The Journal of
Regional
Analysis
& Policy

JRAP 40(2): 160-170.

Economic Impacts of Irrigation Water Transfers on Uvalde County, Texas

Melissa Whited
University of Wisconsin – USA

Abstract. Where water is scarce but demand is growing, water markets offer an opportunity to increase economic efficiency by enabling the reallocation of water among users and sectors. While buyers and sellers willingly enter into such transactions, indirect impacts on agricultural communities can be devastating, as intersectoral transfers may substantially alter the nature of the community's underlying economy. This study investigates the potential economic impacts of irrigation water transfers on Uvalde County, Texas, accounting for the indirect and induced effects that crop mix changes have on agricultural input industries and labor, as well as positive impacts resulting from the influx of water permit payments into the local economy. Results from modeling these impacts using locally-produced crop budgets versus the model's aggregate production functions are compared. Overall we find that water transfers negatively affect the county's employment, labor income, and output significantly, and that labor income changes are particularly sensitive to the use of crop budgets as opposed to aggregate production functions.

1. Introduction

Population and economic growth in the southwestern United States have put increasing pressure on water resources in many areas (Glennon, 2005). As rivers, aquifers, and springflows have declined, conflicts among environmental and human uses of water have emerged or grown in intensity (Molle & Berkoff, 2009; Glennon, 2005). While historically water planners looked to augment water supplies to satisfy growing demand, new opportunities for enhancing supply are limited (Griffin, 2006; Glennon, 2005). Instead, policy makers now focus on rebalancing sectoral allocations to align with changing social values, preserve environmental flows, and achieve optimal economic returns (Glennon, 2005; Griffin, 2006; Molle & Berkoff, 2009). Water used for agricultural irrigation is often viewed as the source for growing urban area water demand, as data suggest that small reallocations from agriculture to urban uses could satisfy demand for decades (Shupe, Weatherford, & Checchio, 1989; Howe, Lazo, & Weber, 1990). Yet the apportionment of water is fraught with trade-offs among communities, the environment, economic activities, and current and future generations.

Over the last 30 years, the application of economic principles to water allocation, particularly tradable permits, has grown in popularity (Gillig, McCarl, Jones, & Boadu, 2004). Economic theory holds that tradable permits are capable of improving economic efficiency by moving water from lower-valued uses to higher-valued uses, thereby maximizing aggregate social welfare and facilitating economic growth (Saliba & Bush, 1987; Michelsen, 1994; Griffin, 2006; Glennon, 2005). When adequate permits are assigned to environmental uses, such a system can also protect ecosystem needs, such as in-stream flows, while preserving flexibility in allocation among human uses.

Water transfers constitute a market when property rights to water permits are fully specified, transaction costs are minimized, and a sufficient number of agents are active in the trade of permits (Saliba & Bush, 1987). Markets promote economic efficiency by enabling exchange between willing buyers and sellers, but they can have disadvantages, particularly when impacts from the transfer are felt by more than the buyer and seller. It has been argued that the property rights for water are not fully specified, as benefits and losses from reallocating water supplies may be felt by entire communities, not only individual appropriators.

Brajer and Martin (1990, p. 36) concede that "it is possible that water may have a 'community value' which may not be captured in the market price of a water right." Water that is individually held, particularly in agricultural areas, generates value to communities by enabling agricultural activity that supports the community's economy and cultural identity, and enables the community's future growth. Sale of that resource can be economically and psychologically damaging to a community, and is ill-captured in individual permit holders' profit-maximization decisions (Brajer & Martin, 1990). These secondary effects are referred to as "indirect economic impacts," and are the focus of this study. When they are large enough, these indirect impacts may result in the decline of rural communities. They may also derail groundwater management plans, reduce economic efficiency, and threaten the preservation of environmental water flows.

2. Edwards Aquifer water market

This study investigates Texas' first groundwater market and considers potential indirect economic impacts of groundwater transfers on Uvalde County, a rural agricultural area in South Central Texas. The accounting stance is the county level – only local economic impacts are considered, whether or not these impacts are offset at the regional level.

South Central Texas, home to San Antonio and a large agricultural community, is among the fastest growing regions in the state. The region's population is projected to grow 76% between 2010 and 2050, with a corresponding increase in water demand of 286,000 acre-feet (Texas Water Development Board, 2010; Texas Water Development Board, 2002). The region relies heavily on the Edwards Aquifer for municipal, industrial, and agricultural water, but recharge has not kept pace with demand (McCarl et al., 1997). The problem is intensified by the presence of several endangered species whose habitat depends on springflows from the Edwards Aquifer.

