Efficiently Allocating Scarce Water Supplies: An Economic Perspective and the Role of Water Markets

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The Value of Water

Water resources provide many kinds of value

• Use Values
  Consumptive Use Values
  Non-Consumptive Use Values

• Non-Use Values
  Option
  Bequest
  Existence

Total aggregate demand for water is a complex function of all these values

Many demands are non-rival in nature (public goods) and these demands are often underrepresented.

Often inadequate private regard for alternative water uses (over depletion)

Water value and the cost of water acquisition (price) are not the same!!!

Value is a marginal concept and total expenditure does not reflect total value!!!
Static Efficiency: One User
Value versus Price

$'s

Net Benefit

MC

$MB$

W*

Water Use
Static Efficiency: One User
Marginal Net Benefit

\[
\text{MNB} = \text{MB} - \text{MC}
\]
Static Efficiency: Two Users
No Water Scarcity

\[ \text{MNB}_1 = \text{MB}_1 - \text{MC}_1 \]

\[ \text{MNB}_2 = \text{MB}_2 - \text{MC}_2 \]
Static Efficiency: Two Users
Water Scarcity

$'s

MNB$_1$
MNB$_2$

W$_2^*$
W$_1^*$

Total Water Supply

Shortage
Static Efficiency: Two Users
Water Scarcity with a Market
(assumes user 1 has senior right)
An Agricultural Transboundary Example: Net Economic Benefits of Agricultural Water Markets in the Rio Grande Basin

Example Focuses exclusively on agricultural use value

Water resources must first be assigned, quantified, enforced, and tradable for markets to arise

Allows water to flow to its highest valued use
Treaty of 1944

- Monitors the allocation of internationally shared water of the Rio Grande River between Mexico and the U.S.

- Article 4 of the Treaty states that Mexico must redirect “one-third of the flow reaching the main channel of the Rio Grande (Rio Bravo) from the Conchos, San Diego, San Rodrigo, Escondido, and Salado Rivers and the Las Vacas Arroyos, provided that this third shall not be less, as an average amount in cycles of five consecutive years, than 350,000 acre-feet annually” to the U.S.
Rio Grande Basin

Colorado River

Rio Conchos Basin

Chihuahua

LRGV

Durango

Coahuila

New Mexico

Texas
U.S. Shadow Price for Water with and without Release ($\Omega$)

\[ \frac{\lambda_{Wus}}{\text{$/ac-ft}} \]

\[ \lambda_{Wus + \Omega} \]

\[ W_{us} \quad W_{us + \Omega} \quad \text{U.S. Water Supply} \]

$\Omega = \text{Contracted water release level to US}$

$\lambda = \text{Shadow price of water}$
Mexico’s Shadow Price for Water with and without Release ($\Omega$)

$\lambda_{WM-\Omega}$  

$\lambda_{WM}$  

$W_M - \Omega$  

$W_M$  

Mexico Water Supply

$\Omega = \text{Contracted water release level to US}$

$\lambda = \text{Shadow price of water}$
Modeling Assumptions

- Contracted water released by Mexico is diverted by farmers in the LRGV for irrigation use.
- Water allocation economic efficiency between the U.S. and Mexico requires that the net marginal economic value of water is equal in both countries:
  \[ \text{NMB}_{US} = \text{NMB}_{M} \]
- Every unit of contracted water withheld by Mexico imposes a marginal damage on the U.S. equal to the \( \text{NMB}_{w} \) that same unit of water would have generated if applied to agricultural production in the LRGV. Thus the \( \text{NMB}_{w} \) function for the U.S. can be used to derive the net marginal damage function for contracted water not released by Mexico.
Economic Gains at Alternative Release Levels

Pay contract exclusively in water if contract is less than $\Omega_2$

$\text{MNB}_{US}$ and $\text{MNB}_M$ drawn for an initial supply level in each country
US and Mexico Net Marginal Benefit Curves (Discounted for Conveyance Losses ($\delta$))

Assumed Contract

Water Level

\( \lambda_{US} , \lambda_{M} \)

\( \lambda_{1} \)

\( \lambda_{\delta} \)

\( NMB_{US} \)

\( NMB_{US} (1-\delta) \)

\( NMB_{M} \)
Research Approach

1. Develop a mathematical programming model to determine the marginal net economic value of the agricultural water supplies to Mexico and the U.S.

2. Use the mathematical programming model to determine under which conditions payment in dollars, or a combination of dollars and water improves the economic welfare of both countries relative to the contractual scheme that releases water to the U.S. as per the negotiated contract.
Procedures

- Updated price and cost data in Robinson’s (2002) mathematical programming model for the lower Rio Grande Valley in Texas

- Perform parametric analysis on water supply to derive $NMB_{US}$ curve

- Updated and performed parametric water supply analysis on Puente-Gonzalez’ (2002) mathematical programming model for the Delicias Irrigation District to derive $NMB_{M}$ curve
Estimated Net Marginal Benefit Functions
\((NMB_{US} \text{ and } NMB_{M})\)

Econometric Model for the LRGV \((NMB_{US})\)

\[
\lambda_{US} = 1387.69 - 0.0091(w) + 0.0013(d \times w) - 83.8338(\ln(d \times w)) - 0.4365(\sqrt{d \times w})
\]

