Welfare Impacts of Rural to Urban Water Transfers: An Equilibrium Displacement Approach

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Introduction Western agriculture has blossomed with the development of water resources that are used in growing crops, which in turn spurs the value-added products like meat, sugar and dairy products. Economic activity is generated directly by these industries when inputs are purchased and wages are spent. Without other viable local base industries to generate revenues and provide employment, a reduction in the agricultural revenue seriously impede a rural regional economy.

Yet, population growth is driving a reallocation of agricultural water resources from rural areas to burgeoning municipalities. By 2030, an estimated 33 million additional people are projected to be living in the West, requiring approximately 30 billion more gallons of water for consumption (Western Governors' Association, 2006). Growth and subsequent water conflicts are often focused in agricultural areas where key water resources are fragile and scarce, as pointed out in the Bureau of Reclamation's Water 2025 Report. Competitive pressure and reallocation is particularly strong in Colorado, where more than an additional 600,000 AF will be needed to meet new municipal and industrial demands (Table 1).

The economic activity estimates in Table 1. do not consider the potential impacts to important downstream industries including feedlots, meat packing, dairies, cheese manufacturing and ethanol production. Their analysis is best viewed at the margin, but clearly the acreage changes described in Table 1 are quite large, so much so that the analysis may misrepresent actual impacts. Their analysis does not allow for endogenous prices and the out-of-state imports of irrigated crops that mitigate potential welfare losses. Significant improvement in policy analysis can be made with a more representative, flexible modeling effort that considers both water transfer scenarios and other water firming projects (e.g., reservoirs) that shift water from less populous regions of Colorado to greater M & I demands (Figure 1).

Research Objective The purpose of this study is to better inform stakeholders of the likely welfare impacts of water initiatives in Colorado, which are relevant to accelerating rural-to-urban water transfers throughout the West. Specific objectives include

a) Creating an equilibrium displacement model (EDM) that accurately depicts the water inflows and outflows for three Colorado river basins, and captures the market based relationships that this natural resource has to Colorado economic sectors;

b) Characterizing scenarios that might be used to meet expected water demands including water transfers, construction of a reservoir, and inflow of water from an out-of-state supply source,

c) Discussing the tradeoffs of the scenarios in (b) according to their direct impacts to the basin of origin and the indirect impacts to other industries.

Methodology Harrington and Dubman (2008) provided comprehensive description of the mathematical programming approach in the EDM. Description of the reduced form EDM by Harrington and Dubman follows:

Max: $Z = F'x - 1/2\, x'\, H\, x$. (1)

Where;

Z is the objective function to be maximized. The objective function can be either the sum of consumer plus producer surpluses or the sum of residual quasi-rents.

F'x is a vector of intercepts of supply and demand processes for the product and commodities

H is Hessian matrix of marginal adjustment costs and demand slopes.

x is a vector of optimized variables (which assure that all solutions are feasible and efficient) The objective function above is subject to the following constraints:

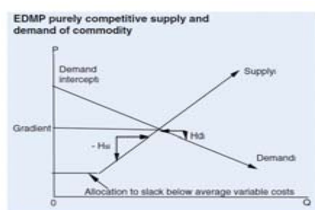
$A11x$ = Free Indicator accounts, (2)

Table 1. Economic activity generated by irrigated agriculture in four basins[a]

Basin	Population Increase by 2030 (%)	Additional Annual Water Demand (AF)	Forecasted Fallowing of Irrigated Acres	Economic Activity for Each Irrigated Acre
Arkansas	55%	98,000	23,000 to 72,000	$428
Rio Grande	35%	43,000	60,000 to 100,000	$1,235
South Platte	65%	409,700	133,000 to 266,000	$690

[a]Population, water demand and lost irrigated acres drawn from the Colorado Water Conservation Board, Statewide Water Supply Initiative (2004). Thorvaldson and Pritchett (2006) provide economic activity estimates.

Figure 1. Surface water flows in Colorado.



Harrington, David H. and Robert Dubman (Feb. 2008). "Equilibrium Displacement Mathematical Programming Models, ... ber 1918, ERS, USDA

Figure 2. Graphical representation of EDMP methods

Unique Element (Part I) To the authors knowledge, a standard EDMP has not yet been adapted to track the flow of water as factor of production and as an intermediate good of exchange. The disposition of water can be measured across time and space, so that transbasin diversions (Figure 3) and surface water storage (Table 2) must be accounted for in a water balance set of equations that include crop consumptive use , municipal demands and interstate compact obligations.

