The Water Transfer Effects of Alternative Irrigation Institutions

Narishwar Ghimire and Ronald C. Griffin

Irrigation districts (IDs) use a large portion of the surface water rights in the American West. Microeconomic analysis of water use conditions within IDs indicates that it can be economically optimal for IDs to engage in less reallocative activities compared to private water rights holders. Institutional insights combine to show that the political orientation of IDs favors irrigation over irrigators in the sense that the rewards of water marketing tend to be incompletely captured. Based on an analysis of 38 years of time series water transfer data, we found that IDs underparticipate in agricultural-to-municipal water transfers relative to non-irrigation districts in terms of water right-weighted transfers. The results support further policy redesign if reallocation is to be viewed as a scarcity-solving strategy in ID-dominated regions.

Key words: Water marketing, irrigation districts, water reallocation, irrigation organizations.

JEL codes: Q25.

As a result of expanded population, urbanization, and economic activity, the municipal marginal value of water commonly exceeds that of agricultural uses (Griffin and Boadu 1992; Carey and Sunding 2001; Donohew 2008). The large value differential of water between agricultural and municipal uses suggests market-based reallocations from low value to high value uses (Hartman and Seastone 1970; Saliba and Bush 1987; Griffin 2006; Brozovic, Carey, and Sunding 2002). Moreover, the development of new water sources has become economically and environmentally costlier, thereby making water transfers one of the more economically attractive demand-side alternatives (Vaux and Howitt 1984; Gould 1988; Wahl 1989; Colby, Crandall, and Bush 1993; Howitt 1994; Graff and Yardas 1998; Easter, Rosegrant, and Dinar 1998; Howe and Goemans 2003; Lach, Ingram, and Rayner 2005; Chong and Sunding 2006).

Yet early snapshots of marketing activities in the western United States indicate that reallocative activities are not taking place as per economic expectations (Carey and Sunding 2001; Eden et al. 2008). Although the prices of water right transfers are increasing in the American West, water transfers from irrigation to municipal uses are less common than water leases or sales among agricultural uses (Brown 2006). A myriad of legal, institutional, political, and physical factors might be responsible for the slow performance of water markets in the west (Brewer et al. 2008; Gould 1988; Howitt and Hansen 2005; Bell and Taylor 2008). One of the least studied aspects of western water markets is the comparative performance of irrigation districts (IDs) and non-irrigation districts (non-IDs) in water transfers.

Commonly found in the 17 western U.S. states, IDs are semi-governmental, nonprofit entities that supply irrigation water to member farmers and possess powers of condemnation, taxation, and bond issuance (Hutchins 1931; Leshy 1982; McCann and Zilberman 2000; Bretsen and Hill 2006). Non-irrigation districts are comprised of individuals, private corporations, cities, and environmental groups (collectively referred to as non-IDs). Though IDs are often alleged to be less enthusiastic about external water transfers than non-IDs (Thompson 1993; Bretsen and Hill 2009; Libecap 2011; Griffin 2012a), economic modeling and empirical studies for the assertion are rather thin. Most

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of the information regarding IDs is anecdotal, and a comprehensive survey of IDs' participation in external transfers is lacking (Thompson 1993). One of the primary reasons for the dearth of studies is the lack of suitable water transfer data.

This paper investigates the internal pressures that affect IDs' willingness to engage in water reallocation. An institutional analysis identifies barriers that arise from internal political pressures, while a microeconomic model illustrates how the collective-type structure of IDs, together with local interdependencies in external water reallocation and internal water delivery, lowers the marginal benefits of water transfers. Subsequent empirical analysis investigates the responsiveness of IDs relative to non-IDs in agricultural-to-municipal water reallocations using 38 years of time series water transfer data in the Rio Grande Valley of Texas. To the best of our knowledge, this is the first empirical study that uses time series water transfer data to test the hypothesis that IDs are reluctant water marketers. Based on the analysis of longitudinal agriculture to municipal water transfer data, the findings reveal that there exists a divergence in water transfer responses among IDs and non-IDs, with the IDs responding slowly relative to their water right holdings.

The paper is organized as follows. Following a literature review, the institutional circumstances of IDs and Texas water transfer procedures are described. A microeconomic model of a transfer-optimizing ID considering the internal implications of transfers is then presented. The remaining analytical sections pursue an empirical model focused on testing the proposition that IDs demonstrate weaker reallocation activity. Our interpretations and conclusions then complete the paper.