While the majority of groundwater in Texas is governed by the rule of capture, a 1991 lawsuit against the state of Texas for failure to enforce the Endangered Species Act to protect aquifer-dependent species led to a turning point in how the Edwards Aquifer is governed. In 1993, SB 1477 created the Edwards Aquifer Authority, an agency responsible for establishing a cap on aquifer pumping and issuing pumping permits. The bill also created means to market groundwater rights by making permits transferable (Boadu, McCarl, & Gillig, 2007; McCarl et al., 1999).

In many water markets, water moves from agricultural irrigation (where it generates fairly low returns) to municipal and industrial uses where a higher value is attached to it (Saliba & Bush, 1987). This is currently happening in South Central Texas, where water is moving from rural, agricultural areas to urban areas for municipal and industrial use. Bexar County, where San Antonio is located, is the dominant purchaser of water leases and rights to irrigation water. Uvalde County is a prominent source of irrigation water permits.

Uvalde County is situated in the semi-arid southwestern portion of Texas, approximately 80 miles west of San Antonio. Farming and ranching has historically played a prominent role in Uvalde County's economy, with irrigated crop farming relying primarily upon water from the Edwards Aquifer. The 1997-2002 average value of Uvalde County crops exceeded $53 million (2008 dollars) (Texas AgriLife Research and Extension Service, 2003), with the farming sector employing more than 1,600 people (United States Department of Agriculture, 2002). Agricultural and forestry support services added an additional $14 million in output. Combined, these two sectors comprised approximately 6% of the county's economic output and 13% of its employment (Minnesota IMPLAN Group, 2008).

When water is transferred out of the area in which it has historically been used, it often results in a reduction in irrigated acreage, which then has impacts on related businesses in the community (Saliba & Bush, 1987). Thus reduced irrigation would result not only in lower crop sales for farmers in Uvalde County, but would also impact industries that supply production inputs to the agricultural sector (e.g., fuel, seed, fertilizer, machinery, labor). In this study, we analyze the extent to which water transfers could impact Uvalde's economy by considering an extreme case in which irrigators transfer all of their water permits out of the county.

3. Literature review

Transfer of water has occurred in many of the western states, including Nevada, California, Colorado, New Mexico, Idaho, and Arizona (Saliba & Bush, 1987; Charney & Woodard, 1990). Indirect economic impacts resulting from such transfers are well-documented in the literature. However, evaluation of indirect economic impacts depends crucially on one's accounting stance. At the regional or state level, local losses are frequently more than offset by gains in other areas and may appear inconsequential (Howe, Lazo, & Weber, 1990). Further, economic theory generally assumes full factor employment and complete mobility, positing that factors of production that become unemployed will relocate to find employment elsewhere (Hamilton et al., 1991). However, Howe, Lazo, and Weber (1990) argue that this theory does not always accurately describe all situations and that permanent income losses to factors of production can and do occur. They write, "In the presence of persistently depressed rural conditions, factors of production left unemployed in agriculture, in agricultural supplying activities, and in agricultural processing activities can be idled for long periods, leading to real national efficiency losses" (p. 1201). In addition, the authors acknowledge the deep economic and psychological costs incurred by these parties.

Input-output analysis is often used to estimate the effect that a change in direct economic expenditures has on a given region (Mann, 2002). Models such as IMPLAN (IMpact Analysis for PLANning) and REMI (Regional Economic Models, Inc.) have been used to estimate the impacts that decreased irrigated agriculture can have on regional economies due to a reduction in farm input expenditures. In Howe, Lazo, and Weber's 1990 analysis of the Arkansas River in southeastern Colorado, the authors used IMPLAN to calculate that each acre-foot of water transferred resulted in an estimated loss of state net income of $53, although cost savings to cities far exceeded this amount. Charney and Woodard (1990) conducted a study of water transfers in La Paz, Arizona, using a statewide econometric model. They found that every 1,000 acres of agricultural land retired due to water sales resulted in a loss of 17 jobs.

In order to more accurately simulate water prices and the positive effect that payments for water may have on the economy, Seung et al. (1998) used a computable general equilibrium model to examine the impacts of reallocating agricultural water to recreational use in Nevada and California. The authors found that the combined effect of water payments and increases in recreation did not offset the losses in the agricultural sector.

