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Implications of current and alternative water allocation policies in the Bow River Sub Basin of Southern Alberta

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ABSTRACT

In this study, economic implications of allocating surface water with the existing policy (seniority rule) and three other alternative (People First, proportional reduction, and trading) policies are investigated to address potential water scarcities in the Bow River Sub Basin (BRSB) of Southern Alberta using a mathematical programming model. The model used an improved calibration technique and 2008 data for three irrigation and three non-irrigation sector users in the BRSB. Results indicate that while the seniority rule favors senior license holding irrigation users and the People First policy favors municipal sector users, irrigation users are better off with the proportional allocation policy even though it affects all users across-the-board. Moreover, if the users can participate in costless trades, then non-irrigation users tend to buy water as they place high value on water at the margin. Some irrigation users find selling water more profitable than utilizing their allocations for crop production.

1. Introduction

The Government of Alberta has declared that surface water in the Bow River Sub Basin (BRSB) has been fully or over allocated and therefore announced that no new licenses for water extraction will be issued (AMEC, 2009). New users can get water only through savings and reallocation of water among the existing users. Growing demands for water from population, economy and environmental needs and potential scarcity in future supply prompted the Government of Alberta to issue the *Water for Life* strategy in 2003, under which an ambitious goal was set to improve conservation, efficiency and productivity of water use in the province by 30% between 2005 and 2015 (Alberta Environment, 2003). To achieve this goal, the Conservation, Efficiency and Productivity definition project team identified seven major water using sectors in the province (irrigation, oil & gas, mining/oil sands, power generation, municipal use, chemical & petrochemical, and forestry), where major improvements can lead to substantial water savings (Alberta Water Council, 2008). For example, a recent estimate by Alberta Irrigation Projects Association (2010) shows that a 4.6% improvement in the efficiency of water use in the irrigation sector alone could save enough water to meet the annual demand of all municipalities in the South Saskatchewan River Basin (SSRB). It is also believed that allocative efficiency of water use can be improved through voluntary transfer and trading of water within and between sectors.

Historically, water allocation in Alberta has been governed by a priority rights principle called ‘first-in-time, first-in-right’ (FITFIR) (Government of Alberta, 2010). It is also popularly known as the ‘seniority’ rule since it entails priority access to the allocations by senior license holders during years of shortage regardless of the purpose of use – the implication being that junior license holders might be denied access to water in years of water shortage. Some irrigation districts in Southern Alberta hold the most senior organizational large-scale water allocation licenses while municipalities, industries, commercial units, and other users generally hold more junior licenses.

A recent alternative suggestion to mitigate anticipated surface water shortages would reduce allocations proportionally to all users instead of depending on the current seniority based system (Droitsch and Robinson, 2009). In their report, Recommendation 3 states, “. . . water licences should be converted to water ‘shares’ that entitle the holder to a portion of the water available for diversion in each time period. While water licences currently provide the right to withdraw a fixed volume of water, a water share would provide the right to withdraw a percentage of water available on a seasonal basis up to a specified maximum volume limit” (p. 23). Proportional sharing strategies have been practiced in other jurisdictions such as Colorado, Mexico, Chile, and Australia with varying degrees of success. A more detailed description of operational definitions of proportional allocation systems and their applications in other parts of the world is available in He et al. (2012).

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The 13 irrigation districts that manage most of the surface water in Southern Alberta have recently proposed another allocation system to alleviate potential problems of water shortages. It has been dubbed the 'People First' policy as it would ensure water availability for municipalities and livestock operations ahead of senior licence holders during acute shortage years. Specifically the press release states, "Alberta's 13 irrigation districts approved a declaration ensuring that in times of drought in Southern Alberta, human and livestock needs will be met before those of irrigated agriculture (News Wire, 2011, March 22)". This declaration is an attempt to mitigate fears that people and livestock operations might be denied water during severe drought years as municipalities generally possess junior licenses with lower priority than the water licenses held by irrigation districts in Southern Alberta. Unlike the proportional shortage sharing system, this declaration therefore tries to address the potential water shortage problem through voluntary cooperation while keeping the historical priority licensing system in force in years when there are no shortages of surface water.

The purpose of this study is to evaluate the economic implications of the current water allocation policy (FITFIR or 'seniority' rule) in the BRSB of Southern Alberta against the two proposed alternative allocation policies described above (proportional shortage sharing and 'People First') in years of water shortages. An existing positive mathematical programming model is modified, updated and then used to conduct the analysis. The results of the three policy analyses are further contrasted against the outcomes of a short-term seasonal trading policy that allows users to buy or sell water during the irrigation season depending on their marginal value of water. Water demands, trading prices, land use changes, cropping pattern changes, and net economic benefits of these four different policies are estimated and compared for three potential water shortage scenarios.

