structure the alternative clearly. There must be consideration of several alternatives in order to determine which is the most cost-effective. This is the case in the Lesotho Highlands Water Project.

For electricity projects, exactly matching the output may be difficult. Different projects have different characteristics of, for example, the amount of time and times of the year that the energy can be available. These have different valuations.

The difficulty of either calculation is indicated by the fact that, where the hydroelectric resource is located entirely in one jurisdiction, there are very few examples of explicit calculation of rent for the purpose of taxation or rent-sharing.

Multipurpose Projects

For multipurpose projects, the first problem is to identify the amount of the rent, or net benefit of the project, that is assigned to the hydroelectric portion of the development. The separable cost-remaining benefit method, described in Chapter 4, is well suited to this purpose.

The nature of the market for the output creates the same methodological distinction for the hydroelectric portion of multipurpose projects as it does for single-purpose projects. Where there are competitive markets for the output, the economic return can be calculated by using the market value of the output as its alternative value in determining rents. If there are no competitive markets for the output, the rent must be computed as the difference in cost between the project and its next best alternative.

In the separable cost-remaining benefit calculation, if there is a competitive market, the amounts on lines 1 and 2 of Table 3 would be the same, and would be the market value of the output. If there is no competitive market, the amount on line 1 is the value of the electricity, and the amount on line 2 is the cost of the least-cost project that would produce the same amount of electricity.

APPLYING THE CONCEPT OF HYDROELECTRIC GENERATION RENTS TO TRANSBOUNDARY RESOURCES

The discussion in Chapter 7B indicates the problems in computing rents explicitly for either single-purpose or multipurpose projects that produce electricity from hydraulic resources. As suggested there, these difficulties generally mean that rents are not computed explicitly.

In transboundary applications for hydroelectric generation, however, explicit calculation of rents may facilitate the cooperative development of the resource, since it allows identification of the amount that can readily be shared among the riparians on the watercourse. Explicit calculation of the rent may also be required to allow sharing of the benefits.

The calculation of the rent for the transboundary project is the same as for a project lying entirely within a single jurisdiction. The difference is primarily in the motivation; explicit calculation is usually not necessary for a project in a single jurisdiction and is therefore usually not done.

Realistically, relatively few actual or potential projects actually lie entirely within a single jurisdiction. Major watercourses often cross or form international boundaries. Even if they are contained within a single country, the watercourse often crosses or forms the boundary between the parts of a federal state. Canada, for example, has several provinces (Quebec, Ontario, Manitoba, British Columbia) with significant hydroelectric resources entirely within their boundaries. Even so, three of those provinces have significant developments on either international or interprovincial watercourses.

The analysis and examples have shown that coordinated and cooperative development of a transborder resource will generally have higher total value than will development by the riparian states individually. Achieving cooperation requires, among other conditions, that there be a distribution of the benefits that is agreeable to all the parties involved. Specifying and quantifying the rents available from such a cooperative solution can be the first step in that process. It allows all parties to see clearly where the benefits are and how much they are. The allocation of the benefits can then be accomplished more readily when their aggregate size is better known.

To quantify the net benefits also requires that all the costs be quantified. That quantification also helps the riparians to understand both the total cost of the developments and their relative position. Together with the quantification of the benefits, needed in order to identify rents, these put the riparians in a position of better understanding the total economics of the developments, and their respective roles in it.

The principles developed also allow at least a first approach at the allocation of the benefits, based on the nature and ownership of the physical resource. This allocation can be consistent with the "reasonable and equitable" allocation guideline set by the UN Convention, in that it is based on one set of the criteria in the guideline.

Any cooperative development of a transborder resource will ultimately require an international agreement, most likely in the form either of a treaty or an agreement by a multinational body. The terms of that agreement must be negotiated and agreed by all the sovereign governments involved in the development.

Agreeing on such developments is difficult. For example, in the Columbia River Treaty, negotiations between the United States and Canada took over five years, where an international commission to investigate and make recommendations on transboundary water issues already existed, and where the two countries have historically close and friendly relations. Negotiations in other river basins, and negotiations involving more than two countries, can be expected to be difficult. Improving the quantitative information available and applying the principles developed here should improve the discussion and help facilitate agreement.

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