Several studies have attempted to quantify the impact that reductions in irrigated agriculture would have on Uvalde County's economy. Lee et al. (1987) explored potential economic impacts resulting from overpumping the Edwards Aquifer. The authors predicted likely replacement dryland cropping mixes using a linear programming model to maximize net returns to land, labor, and water, and then modeled the economic impacts of the resultant cropping mixes using an input-output model. Their analysis found that Uvalde's economy would contract by approximately $23 million (more than $43 million in 2008 dollars) by shifting from irrigated agriculture to dryland agriculture as the aquifer's water elevation dipped below economically recoverable levels.

Ten years later, McCarl et al. (1997) conducted a similar analysis, but included payments to farmers of $90 per acre of land. They estimated that replacing most of Uvalde County's irrigated crops with dryland crops would result in a loss of 559 jobs and reduce output by $35.4 million dollars (more than $47 million in 2008 dollars). Their study used crop enterprise budgets to construct an agriculture simulation model to determine optimal crop mixes and a regional input-output model (IMPLAN) to estimate the impacts of reductions in crop acreages on the local economy.

In 2006, the South Central Texas Regional Water Planning Group estimated that converting irrigated crops to rain-fed crops would reduce gross farm income by $126 and input sales by $84 for every acre-foot of water (South Central Texas Regional Water Planning Group, 2006). However, the study did not consider the impact that an influx of water lease payments (estimated to be $135/AF) would have on the local economy. Moreover, the study assumed that farmers would only lease water from cotton, grain sorghum, wheat, and other grain and would maintain the same crop mix but convert those crops from irrigated to dryland production. This approach may not be realistic if it does not maximize profits for farmers and if it arbitrarily limits the production choices of the farmer.

This study extends previous research in this area. Similar to the studies mentioned above, we examine the potential economic impact of irrigation water transfers on Uvalde County's economy by assuming that all water will be leased to non-agricultural users and that irrigated land will be converted to an optimal mix of dryland crops. These changes in crops are then used to calculate economic impacts using an input-output model. Unlike previous studies, our primary method of analysis does not simply evaluate a change in sectoral output (e.g., changes in output from grain farming or vegetable and melon farming), but rather calculates changes in demand for intermediate inputs specific to the actual crops being taken out of, or placed into, production. This approach is referred to as "analysis by parts," and we believe that it may yield more accurate results, as inter-industry inputs vary significantly among crops within sectors and differ based on whether irrigation is used. Such detail is not captured in the model's aggregate crop production functions. For the purposes of comparison, we present results from both analysis-by-parts and the standard method of modeling changes to aggregate sector output only.

Further, we evaluate the impact of lease payments to farmers using two scenarios – one in which the price is set at $135/acre-foot, and one in which the price is allowed to increase above $135/acre-foot for producers with highly profitable crops. Conducting the study in this manner allows us to better approximate the conditions that would need to occur in order for farmers to lease all of their water permits, and what the consequences of such water payments would be as portions of this income are spent within the local economy.

4. Methods and data

The initial step in this analysis was to determine a baseline of irrigation permits in Uvalde County, the average amount of irrigation water pumped, and the typical crop mix. The year 2000 was selected as the baseline against which to measure changes in the local economy due to irrigation water transfers.

4.1. Baseline irrigation permits

Irrigation permits were typically allocated to historically irrigated farmland at a rate of two acre-feet per acre of land. Of these two acre-feet, one acre-foot was transferable, while the other was to remain with the land, referred to as the "base" acre-foot. The process of issuing irrigation permits has been long, with initial permits issued beginning in the late 1990s and nearing completion by 2006. During this time period, permits were also leased and sold, making it difficult to establish a baseline.

The amount of permits originally held by Uvalde irrigators was estimated by adding the number of permits sold or leased from 1999 to 2008 to the number of final authorized permits in 2008, and subtracting the number of leases that expired during this period. These values were obtained from the Edwards Aquifer Authority's transfer and permit databases and are depicted in Figure 1, below. From this analysis, we estimated that the amount of Uvalde County irrigation permits eventually authorized totaled 116,171 acre-feet, or 20.3% of the 572,000 acre-feet of total permits authorized in all counties.

