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Potential Economic Impacts of Inter-regional Water Sales Under Two Texas Aquifer Scenarios

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Abstract: As metropolitan areas require additional water supplies to meet the needs of growing populations, many are looking to outlying rural areas to provide water. This study examines potential economic impacts from water sales in Burleson and Hale Counties in Texas, focusing on agricultural output, household spending, and trade flows with nearby trade centers. While a net economic gain is estimated for Burleson County when accounting for water leases and agricultural production, Hale County suffers significant losses that extend to the Lubbock County trade center. These results suggest more arid regions are likely to experience greater agriculture losses which may result in overall regional economic decline even though individual landowners benefit. Incorporating trade flows into the regional economic model provides additional information about effects on the broader regional economy, including regional trade centers that serve rural communities.

1. Introduction

As metropolitan areas require additional water supplies to meet growing populations, many cities look to purchase water from outlying rural areas. Transferring water from rural agriculture to higher-valued urban uses promotes economic growth and aggregate social welfare (Michelson, 1994; Griffin, 2006). The question of whether and how to implement water transfers is mired in the economic, social, and environmental questions surrounding what is often call the natural resource curse.

Picking up only on the economic thread, regional and agriculture economists have long held that value chains and local processing of natural resources resulted in a stronger economy than shipping raw commodities (Ross, 1999; Kilkenny and Schluter, 2001; Tunstall, 2015; Lu and Dudensing, 2015). To some people, selling water formerly used for agricultural production is akin to felling the forest and trucking out the logs. Others see water leases as similar to mineral leases, which extract an underground resource and ship it for refining and use in population center (Howe and Skaggs, 2015). Water leases that curtail agricultural production may also affect farmers' ability to feed more than 9 billion people on the planet by 2050.

Water leases can provide reliable income to farmers and other landowners who face substantial risk from low commodity prices, increasing input costs, weather, and pests. In Texas, most groundwater rights are attached to the land, and most groundwater is used for farming, although farmers are reducing their use of the resource through both voluntary and mandatory conservation programs and by adopting less water intensive crop varieties while still enhancing yields and quality (Wagner, 2012). Decreased water use is intended to prevent aquifer depletion and extend the economic use of the aquifer. But these adaptations also enhance landowners' abilities to sell water while maintaining crop incomes and increase incentives to separate water rights from land sales, as is often the case with mineral estates. Likening water leases to oil and gas leases is appealing because oil and gas law is fairly established and understood by landowners (Howe and Skaggs, 2015), and in many cases water transfers are expected to only marginally displace agriculture (Brajer and Martin, 1990). However, the comparison to mineral leases falls short in regions where ground water transfers could significantly curtail irrigated agricultural production.

Agriculture may be significantly affected by reduced revenues resulting from lower water-use crop mixes and reductions in irrigated land, especially in arid regions (Howe et al., 1990; Seung et al., 1998). In turn, reduced agricultural productivity affects the wider economy though both reduced farm income and reduced input purchases as farms transition to lower water use crops and to less input-intensive dryland production. These impacts are unlikely to be reflected in the water price (Brajer & Martin, 1990).

The motivation for this study is a proposed water sale in central Texas as well as increasing discussion of such transfers across the western U.S. The Vista Ridge Consortium plans to pipe 50,000 acre-feet of water annually from the Carrizo-Wilcox Aquifer in Burleson and Milam Counties 142 miles to San Antonio (Huddleston, 2015). A consortium partner holds 71,000 acre-feet in leases for the San Antonio project and an existing project already piping 20,000 acre-feet/year 54 miles to Austin suburbs. The lease rate for the San Antonio project is $46 per acre-foot, a price many landowners view as a source of revenue similar to an oil and gas lease.

The project has faced severe criticism by some Burleson and Milam County residents (Chubb, 2014; Gibbons, 2015) as well as by San Antonio residents facing water rate hikes (Rivard, 2014). Although rural residents are concerned about losing irrigation water, the regional groundwater conservation district believes there are sufficient water supplies and that the district has the ability to maintain water availability (Day, Totten, and Westbrook, 2015). Vista Ridge is the latest of several well-documented attempts by San Antonio to secure water from rural areas (Lee et al., 1987; Whited, 2010).

