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Mitigating hydrologic financial risk in hydropower generation using index-based financial instruments

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ABSTRACT

Variability in streamflows can lead to reduced generation from hydropower producers and result in reductions in revenues that can be financially disruptive. This link between hydrologic and financial uncertainties, and the possibility of increased hydrologic variability in the future, suggests that hydropower producers need to begin to consider new strategies and tools for managing these financial risks. This study uses an integrated hydro-economic model of the Roanoke River Basin to characterize the financial risk faced by hydropower generators as a result of hydrologic variability, and develops several index-based financial hedging contracts intended to mitigate this risk. Several different indices are evaluated in terms of their ability to serve as the basis for effective financial contracts. Contract structures are then developed and evaluated using a 100-year simulation that describes hydropower operations in the Roanoke basin. Basis risk, contract pricing, and risk mitigation are investigated for three styles of contracts: insurance, binary, and collar. In all three cases, the contracts are shown to be capable of substantially reducing the risks of very low revenue years for costs that are a small fraction of total annual revenues (1–3%).

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1. Introduction

Streamflow provides the “fuel” for hydropower generation at a very low marginal cost, but its highly variable nature exposes generators to financial risk. This risk can manifest itself during drought as lower revenues from reduced power sales or increased costs driven by a generator's need to purchase, or produce, more expensive replacement power to make up for lost generation. In either case, the financial impacts are exacerbated by the fact that hydropower dams often primarily generate more valuable “peaking” power, and reductions in generation often coincide with periods when electricity demand, and price, are high (e.g. summer months) [36]. While reservoir storage provides some buffer from short-term fluctuations in streamflow, persistent periods of low inflow still translate to less generation and lower revenues over time. The financial vulnerability posed by hydrologic variability, and the possibility of increased variability in the future, suggests that hydropower generators need new tools for managing their financial risk [5,6,28].

In general, financial risk management practices consist of activities designed to increase firm value by reducing the impact or likelihood of financial disruption (e.g. bankruptcy, tax costs, and credit risk) resulting from large, intermittent fluctuations in either operational costs or revenues [10]. In electricity production, two forms of financial risk that result in revenue fluctuations are “price risk”, related to uncertainty over future electricity prices, and “demand risk,” related to uncertainty over future electricity demand. Tools for hedging price risk, such as electricity futures/forwards, are common [13]. Instruments for mitigating demand risk also exist, typically in the form of temperature-indexed contracts using heating/cooling degree days [27] which take advantage of the strong correlation between temperature and heating/cooling power demand. Power utilities also attempt to manage a third form of financial risk, “supply risk,” which for thermal generators (e.g. coal or gas) is mostly related to fuel cost and availability, via futures/forward contracts on fuel inputs. For a utility with a diverse generation portfolio, managing the cost of inputs and securing their future availability results in a more stable overall generation cost ($/kW h), an important consideration for regulated utilities that cannot quickly alter consumer prices to compensate for unexpected swings in costs or revenues. Given that financial stability is a key determinant in important financial factors, such as cost of capital and share price [29], maintaining a stable financial condition is a primary objective for many firms.

In hydropower production, supply risk, which is largely linked to streamflows into the reservoir, is not as straightforward to manage as in thermal generation. Streamflows are a result of natural processes that are difficult to control, but, fortunately, they often display reasonably consistent patterns. An ability to understand these patterns provides an opportunity to develop indexed financial instruments for managing the financial risk linked to fluctuations in water supply and complete an actuarial analysis of such instruments. In general, indexed financial instruments are contracts that utilize an established metric, such as precipitation over a month, and predefined threshold values to trigger payouts that compensate the contract buyer when s/he experiences a loss. The index is the key to an effective contract and it should be transparent; reliable; difficult to manipulate, and thereby mostly free of concerns over moral hazard; and highly correlated with the financial losses experienced by the buyer. Index-based financial contracts are already used in many sectors to provide coverage against financial risk associated with environmental variability. In the case of hydropower, these contracts have not previously been adequately described or widely used. This paper fully develops a set of indexed financial instruments for a particular series of hydroelectric dams and evaluates their ability to serve as useful tools for risk management.

Several industries that are financially vulnerable to environmental conditions have developed and evaluated contracts that used physically measurable environmental indices [8]. Brown and Carriquiry [9] found that index insurance contracts linked to reservoir inflows were partially effective in reducing the impact of high costs incurred when a community had to purchase water to augment its supply during drought. Recent research has also explored the development of index insurance contracts for mitigating water utility revenue losses arising from conservation measures (e.g. outdoor use restrictions) imposed during drought [51]. Leiva and Skees [22] used an integrated hydrological and economic model to evaluate the effectiveness of contracts using a river flow index to address