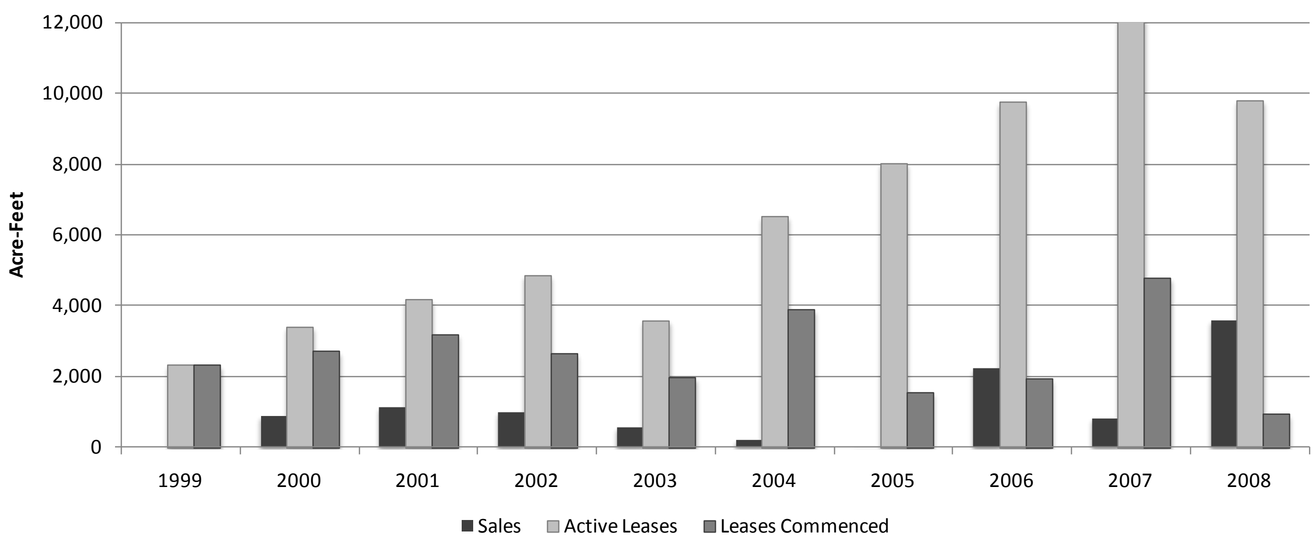

Figure 1. Uvalde water transfers 1999-2008 (compiled from Edwards Aquifer Authority Permit Transfer Database data as of July 2009).

Many owners of land in Uvalde are absentee, residing in San Antonio or other areas outside of the county. Estimating the amount of permits actually held by Uvalde County residents was critical for calculating the impact of water permit payments on the local economy. It was assumed that absentee landowners would spend most or all of payments received outside of Uvalde County, while Uvalde County residents would be more likely to spend a portion of the payments within the county at local businesses.

Of Uvalde County irrigation water permits, approximately 37% were registered to entities with addresses outside of the county, many to families who no longer engaged in agriculture in the county but leased their land and water rights to others.[1] From

[1] Personal communication with several Uvalde farmers indicated that this was common.

this data, it was estimated that Uvalde County residents held 73,188 acre-feet of the final Uvalde irrigation permits issued.

4.2. Baseline crops and irrigation water used

To approximate the baseline acres of crops planted in Uvalde County prior to significant water market activity, we averaged harvested acres of crops reported in the 1997 and 2002 USDA Census of Agriculture, and adjusted these acres to planted acres using data from the National Agricultural Statistics Service. According to these statistics, 55,276 acres of land were irrigated in Uvalde County, of which 7,974 acres were double-cropped. The primary irrigated crops were corn, winter wheat, sorghum, cotton, vegetables (cucumbers, cabbage, spinach, onions), forage and hay, oats, and pecans. The average value of crops grown in Uvalde County in 1997 and 2002 exceeded $53 million (2008 dollars) (Texas AgriLife Research and Extension Service, 2003), representing nearly 5% of Uvalde County's output.

The amount of water pumped to irrigate these crops varies due to fluctuations in rainfall and temperature, as well as cropping mix. Mean precipitation in the county is 24 inches, but drought occurs frequently, with 23% of years receiving 6 inches less rainfall than the mean (Texas AgriLife Research and Extension Center at Uvalde 2009). From 1999 to 2008, water pumped for irrigation in Uvalde County ranged from a low of 15,249 acre-feet to a high of 79,076 acre-feet (Edwards Aquifer Authority, 2009). Given the frequent incidence of drought, it was estimated that irrigators likely retain an additional half-acre-foot of water per irrigated acre than would be necessary under average precipitation. It was thus estimated that irrigators in Uvalde County reserved a total of 80,807 acre-feet for crop production. The primary irrigated crops and drought water consumption are depicted in Figure 2, below.