\(R\)-squared value is .999, number of observations is 142, \(t\)-values in parentheses

Econometric Model for the Rio Conchos Basin \((NMB_{M})\)

\[
\lambda_{M} = 320.5757 - 22.6263(\ln(w_M))
\]

\(R\)-squared value is .855, number of observations is 120, \(t\)-values in parentheses
$NMB_w$ for the U.S.
$NMB_w$ for Mexico
$NMB_{US}$ and $NMB_M$ Curves

![Graph showing $NMB_{US}$ and $NMB_M$ Curves](image)

- Shadow Price/Marginal Damage ($/AF$)
- NVMP for Mexico (Discounted)
- Marginal Damage Curve (Discounted)

Water Supply (10,000s Ac-Ft)

- Shadow Price ($/ac-ft$)

Legend:
- $NMB_M$ (Discounted)
- $NMB_{US}$ (Discounted)
Water Marketing Approach

Provides a process in which both the U.S and Mexico can achieve net gains by agreeing to a mutually beneficial flexible release agreement. Allows the water resource to achieve its highest economic return and fair compensates both trading partners.
## Alternative Water Supply Scenarios: Before Contract Release

<table>
<thead>
<tr>
<th>Supply Scenario</th>
<th>LRGV Agricultural Use</th>
<th>Rio Conchos Basin Agricultural Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>600,000 acre-feet</td>
<td>300,000 acre-feet</td>
</tr>
<tr>
<td>Average</td>
<td>900,000 acre-feet</td>
<td>850,000 acre-feet</td>
</tr>
<tr>
<td>High</td>
<td>1,200,000 acre-feet</td>
<td>1,200,000 acre-feet</td>
</tr>
</tbody>
</table>

Optimal Contract Release: Low Water Supply both Regions

\[ \Omega_e = 34,000 \text{ ac-ft} \]
\[ \lambda_e = 32.25 \text{ ac-ft} \]
\[ \Omega = 300,000 \text{ ac-ft} \]

Water Supply/Deficit (acre-feet)

Shadow Price/Marginal Damage ($/af)

NMB Mexico
MD US
Optimal Contract Release: Average Water Supply both Regions

\[ \Omega_e = 55,000 \text{ ac-ft} \]
\[ \lambda_e = $11.20 \text{ ac-ft} \]
\[ \Omega = 300,000 \text{ ac-ft} \]
Optimal Contract Release:
High Water Supply both Regions

\( \Omega_e = 0 \text{ ac-ft} \)
\( \lambda_e = $3.27 \text{ ac-ft} \)
\( \Omega = 300,000 \text{ ac-ft} \)
Annual US Net Benefit and Net Cost to Mexico of Annually Releasing 300,000 Ac-ft of Water at Alternative Water Supply Levels

<table>
<thead>
<tr>
<th>Water Supply Scenario</th>
<th>US Net Benefit</th>
<th>Mexico’s Net Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Water Supply</td>
<td>$7,069,344</td>
<td>$14,751,347</td>
</tr>
<tr>
<td>Average Water Supply</td>
<td>$2,371,158</td>
<td>$4,138,050</td>
</tr>
<tr>
<td>High Water Supply</td>
<td>$299,088</td>
<td>$1,773,604</td>
</tr>
</tbody>
</table>
Net Gain Calculations

- **U.S. Net Gains** =

\[
\lambda_e \{\Omega - \Omega_e \} - \int_{w_{US} - \Omega}^{w_{US} - \Omega_e} [1,387.69 - .00091(w_{US}) + .00113(d \times w_{US}) - 83.8338(\ln(d \times w_{US})) - .4365(\sqrt{d \times w_{US}})]dw_{US}
\]

- **Mexico Net Gains** =

\[
\int_{w_M - \Omega}^{w_M - \Omega_e} [320.5757 - 22.6263(\ln(w_M))]dw_M - \lambda_e (\Omega - \Omega_e)
\]
Annual US Net Benefit and Net Cost Saving to Mexico of establishing a flexible water market contract for the 300,000 Acre-ft Water Supply Scenario

<table>
<thead>
<tr>
<th>Water Supply Scenario</th>
<th>Increased US Net Benefit</th>
<th>Decreased Mexico Net Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Water Supply</td>
<td>$2,677,087 (38% more)</td>
<td>$5,116,335 (35% less)</td>
</tr>
<tr>
<td>Average Water Supply</td>
<td>$1,076,421 (45% more)</td>
<td>$801,756 (19% less)</td>
</tr>
<tr>
<td>High Water Supply</td>
<td>$681,316 (228% more)</td>
<td>$792,604 (45% less)</td>
</tr>
</tbody>
</table>
Conclusions

➢ Water marketing increases the net economic return to water rights/access to the U.S. and decreases the cost of contract compliance to Mexico

➢ The bargaining approach provides net economic gains to both countries (assuming negotiation costs are small)
Conclusions

- Creating a water market can be difficult when water is abundant because transaction cost can be greater than net social benefit.

- Markets require well defined property rights.

- Markets recognize opportunity cost of scarce resource use and can result in increased technical efficiency.
Future Research

- Dynamics need to be introduced into the model (storage value currently ignored)

- Generalize to more complex water negotiations [other industries (including recreation), maintenance of minimum stream flow levels, improvements in water quality, and ecological protection]
Questions?