The Vista Ridge project provides the scenario for this case study comparing the potential economic impacts of water sales in a Texas county with moderate rainfall, low irrigation use, and an aquifer with a faster recharge rate to a semi-arid county with a heavily irrigated, low-recharge aquifer in the Texas High Plains. The study is unique in (1) comparing how individual industries are affected by water lease income versus decreased agricultural productivity and (2) incorporating trade flows between the rural county and a nearby metropolitan area.

2. Literature review

2.1. Water economics

Growing cities have long looked to other regions to supply water needs (Lee et al., 1987; Howe et al., 1990; Albrecht, 2014), and some economists believe interest in rural-urban water transfers is increasing (Molle and Berkoff, 2009). Studies of water quality trading programs are perhaps more common and provide information relevant to this study. In fact, this journal had a 2012 special issue dedicated to that topic (Cropper et al., 2012; Greenhalgh and Selman, 2012; Mitchell and Willett, 2012; O'Hara, Walsh, and Marchetti, 2012; Smith et al. 2012; Smith et al. 2012). There has been a steady flow of studies on the economics of water transfers and sales since at least the 1980s (Howe et al., 1986; Michelson, 1994; Knapp et al., 2000; Rosegrant et al., 2000; Howe and Easter, 2013). Many studies have estimated the economic impacts of water transfers through input-output analysis (Howe et al. 1990; Thorvaldson and Pritchett, 2006) or computable general equilibrium (CGE) models (Seung et al., 1998; Goodman, 2000). In fact, several impact studies have focused on Texas water transfers (Lee et al., 1987; McCarl et al., 1997; Whited, 2010). Other studies have considered the economic impacts of water allocations and/or curtailments (Lichty and Anderson, 1985; Vinlove and Emerson, 1990; Varela-Ortega 2011). Of course, economic impact studies of non-water natural resource concerns are also relevant to modeling water impacts (Marcouiller, Schreiner, and Lewis, 1990; Irland et al., 2001; Paul et al., 2013).

Focusing on trading of groundwater, Whited (2010) estimated losses of $30 million in output and more than 750 jobs in Uvalde County, Texas, due to potential water sales to San Antonio. Her analysis assumed that all water was converted to non-agricultural use and modeled a conversion of 63,250 irrigated acres to 55,276 dryland acres supporting wheat and sorghum production. This crop conversion was modeled in IMPLAN using an analysis by parts method to incorporate differences in irrigated and dryland cost functions specified from Texas Extension crop budgets. Negative economic impacts from crop conversion were estimated at $35.4 million in total output, but this figure was offset by estimated output impacts of $4.4 million from lease payments starting at $135/acre-foot, or $10 million in aggregate.

Lee et al. (1987) found that Uvalde County impacts were negative, but these differences were mitigated at the regional level. Whited did not consider regional impacts, which support overall efficient allocation of resources but matter little to the county that loses economic value. Seung et al. (1998) found that regional losses to agriculture did not offset recreation-related gains and water payments in the Walker River Basin of Nevada and California.

Conflicting results are in keeping with research that shows rural counties react differently to a variety of economic scenarios. When considered in water trading scenarios, water exhibits the properties of mineral rights. Deller (2014) found that non-oil and gas mining has a positive relationship income growth in many rural counties but a negative association in others. Deller also found similar heterogeneity between rural areas in both the effects of tourism on poverty (2010a) and the effect of microenterprises on population and employment growth (2010b). Deller (2014, 46) concludes, "the heterogeneity of the rural U.S. makes broad generalizations difficult if not simply wrong."

Furthermore, the instability of mining operations creates uncertainty that limits positive economic potential because businesses are hesitant to form or expand (Deller, 2014). The decisions of businesses related to water-intensive industries may be affected by uncertainty about whether landowners will lease their water and about if and when leased water will actually be exported. Wheeler et al. (2012) found that intent to sell water was related to debt, low farm income, and low water allocations, all of which relate to agricultural uncertainty, especially in drought scenarios.

2.2. Case study regions

This case study considers two regions of Texas with vastly different climatic, hydrological, and economic scenarios. Hale County in the semi-arid Texas High Plains averages 19.90 inches of precipitation annually. More than 40% of annual precipitation occurs in May, June, and July. Winters tend to be dry with most precipitation falling as snow; less than three inches, or 14%, of annual rainfall occurs between November and February (Alvarez and Plocheck, 2013). The average minimum January temperature is 24.4°F and the average maximum July temperature is 91.0°F.