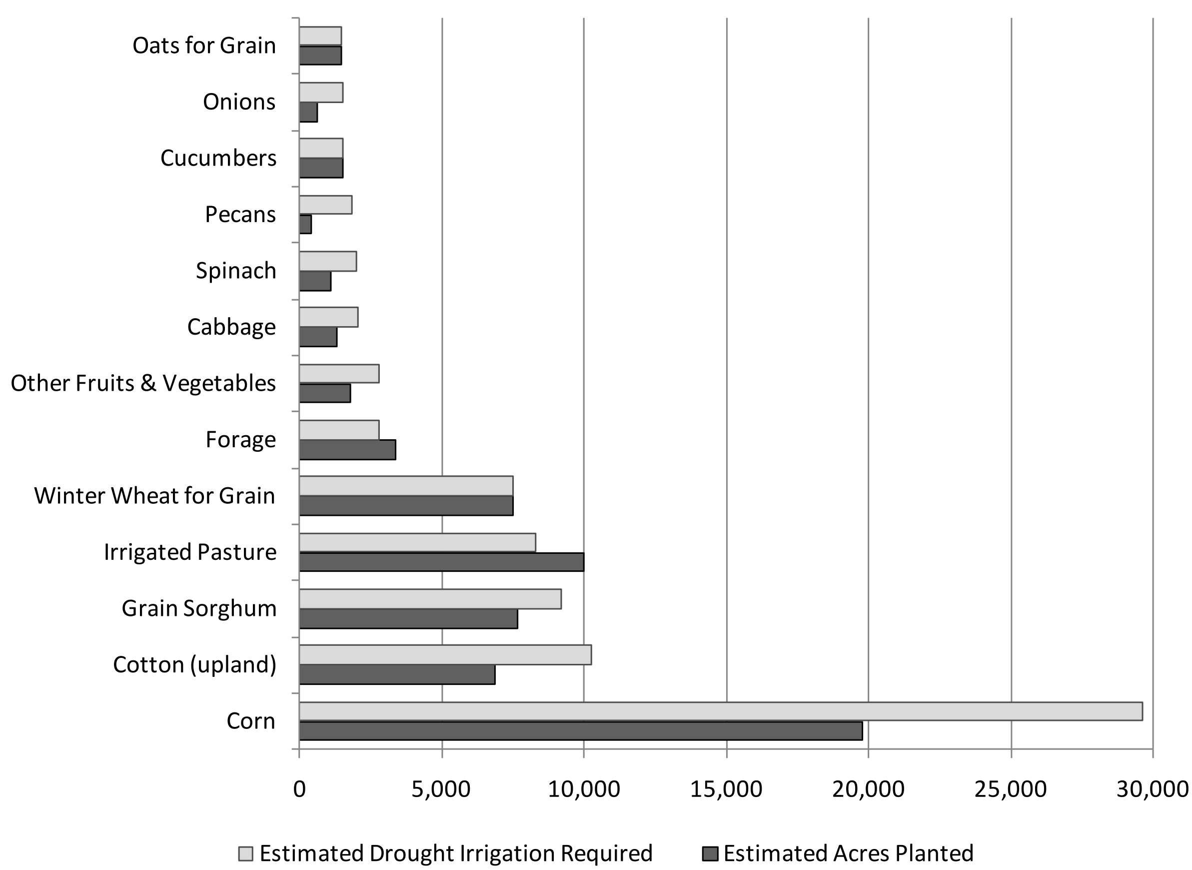

Figure 2. Irrigated crops planted (average of 1997 & 2002) and total crop water consumption under drought conditions for Uvalde County (compiled using data from USDA, 2002 and crop budgets from Texas Agricultural Extension Service, 2003, 2004, 2007).

4.3. Crop mix and input changes

Our analysis assumes that Uvalde County farmers keep the total acreage of agricultural land constant, but upon transferring water permits, water intensive crops are traded for a mix of the most profitable dryland crops. The selection of dryland crops to replace irrigated crops was based on an analysis of crop profitability, risk mitigation, historical cropping patterns, and agronomic considerations.

Sorghum and winter wheat were found to be the most common dryland crops planted in the county, with sorghum's popularity increasing in recent drought years. In terms of profitability, sorghum's net returns are lower than those accruing to winter wheat, but the crop's tolerance of drought and beneficial agronomic effects in rotation suggest that it will likely remain a popular dryland crop in Uvalde County.[2]

From this analysis, two dryland crops – sorghum and winter wheat – were selected as likely replacement crops for irrigated agriculture in Uvalde County. It was assumed that these crops would be planted based on historical proportions of 62% winter wheat and 38% sorghum.