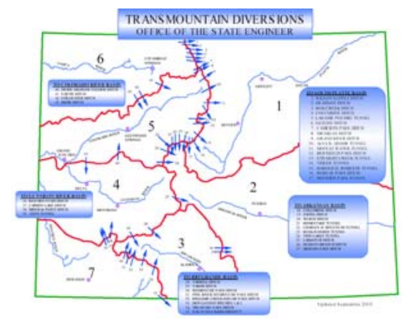


Figure 3. Transbasin diversions modeled it he Colorado EDMP

Table (XX) Water Diversions, Major Uses, Storage, Imports, and Exports by River Basin in Colorado

River Basin	Total Diversion (Million AF)	Major Uses (AF): Irrigation	Municipal / Industrial	Fishing and Recreation	Storage	Power	Recharge to Ground water	Total Use
Arkansas River Basin	3.7	2,000,000	320,000		1,300,000			3,620,004
Colorado River Basin	2.9	2,200,000	55,610	160,827	434,000			2,850,440
Rio Grande Basin	1.3	1,100,000	10,847		58,052			1,168,900
North Platte Basin	2.9	404,195			6,433			410,631
South Platte Basin (excluding metro)	4.1	2,200,000	253,500		1,100,000		104,656	3,658,160
Gunnison	2.9	2,200,000		160,827	434,000			2,794,830
Yampa/White	1.4	719,124		35,227	31,072	525,649		1,311,073
Denver/South Metro countries								
Dolores/San Juan/San Mig	1.5	938,788	518,900	305,015	193,010			1,955,715
Total	**19.2**	**11,762,107**	**1,158,857**	**661,896**	**3,556,567**	**525,649**	**104,656**	**17,769,753**

Source: Colorado Water for the 21St Century, A Public Education Project, Project Final Report, 2008 June 30 - Combined from Colorado river basins roundtables meetings results.

Unique Element (Part II) A key element of this model is the accounting stance used in water transfers. Rather than transferring an entire diversion of water, parties are only allowed to transfer the consumptive use of their water right allocation. the water reallocation. Additional activities to the standard EDMP include the crop consumptive use that vary by basin. Likewise, water transfer scenarios are measured in consumptive use units.

For further information

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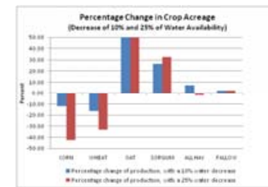
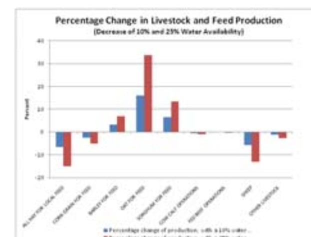
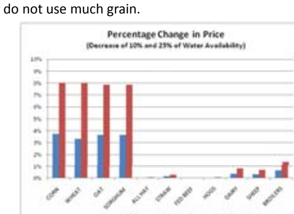
Scenarios: Attention is focused on the South Platte River Basin, where increasing population pressure is the greatest vis a vis other basins, and farm gate revenues are greater than $600 million. In addition, new transfers between basins are highly controversial, thus it is not expected that western Colorado water demands will be used to meet growing populations in the South Platte. The first scenario reduced agriculture water availability by 10% while the second is a more substantial reduction of 25%.



Changing crop mix: The interdependence of the grain and livestock sectors are evident as the decrease in water availability causes a shift in acreage out of corn and wheat into oat and sorghum, which are mostly used in feed rations. Although the acreage for oat and sorghum is smaller in absolute terms, the percent increase is large showing the dramatic shift out of irrigated ration to dry ration grain production. The hay acreage increases for a 10% decrease of water availability, but decrease when water is limited by greater proportions.



Indirect impacts on livestock: For a decrease in irrigation water all hay into feed decreases by more than 5%, while the grains for feed increase, especially sorghum increasing by more than 30% . Cow calf and fed beef operations remain at about the same levels of production, while sheep production declines due to less forage availability, since they do not use much grain.



Price and Welfare Impacts: Prices for crops that use water increase, as well as for crops in higher demand by the livestock sector. Prices for dairy, sheep and broilers increase. Finally, the decreasing water availability in agriculture decreases the combined producer and consumer surplus by $5 million and $19 million respectively.

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