Burleson County is in the Post Oak Belt of the Gulf Coastal Plains. Annual rainfall of 38.5 inches is almost double Hale County's precipitation, including both a wet spring and a wet fall. The average minimum January temperature is 36.4°F and the average maximum July temperature is 96.7°F.

Burleson County sits atop a stratified series of aquifers, including the Queen City, the Sparta, and Carrizo-Wilcox, the region's major aquifer (George et al. 2011). In all three of these aquifers, water flows (although very slowly) from a northern outcrop on the land surface toward the south. The Carrizo-Wilcox has an average freshwater thickness of 685 feet, and major irrigation from the aquifer occurs in the Winter Garden region, which is a deeper portion of the aquifer to the south of Burleson County.

Hale County relies primarily on the Ogallala Aquifer, the largest in the U.S., for its water. The Ogallala has a saturated freshwater thickness of only 95 feet. More than 95% of water in the county is used for agricultural purposes, and irrigation from the Ogallala has resulted in decreasing aquifer levels to the point that pumping costs have become inefficient for some farmers (Peterson et al., 2003; TAWC, 2013). Farmers have reduced water needs through increased irrigation efficiency, but the aquifer continues to be depleted (Peterson and Ding, 2005; Johnson et al., 2011). The regional groundwater management district limited pumping to 1.5 acre-feet per contiguous acre in 2014 and 2015 and to 1.25 acre- feet per contiguous acre in 2016 (TAWC 2013). However, farmers can apply more water to some acres by applying less to contiguous land. Furthermore, the restriction does not apply if only one harvestable crop is planted. As noted by Peterson (2003), Texas is not inclined to enact strong water regulation.

Irrigation use is much different in the two counties. Only 19,598 (5.8%) of Burleson County's 335,346 acres in farms were irrigated in 2012 (USDA, 2014b), and the pumping limit is 2 acre-feet per year. In Hale County, 202,238 (31.6%) of the county's 640,609 acres in farm are irrigated. The number of irrigated acres decreased by 16.9% between 2007 and 2012 even as the number of acres in all farms increased by 8.8%. Higher pumping costs associated with lower Ogallala Aquifer levels contributed to decreased irrigated acreage.

Differences in climate and water availability result in very different agricultural practices. Cotton is the dominant field crop in both Burleson and Hale Counties, but cash receipts from cotton are almost 8 times higher in Hale County (2011-14 average of $125.6 million) than in Burleson ($16.0 million) (Salinas and Robinson, 2015). Cotton receipts have been dramatically reduced since 2013 by drought as well as water restrictions and costly pumping (Figure 1). Like cotton, feed corn is a popular but water-intensive crop in both counties. Sorghum and wheat, both of which are productive dryland crops, are also important crops, although far less important than cotton.

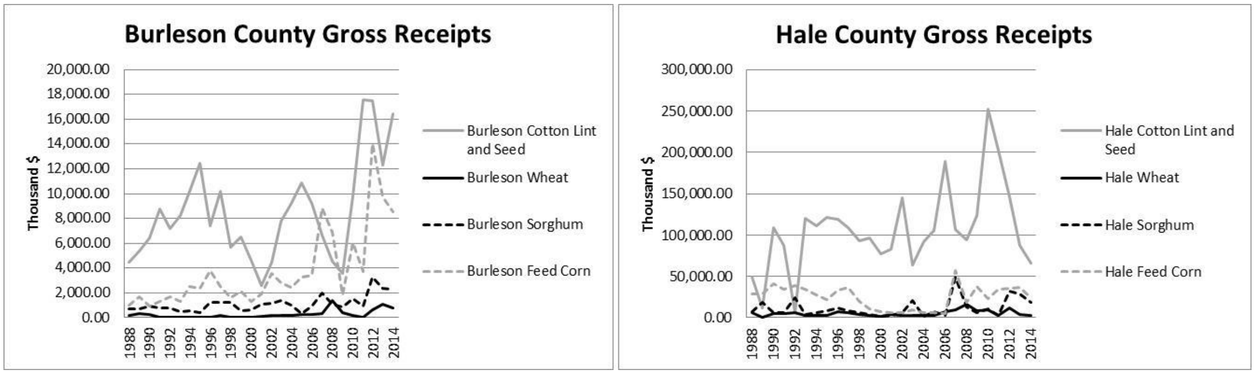

Figure 1. Gross receipts from selected agricultural commodities in Burleson and Hale Counties in Texas, 1988-2014.