Change in demand for agricultural inputs was measured by first determining the intermediate input requirements for each crop as specified in the crop enterprise budgets assembled by the Texas AgriLife Extension Service in Uvalde (Texas AgriLife Extension Service, 2009). Approximately thirty separate inputs were tracked, ranging from labor for planting, harvesting, and irrigating, to fuel requirements, seed, and government licenses. These per-acre input requirements were then multiplied by the number of acres to be substituted. The original amount of inputs demanded was subtracted from the level of inputs for dryland crops to arrive at net change in inputs. The results were aggregated into 14 categories to correspond to those used in IMPLAN.

$$\textit{Input Change} = \sum (\textit{Dryland Inputs} \times \textit{Acres}) - \sum (\textit{Irrigated Inputs} \times \textit{Acres}) \quad (1)$$

[2] Sorghum's average net returns from 2005-2009 are negative when land rent is accounted for, yet since 1973 it has averaged 38% of dryland crop acres. This is likely due to the willingness of owner-operators to accept below-market returns to their land assets in order to diversify their crop mix and reap the benefits of the rotation effect from incorporating sorghum in their crop rotation. Planting different crops during the same year allows a farmer to spread out labor needs and decreases his or her risk to climatic variability and market fluctuations (Miles and Brown, 2005). Further, crop trials in Bushland, Texas, and Tribune, Kansas, demonstrated that including sorghum in a rotation with wheat increased average grain yields approximately 50% over continuous wheat or wheat-fallow rotation sequences (Baumhardt and Anderson, 2006).

4.4. Payments for water permits

Payments to Uvalde County residents for water permits were calculated under two scenarios. The first assumed that all water permits would be transferred at a price of $135/acre-foot, based on estimates from the South Central Texas Regional Water Plan for 2006 (South Central Texas Regional Water Planning Group, 2006). The second method calculated the minimum price at which a farmer would sell their water permit, based on the difference between the irrigated crop's marginal profit and the dryland crop's marginal profit, and the water consumption of the crop. This payment scenario assumes the farmers own the permits to their irrigation water and therefore internalize the opportunity costs associated with irrigated agriculture and water transfers.

Based on this methodology and a price floor of $135/acre-foot, prices for water permits increased up to a high of $631 for cabbage irrigation water. Payments to farmers were calculated for each crop by multiplying the average acres of crop planted in 1997 and 2002 by the crop's water requirements (under drought conditions) and the price per acre-foot:

$$\textit{Water Permit Payments} = \textit{Acres of Crop} \times \textit{Crop Water Consumption} \times \textit{Permit Price} \quad (2)$$

4.5. Modeling economic impact

Secondary economic impacts resulting from conversion of irrigated crops to dryland crops can be estimated using an input-output model such as IMPLAN. Input-output models are constructed using internally consistent datasets that describe an economy's inter-industry linkages and adjust for trade through regional purchase coefficients (Shaffer, Deller, & Marcouiller, 2004). IMPLAN estimates the cumulative impact of a "shock" to one sector of the economy on the economy as a whole. The cumulative impact is measured by summing direct impacts (e.g., changes in industry output), secondary effects on suppliers of an industry ("indirect impacts"), and the effects resulting from changes in household income ("induced impacts"). Thus input-output models trace the flow of money as it circulates through an economy (Miller & Blair, 2009; Shaffer, Deller, & Marcouiller, 2004; Stynes, 1999).

One method used to estimate the impacts of eliminating irrigated crops is to reduce the output of those sectors in the input-output model by the net change in market value of the crops (value of dryland crops less value of irrigated crops). However, IMPLAN combines multiple crops with very different production functions into general categories such as "grain farming" and "vegetable and melon farming." Changes in output level from a crop is modeled using an aggregate sectoral production function, which averages several different crops' production functions.

Additionally, these sectors do not reflect the difference in production functions for a crop grown under irrigation compared to a dryland crop. In our study this would lead to skewed results, as, for example, the weighted average value of inputs for irrigated grain crops removed from production is $490, while the weighted average value of inputs for the dryland grain crops introduced is only $157 – a substantial difference which may not be fully captured by simply introducing a shock to IMPLAN's aggregated crop sectors. For these reasons, we calculated changes in intermediate inputs for each sector as well as changes in farm proprietor income and used these as the shocks to the county's economy, rather than simply modeling a shock to IMPLAN's aggregated crop sectors.

5. Results

The economic impacts of converting irrigated crops to dryland crops in Uvalde County were modeled by converting 63,250 acres of irrigated crops to 55,276 acres of dryland winter wheat and sorghum, as detailed in Table 1.[3]

5.1. Reductions in intermediate inputs

Each acre-foot of Uvalde irrigation water permits transferred (whether or not the permit was held by a Uvalde County resident) reduced demand for intermediate inputs by an average of $292, with a total reduction in demand for intermediate inputs of approximately $34 million. After applying margins to retail sales, the direct impact on Uvalde County's economy was more than $27 million in reduced output. Additional indirect losses due to backward linkages of agricultural support businesses summed to more than $8 million, resulting in total output losses of more than $35 million.

