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Water Allocation Alternatives for the South Saskatchewan River Basin: Optimization Modelling for Improved Policy Choices

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Water allocation alternatives for the South Saskatchewan River Basin: Optimization modelling for improved policy choices

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Abstract

This paper examines the effects on economic welfare of choosing alternative allocations of surface water in the South Saskatchewan River Basin of Alberta, Canada, including those allocations consistent with a market outcome. The study region presents many challenging issues in water allocation. There are four major river sub-basins running, as an annual average, about 9,280 Mcm of water through the basin. Water allocation conflicts are expected to increase since this water has to be shared by four major cities (more than 1.2 million people, and a developed industrial sector), thirteen irrigation districts (irrigating over 500,000 ha), eleven hydropower plants (with a generating capacity of 325 MW), recreational activities and environmental concerns. As water use conflicts grow in incidence and severity, it may become more and more difficult to identify policy responses that could reconcile these competing demands. The identification and analysis of alternative market-based outcomes may characterize an efficient allocation and could support the adoption of relevant policy decisions and policy instruments.

Previous research in this area (Horbulyk and Lo 1998, Mahan et al. 2002) presented the benefits of implementing a water market framework. Specifically, they showed the relative advantage, as an improvement in social welfare, of trading water rights within sub-basins, and with a higher positive impact, across sub-basins. The current research extends the use of empirical optimization modelling to produce a more complete image of an economic efficient allocation. The results are not directly comparable as the modelling approach is different in many senses. Specifically, the current research extends the time period (from a five-month agricultural irrigation season to twelve or twenty-four months). The water demand functions have a different functional form (exponential or linear). The current model is built upon discrete monthly data (instead of averaging across a five-month season) and allows for seasonal variations (seasonally adjusted demand functions in agriculture and municipal use, evaporation and in hydroelectric availability).

In the principal analytical steps undertaken here, the base model is altered such as to show the welfare implications of variations in water demand (changes in demand for municipal and irrigation uses), and variations in water supply (variable hydrologic regime). Consequently, the extended model produces comprehensive decisions support information.

The model is one of the first that simulates alternative water allocations using the new *Aquarius* (Diaz et al. 2000) optimization and simulation software package. A key economic criterion used in the water allocation process is the marginal revenue generated by each water use. Water is reallocated until these marginal returns are equal across all water uses. This leads to maximization of the sum of all economic benefits from the instream and off-stream water use. Physical, operational and institutional restrictions can be imposed, such as limitations on reservoir storage, water supply capacity or seasonality, and exogenous or contractually invariant allocations for municipal demand or for instream flow needs.

In this model, the South Saskatchewan River Basin is represented as a network of approximately seventy-five demand and supply nodes. On the supply side, only surface water is considered, as the level of groundwater resource use is not yet significant. The instream uses include: storage reservoirs, hydropower generation, instream recreation, reservoir recreation and instream flow

protection. For off-stream uses, the model includes: agricultural irrigation as well as urban and industrial demands. The allocation derives from the competing demand schedules, where constant or exponential demand curves are specified for all water uses (excepting instream flow protection), after the restrictions are enforced. Quantitative data describe the physical characteristics of the demand and supply nodes (such as water supply for headwater catchments, power plant characteristics and the operational rules and storage capacities of storage reservoirs). The economic data describe the demand curves, or social marginal benefit for allocations across various uses.

The model's optimization algorithm uses sequential quadratic programming. The objective is to maximize total benefits (regarded as consumers' and producers' surpluses in each water use), subject to the specified constraints. The results show how a water market might function, presenting the best strategy with respect to the physical and economic restrictions specified and illustrating the welfare implications of different scenarios. The model solution characterizes such variables as: controlled releases from storage reservoirs, hydropower releases, storage volumes, and irrigation and municipal flows, all in monthly figures. Also presented are monthly marginal valuations for each demand node along with an aggregation of total benefits.

This case study illustrates the role of economic instruments in guiding the sensitive policy area of allocating water. Even if market-based processes are not used in future to allocate these waters, the characterization of efficient allocations under alternative criteria could recommend alternative policy actions and economic mechanisms (such as regulations, subsidies, taxation) to improve social welfare.

References

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