3. Conceptual framework

This study employs an input-output modeling framework with multi-regional considerations. Shaffer (1999) provides a thorough description of the logic and construction of input-output models, and the interested reader is referred to Shaffer's paper, as well as to similar discussions by Miernyk (1965) and Davis (2001) and to Holland and Wyeth (1993) for inclusion of household income to generate social accounting matrices. Most input-output models are concerned with a single region. Lindall, Olson, and Alward (2009) discuss the concepts and particulars of modeling trade flows between regions, or multi-regional analysis.

This paper assumes that farmers and other landowners with the opportunity to sell water may choose do so if the income from water is greater than income foregone from other agricultural enterprises (essentially a profit maximization scenario in which the decision is already known); this assumption is plausible in that Burleson County farmers have already sold water at a given price and a price can be set that equals calculated returns to agricultural water use in the High Plains. However, widespread changes in crop mix and production practices (i.e., input intensive irrigated v. dryland production) result in changed purchase patterns that must be accounted for in the regional economic analysis.

In conceptualizing a model incorporating changing industry production functions, a few points bear special mention. The multipliers generated by input-output models are based on data accounting for transactions between industries, households, other institutions, and the world outside the modeled economy (Shaffer, 2004). Within a transactions table, supply is equal to demand. Using the common symbolic summary, total sales by a given sector *i* (X_i) is the sum of sector *i*'s intermediate sales to all other sectors, including to household sectors, and final demand sales (Y_i):

$$\begin{aligned} X_1 &= X_{11}+X_{12}+\ldots+X_{1n}+Y_1 \\ X_2 &= X_{21}+X_{22}+\ldots+X_{2n}+Y_2 \\ &\vdots \\ X_n &= X_{n1}+X_{n2}+\ldots+X_{nn}+Y_n \end{aligned} \quad (1)$$

or more succinctly:

$$X_i = X_{ij}+Y_i \quad (2)$$

A direct requirements table is created by dividing industry *j*'s use of industry *i*'s product by the sum of industry *i*'s total sales. Given final demand Y, the number of equations is reduced to the number of unknowns (Shaffer, 2004). Thus, the demand by sector *j* for sector *i*'s products (Xij) is a function of sector *j's* level of production (X_j):

$$X_{ij} = a_{ij}X_j \quad (3)$$

where a_{ij} is a coefficient describing the dollar value of sector *i* production required to produce a dollar of sector *j* output.

From here, the model is often represented using matrix algebra as

$$Y = X - AX \quad (4)$$

with Y the vector of final demand, X the matrix of industry sales, and A the matrix of a*ij* coefficients. Using an identify matrix I:

$$Y = (I-A)X \quad (5)$$

Equation (5) can then be rearranged to solve for X:

$$X = (I-A)^{-1}Y \quad (6)$$

with the $(I-A)^{-1}$ matrix providing the Leontieff (1966) multipliers.

While economists often refer to abbreviated matrix notation to set up discussions of input-output models, the individual a_{ij} derived from the transactions table are critical to forming the industry multipliers through the (I-A) matrix inversion. Farm profit maximization is a function in which both income and expenses vary with water use, as profit (Π) is a function of income from water leases (WLI) plus crop income less crop production expenses:

$$\Pi = WLI + \sum_{c=1}^{n} P_c Q_c(w) - \sum_{z=1}^{n} C_z Z_z(w) \qquad (7)$$

where P_c is the price of commodity *c*, Q_c is the quantity of commodity *c* produced, C_z is the cost of input *z*, and Z is the amount of the input used. Both Q and Z are a function of water use. Over a large number of producers, different production functions (e.g., different expenses patterns in producing irrigated v. dryland cotton) result in different transactions tables and, subsequently, different direct requirements coefficients (a_{ij}) and multiplier values for the region.

4. Methods and data

Water sales generate additional income to households, similar to the effects of oil and gas sales. However, if water prices are greater than the value of another unit of irrigation to agricultural production, farmers may reduce their agricultural water use to be able to sell at least a portion of their water on the market. In this case, there is a simultaneous loss to the economy that results from reduced input purchases as farmers transition to crops and production methods that better fit reduced irritation scenarios.