Of greatest importance for Uvalde County's economy is the impact of these changes on labor income and employment. Labor income losses resulting from the conversion of irrigated agriculture to dryland agriculture total $16.6 million, and employment was reduced by more than 800 jobs, primarily in the agricultural support services.

[3] Dryland crop acres are less than irrigated crop acres because dryland crops cannot be double-cropped due to soil moisture limitations.

Table 1. Summary of acres converted from irrigated crops to dryland crops.

Crops	Irrigated Crop Acres (Includes Double-Cropped Acres)	Dryland Acres (No Double-Cropping)
Corn	19,763	0
Irrigated Pasture	9,963	0
Sorghum	7,681	21,005
Winter Wheat	7,479	34,271
Cotton (upland)	6,847	0
Forage	3,383	0
Other Fruits & Vegetables	1,773	0
Cucumbers	1,510	0
Oats for Grain	1,453	0
Cabbage	1,292	0
Spinach	1,102	0
Onions	601	0
Pecans	406	0
Total	**63,250**	**55,276**

5.2. Impact of payments for water permits

Payments for water permits to Uvalde County residents are expected to have a positive effect on the county's economy, offsetting some of the reduction in agricultural inputs with increased consumer spending. However, the small size of Uvalde County's economy implies that there will be significant leakage of these payments to other regions, particularly to the urban area of San Antonio.

Payments for water at $135/acre-foot totaled nearly $10 million, while payments under the variable price scenario totaled $11.6 million. However, leakages from these payments were substantial and offset losses in output, labor income, and employment only minimally, as depicted in the table below.

The combined direct, indirect, and induced impacts resulting from reductions in agricultural inputs and the inflow of payments for water permits are significant for Uvalde County. Overall, the economy suffers losses of more than $30 million in output, $15 million in labor income, and more than 750 jobs, regardless of whether the water permit prices remain fixed at $135/acre-foot or increase to amounts that would equate actual producer returns. The majority of these impacts are felt in the agricultural sector, but significant losses also result in wholesale trade and retail trade sectors.

Table 2. Summary of economic impacts resulting from conversion to dryland agriculture and payments for water permits in terms of economic output, labor income, and total employment.

IMPLAN Category	Description	Total Output Impact	Total Labor Income Impact	Total Employment Impact
(Varies)	Seed	($1,211,513)		
19	Agricultural Support Services	($12,315,826)	($11,362,814)	(636)
31	Electric Power	($1,956,017)	($419,255)	(4)
187	Irrigation Equipment Manufacturing	($176,161)	$0	0
319*	Farm Implements & Equipment	($1,023,545)	($375,221)	(8)
320*	Light Truck Dealers	($169,557)	($96,816)	(3)
323*	Farm Supply Stores	($2,876,417)	($1,145,072)	(38)
331	Diesel Fuel Dealers	($3,344,596)	($21,100)	(2)
335	Farm Products Hauling	($1,490,407)	($503,385)	(13)
354	Credit Lending	($144,318)	($39,408)	(1)
357	Crop Insurance Carriers	($567,646)	($181,549)	(5)
360	Agricultural Property Leasing	($3,615,612)	($543,667)	(22)
414	Truck Repair and Maintenance	($27,958)	($272,585)	(6)
417	Agricultural Equipment Repairs	($842,776)	$0	0
429	Licenses from Government	$126,064	$0	0
(Varies)	All other sectors	($5,730,902)	($1,676,592)	(76)
Subtotal: Crop Conversion Effect		**($35,367,186)**	**($16,637,465)**	(814)
	Water Permit Payments @ $135/AF		$1,247,637	46
TOTAL Crop Conversion + Water Payments of $135		**($30,925,865)**	**($15,389,828)**	(768)
	Water Permit Payments @ Variable Prices		$1,465,011	55
TOTAL Crop Conversion + Variable Water Payments		**($30,152,061)**	**($15,172,454)**	(759)

5.3. Comparison to Standard Impact Analysis

The total impacts on output, labor income, and employment given above from an analysis-by-parts method differ markedly from those produced by IMPLAN when simply reducing the value of output from each crop's sector, which is what might be considered a standard approach. This standard method estimates that output reductions from crop conversions and $135/acre-foot payments total $35.5 million, more than $4.5 million more than losses estimated by disaggregating the crop production functions. Estimated employment losses under the standard method total only 589 jobs (23% less than our estimates), while labor income losses sum to $8 million (approximately 47% less). A comparison of these impacts, averaged over the cropland converted and the total number of Uvalde irrigation water permits, is presented in Table 3 below.