2. Water allocation models

Past studies that used economic optimization models of water allocation policies in Southern Alberta include Horbulyk and Lo (1998), Mahan et al. (2002), He and Horbulyk (2010), and He et al. (2012). The earlier two studies employed sub-basin scale models to analyze gains in allocative efficiency from within and across sub-basin transfers of water in the four sub-basins (Red Deer River, Bow River, Oldman River, and South Saskatchewan River) of the SSRB. The study by Mahan et al. (2002) expanded the scope and coverage of the earlier study by Horbulyk and Lo (1998) by adding six different water user groups including a detailed irrigation sector sub-model of six major crops produced in the region. Results from trading of water showed a 3% efficiency gain for a water surplus season, 6% for an average flow season, and 15% for a drought season.

The latter two studies used irrigation district scale models to analyze the impact on agricultural producers' surpluses of alternative water allocation and pricing policies for moderate to severe water shortage scenarios in the BRSB of Southern Alberta. The study by He and Horbulyk (2010) specifically investigated water pricing and short-term trading policies as a substitute for the existing FITFIR or seniority based water allocation policy while the study by He et al. (2012) investigated three different mechanisms of proportional shortage sharing in comparison to the FITFIR and short-term trading policies for three irrigation districts (Western Irrigation District (WID), Eastern Irrigation District (EID), and Bow River Irrigation District (BRID)) in the BRSB. Both studies used a mathematical programming model with the positive mathematical programming (PMP) calibration technique introduced by Howitt (1995a,b), which involves estimating a non-linear (quadratic) cost function from the dual values of the calibration constraints in order to maximize a modified non-linear objective function subject to a set of physical, economic, and regulatory constraints.

Over the past decade, a number of European-based studies has made improvements to two key weaknesses of the standard PMP calibration technique developed by Howitt (1995b, 2005). First, when a crop is produced with two different irrigation technologies or two varieties of a crop are produced with the same irrigation technology, they are treated as different activities by the standard PMP, which may lead to unsatisfactory estimates of the cost functions used to modify the objective function. Röhm and Dabbert (2003) proposed an approach for general improvement of the standard PMP method that could be used in various research areas including irrigated agriculture. Assuming that the elasticity of substitution between variants of the same crop would be higher than between two crops, Röhm and Dabbert proposed the addition of an extra slope parameter to the cost function to represent each variant of the same crop. To recover the extra parameter, an extra calibration constraint on all varieties of the same crop is added to the model.

Second, by design, the calibration constraint in the standard PMP technique limits the model-chosen activity levels to their perturbed base year values. If some crops or activities are not produced (observed values are zero) in the base year growing conditions, they have no chance to emerge (become profitable) in the simulations of different growing conditions when markets or policies change. Cortignani and Severini (2009) addressed this problem by adding another linear parameter to the modified cost function proposed by Röhm and Dabbert (2003) to represent the additional marginal costs of the unobserved activities. This additional parameter is then recovered by introducing an additive perturbation constant (a very small positive number) to the two calibration constraints, which requires difficult-to-obtain data on costs and yields of the unobserved crops or activities from experimental field trials or from other regions.

Following the methodology of Paris and Arfini (2000), Iglesias and Blanco (2008) and Blanco et al. (2008) suggested a 'wide-scope' PMP calibration technique that is applicable to a wide range of approaches aimed at addressing the issue of unobserved base year activities. For a sub-regional model, this method involves specifying a non-linear (quadratic) cost-function (and the corresponding average cost-function) for the least-cost sub-region and then adding an additional parameter for the other sub-regions to represent the additional costs in those regions. To recover these parameters, two calibration constraints are needed – one for the total land allocated to the activity and another for the land allocated to the activity in each sub-region. The advantage of this method over the Cortignani and Severini (2009) approach is that it does not require any additional data from outside as it is always possible to identify the least-cost area from the observed data. In our model, we have adopted this 'wide-scope' PMP calibration method due to its simplicity and non-reliance on additional external data.

3. Our model

Our approach in this study is to adapt the existing economic optimization model in Southern Alberta by taking advantage of the methodological advancements of the PMP calibration technique proposed in some of the European studies above. Specifically, our model in this study builds upon the modeling structure of the most recent studies (He and Horbulyk, 2010; He et al., 2012), but adapts and improves them in four respects. First, we augment the scope of the analysis by incorporating water demands from the non-irrigation sectors (municipal, industrial, and commercial sector demands) so that the augmented model can inform on allocative efficiency gains both between and within sector water trading