For example, conventional dryland cotton in the southern high plains generates expected revenue of $254.82 per acre while higher-yielding, pivot-irrigated cotton generates $909.84 per acre (Texas A&M AgriLife Extension, 2015a, 2015b). Irrigated crops do generate larger profits, but they also have higher fixed and variable costs. Variable costs are estimated at $760.05 for irrigated cotton and $288.50 for dryland. A decision not to irrigate cotton results in reduced purchases of seed, fertilizer, chemicals, and energy. Many of those purchases are made locally or regionally, so losses are multiplied as supplying businesses also experience declining sales. Different industries are likely to benefit from increased income and hurt by changes in agricultural production. County-level and regional economy-wide impacts of increased household income from water sales and potentially decreased agricultural production are modeled using input-output analysis, specifically IMPLAN (IMPLAN Group, 2014).

Low levels of irrigation in Burleson County suggest that water sales are unlikely to constrain agricultural production. Water sales are economically equivalent to sales of oil and gas, which are widespread in Burleson County. That is, water sales are a source of income without reducing agricultural production. Thus, expected water sales can be modeled simply as an increase to household income. The planned Vista Ridge water project included approximately 25,000 acre-feet of Burleson County water at a cost of $46/acre-foot, so a $1.15 million Burleson County water sale was modeled as income to households with annual incomes in the $35,000 to $50,000 range, the appropriate income group as defined by IMPLAN. Median household income in Burleson County was $45,650 with a mean income of $56,682 in the 2012 American Community Survey (Census Bureau, 2015). Similarly, farm operators reporting net gains averaged annual incomes of $41,929 (USDA, 2014). Farm incomes are relevant because most water sales will be from farmers or others with agricultural land holdings.

Median household income in Hale County was $45,650 with a mean income of $56,682 in the 2012 American Community Survey (Census Bureau, 2015). Farm operators reported average annual incomes of $45,152, although farm operators reporting net gains averaged annual incomes of $132,439 (USDA, 2014). Still, the value of water sales was modeled as an increase in income to households with $35,000 to $50,000 annual incomes due to the variability of crop revenues and the fact that a good deal of land, and therefore water, is owned by retirees with relatively low incomes.

Agricultural irrigation accounts for more than 95% of water use in Hale County, and irrigation from the Ogallala aquifer in that region is near maximum levels. Thus, agricultural irrigators may opt to use less water in their agricultural operations and sell a portion of their water to outside interests. In this case, increased income from water sales is offset by reduced agricultural production. The most likely scenario given crop water use requirements would be to convert land from irrigated cotton to dryland cotton or to irrigated small grains, which require less water than does irrigated cotton (Masoner et al., 2003).

Estimating the effect of decreased water use requires modifying IMPLAN cost functions to represent both irrigated and dryland crop production. Rather than relying on analysis by parts to change costs following Whited (2010), this study customized IMPLAN coefficients following Dudensing and Falconer (2009) and Dudensing, Robinson, and Hanselka (2016). IMPLAN value-added coefficients represent employee compensation, proprietor's income, other property income, and taxes as a proportion of an industry's final demand sales, while absorption coefficients represent expenditures for goods and services purchased from other industries. Because value added and absorption coefficients are based on expenditures per dollar of final demand sales, each expense in the cotton and wheat budgets was divided by expected revenue to convert per acre expenditures to a per-sales-dollar or proportion of revenue basis (Texas A&M AgriLife Extension Service, 2015a, 2015b).

The 2015 budgets for both dryland and irrigated cotton and wheat estimated slightly negative returns above total costs, which are partially compensated by crop insurance and disaster payments after harvest. Farmers enter a cropping year with the intent to break even or be profitable and purchase inputs in line with those expectations. Thus, revenues were increased to breakeven levels for purposes of modifying IMPLAN coefficients; this allowed budget proportions to sum to 1 and was equivalent to proportioning expenses. Each item in the budget from seed to proprietor's income was matched to the appropriate IMPLAN sector.