The primary reason that the standard approach likely overestimates output impacts and underestimates labor income and employment impacts is due to aggregation of production functions. As discussed above, the replacement of high-input crops with extremely low-input crops implies that aggregated crop production functions do not fully capture the change in inputs required in shifting from irrigated agriculture to dryland agriculture.

Table 3. Comparison of per-unit impacts resulting from including payment for water permits and from employing an analysis-by-parts versus a standard approach.

	Analysis by Parts		"Standard" Analysis
	No Payments	$135/AF Payments	$135/AF Payments
Labor Income Change			
Per Acre Cropland Converted	$301	$278	$148
Per Acre-foot of Total Uvalde Permits	$143	$132	$70
Output Change			
Per Acre Cropland Converted	$640	$559	$643
Per Acre-foot of Total Uvalde Permits	$304	$266	$306

6. Policy implications and conclusions

Impacts resulting from the transfer of Edwards Aquifer permits are not borne equally by Uvalde County residents. Labor income in Uvalde County is reduced by more than $15 million, yet water permit holders receive payments totaling approximately $10 million for the transfer of their groundwater. These payments generate only $1.2 to $1.4 million in induced labor income, indicating that their effect on the overall economy is relatively small and that those who stand to gain from the transfer of water permits are largely distinct from those who are negatively impacted. Moreover, permit payments will not be evenly distributed among Uvalde County agriculturalists, as one third of irrigated farms in Uvalde County account for 75% of the total irrigated land (United States Department of Agriculture, National Agricultural Statistics Service, 2002).

The replacement of high return, labor-intensive agriculture (such as vegetables) with low-labor crops (such as winter wheat and sorghum) has the potential to greatly reduce the number of jobs available in agricultural support services in Uvalde County. Our results indicate that more than 750 jobs may be lost in these sectors, due to a decline in demand for agricultural inputs of approximately $34 million. However, further research is needed to explore alternative non-irrigated land uses, such as ranching or recreation, which may have significantly different impacts on the local economy.

Additionally, it is unclear how quickly the impacts described above would be felt, particularly if the conversion from irrigated agriculture to dryland agriculture occurs over an extended timeframe. To date, an average of only 3,700 acre-feet of water have been transferred out of Uvalde County annually. If the rate of transfers does not increase, irrigated agriculture will persist in Uvalde County until 2035, thereby greatly diminishing the annual rate of job losses.

Despite the potential negative impacts on Uvalde County's economy, it is unclear what role, if any, policy should play. The transition away from irrigated agriculture could result in output in Uvalde County contracting by approximately 3%. The number of jobs would likewise be reduced by 6%. While this is a significant impact, it is not necessarily more than the economy can absorb, particularly if it is spread out over many years or if revenues from water transfers are invested in new or expanding industries. In addition, these losses may be more than offset by output and employment increases in San Antonio as a result of increased water availability.

In terms of compensation to parties affected by the transfers, McCarl et al. (1997) argue that compensation to third parties is rare when owners of private assets or businesses suspend economic activity in an area. For example, they note that "over the last hundred years, technological developments in agricultural and industrial sectors have created mass migrations of people from rural areas to urban areas with no attempt made to compensate the rural areas…. The economic argument against compensation has been that resources are mobile and, if displaced… will find employment elsewhere" (p. 12).

However, it is important that the community maintains an awareness of the potential negative impacts of water transfers in order to best prepare for and mitigate them. A potential policy option is to levy a tax on water leases and sales that is diverted to a fund to assist those suffering job losses or seeking job retraining due to reductions in irrigated agriculture. Alternatively, such revenue could be directed to promote other sectors such as outdoor recreation along the county's rivers and prime wildlife areas.

Although the decision regarding whether or not to transfer water ultimately lies with the individual buyers and sellers, community stakeholder discussions regarding third-party impacts and visions for the community's future could influence permit holders' decisions. At a minimum, such discussions will enable the community to proactively develop economic development priorities and strategies useful for navigating an altered economic environment.

Acknowledgements

I wish to thank Professors Dave Marcouiller and Tom Cox for their feedback and encouragement in this research. This research was made possible in part through support from the Integrative Graduate Education and Research Traineeship (IGERT) funded by the National Science Foundation (Award 0549407).

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