An IMPLAN model was modified to represent a specific commodity and production method combination (e.g., irrigated cotton or dryland wheat) in two phases. First, study area data were customized to represent the appropriate Extension budget's value added coefficients based on proprietors' income, rental or share-rent values, and wages. Second, industry production was customized by replacing some default absorption coefficients with values calculated from the crop budget. Extension crop budgets focus on major expenses and do not consider payments to all sectors of the economy. For example, Extension crop budgets do not have a line for accounting services or computer equipment, but IMPLAN does. In fact, the irrigated and dryland cotton budgets respectively list 33 and 28 expenses represented by 12 IMPLAN sectors, but the IMPLAN cotton cost function includes absorption coefficients for 99 sectors. To estimate payments across the entire economy, the budget-driven coefficients were not held as fixed but rather were allowed to vary when the model rebalanced, which is an automated process in the IMPLAN model.

The magnitude of cropping changes and the direct effects of water sales on agricultural production was estimated based on irrigation water use by irrigated cotton versus wheat and grain sorghum. Cotton irrigation was set at 25 acre-inches (2.1 acre-feet) annually (Warrick et al., 2002; Masoner, 2003). Wheat and sorghum irrigation was set at 19.5 acre-inches (1.6 acre-feet) (Rogers and Sothers, 1996; Masoner, 2003; Almas and Collette, 2006; Adusumilli et al., 2011).

Twelve thousand irrigated cotton acres would need to be converted to dryland to support water sales of 25,000 acre-feet, the same volume as the Vista Ridge project in Burleson County (Table 1). This would decrease the value of cotton production by $7.86 million because dryland cotton yields only 350 pounds/acre compared to 1,250 pounds for irrigated cotton. Farmers could choose to convert irrigated cotton acres to dryland wheat, which has higher profitability than dryland cotton; however, because dryland wheat also has lower revenues, the value of agricultural production would decrease by $9.32 million. Alternatively, 15,385 acres of irrigated wheat could be converted to dryland wheat or sorghum, decreasing the value of grain sales by $4.08 million. Conversion of irrigated cotton to irrigated wheat or sorghum is not logical given large negative returns to irrigated small grains in the Extension budgets for both 2015 and 2014; conversion to dryland cotton or wheat is more profitable. If irrigated small grains were to become profitable, the vast number of acres required would require significant coordination.

Table 1. Expected Hale County crop acreage and value changes due to water leases.

Scenario	Required acreage shift	Loss to original crop	Gain to conversion crop	Difference
Irrigated cotton to dryland cotton	12,000.00	$10,918,080.00	$3,057,840.00	-$7,860,240.00
Irrigated cotton to dryland wheat	12,000.00	$10,918,080.00	$1,596,000.00	-$9,322,080.00
Irrigated cotton to irrigated wheat or sorghum	54,545.45	Not preferred under current conditions		
Irrigated wheat to dryland wheat	15,384.62	$6,123,076.92	$2,046,153.85	-$4,076,923.08

The losses and gains for the three viable agricultural scenarios as well as the household income generated by water sales were modeled in individually in IMPLAN. Because each commodity production method had a unique cost function, the loss or gain for each commodity/production practice combination was analyzed in a separate model, and results were summed. Models were also created for Brazos and Lubbock Counties, metropolitan counties adjacent to Burleson and Hale Counties, respectively, to capture the trade flow impacts of local economic changes.

5. Data analysis

The direct effects on water payments to households and changes in agricultural production result in two types of multiplier effects: *indirect effects* from the purchase of inputs among local industries and *induced effects* from the expenditures of institutions such as households and governments benefitting from increased the activity among local businesses (Davis, 2001). The total effects are the sum of direct, indirect and induced effects for each of four outcomes: output (gross sales), total value added (contribution to gross regional product), labor income, and employment. Labor income is a component of value added, which is a component of output, so the figures in the tables below cannot be summed.

The Burleson County model included only the increased income from lease payments at $46 per acre-foot as water sales there do not require a decrease in irrigated crop production. The total impacts of the $1,150,000 lease payments in the county were $565,100 in output and 4.8 full- and part-time jobs (Table 2). Leakages from household income are high because a large share of money is saved or invested, as well as being spent outside the local economy. The impact of the leases is most likely lower than estimated by the model because all leases were assumed to be made to Burleson County residents, which is unlikely.

Table 2. Total economic impacts estimated for water sales scenarios.

Burleson County Water Lease Payments				
	Output	**Value Added**	**Labor Income**	**Employment**
Lease Income =Total Effects	***$565,100***	***$347,500***	***$153,900***	***4.8***
Hale County: Conversion of Irrigated Cotton to Dryland Cotton				
	Output	**Value Added**	**Labor Income**	**Employment**
Lease Income	$1,083,700	$627,100	$304,400	9.6
Irrigated Cotton Loss	($16,046,500)	($4,270,200)	($2,137,800)	-82.4
Dryland Cotton Gain	$4,457,600	$1,437,300	$894,700	23.7
Overall Total Effects	***($10,505,200)***	***($2,205,800)***	***($938,700)***	***-49.1***
Hale County: Conversion of Irrigated Cotton to Dryland Small Grains				
	Output	**Value Added**	**Labor Income**	**Employment**
Lease Income	$1,083,700	$627,100	$304,400	9.6
Irrigated Cotton Loss	($16,046,500)	($4,270,200)	($2,137,800)	-82.4
Dryland Small Grains Gain	$2,353,300	$624,400	$331,300	12.5
Overall Total Effects	***($12,609,500)***	***($3,018,700)***	***($1,502,100)***	***-60.3***
Hale County: Conversion of Irrigated Small Grains to Dryland Small Grains				
	Output	**Value Added**	**Labor Income**	**Employment**
Lease Income	$1,083,700	$627,100	$304,400	9.6
Irrigated Small Grains Loss	($8,979,800)	($2,160,000)	($968,600)	-41.1
Dryland Small Grains Gain	$3,017,100	$800,500	$424,800	16.1
Overall Total Effects	***($4,879,000)***	***($732,400)***	***($239,400)***	***-15.4***

In Hale County, higher water rates were assumed based on water's agricultural value. The value of water was estimated at $75 per acre-foot based on a share of returns above variable costs in the irrigated and dryland extension crop budgets. This value was in line with estimates cited by the EPA (2012) and

Ziolkowska (2015). These lease payments totaling $1,875,000 would be expected to generate $1.08 million in output and 9.6 jobs.

The Hale County scenarios assumed that leased water was diverted away from agriculture. When irrigated cotton was converted to dryland cotton, economy-wide losses of $10.51 million in output and 49.1 jobs were expected (Table 2). Decreased agricultural revenue and accompanying decreases along the agricultural supply chain outweighed the value of lease payments in every scenario. When irrigated cotton was converted to dryland small grain (wheat and sorghum) production, total economic losses included $12.61 million in output and 60.3 jobs. When irrigated small grains were converted to dryland wheat or sorghum, losses included $4.88 million in output and 15.4 jobs. It is tempting to think that, facing large direct losses in agricultural sales, farmers would not sell their water; however, profits are a small share of gross commodity sales and are often negative without crop insurance payments or government subsidies. Water leases involve much less risk than does crop production.

Losses were not distributed equally across the county economy. The direct losses to agriculture production were largest. Relative effects on other sectors depended upon the industry or household group with sales increases or decreases. This is illustrated well in the case of irrigated cotton acreage converted to dryland small grains (Table 3). Home ownership and real estate, retail, restaurants, and healthcare were most affected by lease income to the $35,000 to $50,000 household income group. Agricultural support, insurance, and equipment repair ranked among the most affected industries for agriculture commodities.

Table 3. Total Hale County output impacts for each aspect of an irrigated cotton to dryland small grains conversion ranked by top 10 sectors affected.

	Lease Income		Irrigated Cotton Loss		Dryland Small Grains Gain	
Rank	**IMPLAN Sector**	**Output Change**	**IMPLAN Sector**	**Output Change**	**IMPLAN Sector**	**Output Change**
--	Total	$1,083,663	Total	($16,046,480)	Total	$2,353,318
1	Owner-occupied dwellings	$215,575	Cotton farming	($11,044,729)	Grain farming	$1,613,847
2	Real estate	$51,054	Support activities for agriculture & forestry	($1,184,012)	Insurance agencies, brokerages, & related activities	$170,196
3	Wholesale trade	$40,497	Electric power transmission & distribution	($595,702)	Support activities for agriculture & forestry	$117,314
4	Limited-service restaurants	$37,294	Insurance agencies & brokerages	($475,068)	Commercial and industrial equipment repair & maint.	$48,423
5	Hospitals	$36,695	Maintenance & repair of nonresidential structures	($386,059)	Wholesale trade	$39,667
6	Electric power transmission and distrib.	$30,612	Wholesale trade	($196,927)	Real estate	$36,802
7	Retail - General merchandise stores	$30,068	Commercial & industrial equipment repair & maint.	($193,323)	Nitrogenous fertilizer manufacturing	$34,100
8	Retail - Food and beverage stores	$28,795	Nitrogenous fertilizer manufacturing	($175,180)	Owner-occupied dwellings	$25,811
9	Other local government enterprises	$28,590	Owner-occupied dwellings	($172,934)	Monetary authorities & depository credit intermediaries	$18,585
10	Automotive repair & maintenance	$25,536	Real estate	($160,853)	Other local government enterprises	$16,313

This study did not consider the economic benefits of the water received by the purchasing city. Such an analysis is outside the immediate scope of interest to the rural county facing decreasing economic activity resulting from the sale, although it should be of interest to the broader region. However, we used IMPLAN trade flows between the water importer and exporter to consider how the economic relationship between the rural county and a nearby city affect the economic impacts. Trade flows to neighboring Brazos County from Burleson County lease payments were modeled but were associated with only $3,700 in additional output in the Brazos County economy.

Hale County is adjacent to metropolitan Lubbock County, which could conceivably purchase water from Hale County. Even if Lubbock did not purchase the water, the higher ordered city would likely experience trade flow effects from Hale County. In addition to being a regional shopping and medical care destination, Lubbock has a large cottonseed oil mill that relies on cottonseed from the surrounding area as well as agricultural finance, insurance, and supply firms. The Lubbock County economic loss from Hale County converting 12,000 acres of irrigated cotton to dryland cotton was estimated at $2.16 million in output and 12.7 jobs (Table 4).

Table 4. Economic impact on Lubbock County of Hale County water leases and associated cropping changes.

	Output	Value Added	Labor Income	Employment
Direct Effect	$0	$0	$0	0
Indirect Effect	($1,832,200)	($909,400)	($469,400)	-9.8
Induced Effect	($330,000)	($190,000)	($102,700)	-2.9
Total Effect	($2,162,200)	($1,099,400)	($572,200)	-12.7

While Lubbock County's output impacts associated with Hale County lease income totaled only 4.91% of the lease payments, Lubbock total output losses totaled 27.18% of irrigated cotton losses in Hale County due to the links within the regional cotton industry. As a result, indirect or business-to-business effects are 4.5 to 5 times larger than induced effects, meaning that the relatively more vocal and politically active business community may take a stand in regional water plans, particularly if water is exported outside the region. Business interests may be divided if water leases benefit local industry and residents. Trade flow effects back to Hale County were negligible, ranging from $340 (0.03%) for the lease payments to $40,750 (0.25%) for revenue loss from irrigated cotton. Trade flow effects appear to be important considerations in determining the regional impact of water transfers.

6. Conclusions

These results indicate that in situations where an aquifer is irrigated at or exceeding maximum sustainable levels, water leases are not equivalent to leases on mineral rights. Rather, losses to agricultural productivity offset gains in income to households. For rural, agriculture-dependent counties, these agricultural losses likely outweigh economic gains from lease payments. Counting the entire value of water leases as income to the local economy may be misleading, as only about half of that income stays in the economy. Not considering impacts of lost agricultural productivity overlooks another important component of a water transfer. Furthermore, sectors of the economy are affected differently by shocks to income and agricultural production, and an understanding of likely impacts across sectors can help communities to plan for future scenarios.

Incorporating trade flows into the analysis of water leases recognizes that other jurisdictions within the regional may experience losses. If water is transferred within the region, trade flow losses should be included along with analyses of the economic benefits to the importing jurisdiction. If water is exported outside the region, losses will not offset benefits to the importer but will magnify losses in the exporting region—a fact that should be acknowledged by state-level planning bodies.

This study considers only the backward-linked economic impact of water sales in the cases of previously unused water and water reallocated from agriculture to export. It does not consider the effects on forward linked processing plants, such as denim mills or flour mills that may be constrained or benefit from changes in local crop availability. Furthermore, the study does not address issues of social equity and impacts, environmental issues, or legal concerns, each of which poses additional threats to water transfer deals and to water-exporting regions.

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