Literature Review

The existence of value differentials among various water uses identifies an underutilized opportunity to move water from low value to high value uses in many western states (Hartman and Seastone 1970; Saliba and Bush 1987; Howe, Schurmeier, and Shaw 1986; Brozovic, Carey, and Sunding 2002). Carey and Sunding (2001) find marginal value differentials of approximately three to four times between agriculture and industrial water uses in California. Even more dramatically, Griffin and Boadu (1992) report an average value differential of water of about 9 to 21 times between agricultural and municipal water uses in the Rio Grande Valley of Texas.

Vaux (1986) argues that water scarcity in the American West is caused not by the physical scarcity of water but by inefficient and outdated water institutions. The appropriative system of water ownership practiced in many western states quantifies water rights, which may be transferable if the revised water use is beneficial and does not harm public interests (Milliman 1959; Gould 1988; Kaiser 1996; Ruml 2005). However, the system has been criticized for restricting water transfers. Some researchers contend the beneficial use, due diligence, and historical use requirements, along with the abandonment (or forfeiture) clauses of states' water codes, are significant deterrents for external water transfers because they introduce uncertainty and insecurity in water right tenures (Milliman 1959; Ruml 2005; Howitt and Hansen 2005). Howitt and Hansen (2005) and Brewer et al. (2008) pinpoint a number of factors such as the occasional public good nature of water, supply uncertainty, usufructory considerations, transaction costs, return flow externalities, and other third party impacts as being the most important impediments for the slow development of water markets in the west. Gould (1988) emphasizes the third party impacts resulting from the deficient definition of water rights as a significant barrier for water transfers.

There may be other obstacles to water transfers in the west. One of the somewhat lightly studied aspects of the western water market concerns activity by differing irrigation organization (IO) types relative to others in external water reallocation. There are several IO types in the 17 western states, with the major one being categorized as IDs (Griffin 2012a). According to the last census of IOs (1978), IDs in the 17 western states serve more than 25% of all irrigated acres (over 10 million acres) and deliver more than one third of the total IO water (Bretsen and Hill 2009; Griffin 2012a). Further, IDs in the Lower Rio Grande Valley of Texas hold more than 80% of the surface water rights there (Jarvis 2008). Yet the organizational and water right structures of IDs are such that there can be significant barriers for external water reallocations.

Griffin (2006) argues that IDs are unenthusiastic participants in the western water market because use rights are disconnected from ownership rights. Rosen and Sexton (1993) indicate that water in public water districts is treated as a common property resource, thus triggering substantial "intra-organizational conflicts" in water management. These authors also observe that because of the conflict arising from the poorly defined property right structures, gains from water trades are dissipated, thereby reducing incentives for water transfers. According to Smith (1989), water trade in IDs faces a "compensation problem" as the IDs' governing boards and managers have to decide appropriate prices for transfers, design convincing plans to distribute the gains of water transfers, as well as compensate members for their conservation efforts. Gould (1988) concedes that there are numerous legal problems in external water transfers in IDs. None of these studies have theoretically and empirically shown IDs' reluctance in water transfers relative to non-IDs.

Political Structure and Water Reallocation

Water rights in most IDs are vested to the district itself, and provide members with only use and exclusion rights as opposed to full ownership rights. This invites comparisons to common property resource scenarios, which involve the sharing of use rights, as well as to anti-commons[1] which indicate the presence of shared exclusion rights (Buchanan and Yoon 2000; Fennel 2004). Multiple uses rights may cause a resource to be overpressured while shared exclusion rights can cause the opposite to happen, that is, under-utilization due to the number of excluders whose permission is required (Buchanan and Yoon 2000; Bretsen and Hill 2009). Both conditions suggest misallocation. When water is treated as common property in an ID, members tend to underconserve water (Rosen and Sexton 1993). Since members cannot gain ownership over conserved water and ID water rates exclude the value of water, incentives to conserve are inefficient. On the other hand, water is potentially underutilized in the sense that transfers to external parties such as cities require collective action by ID members. The transaction costs of coordinating use and exclusion in IDs dissuades water reallocation to higher valued uses. When multiple excluders must agree to reallocative transfers, efficiency can be hampered by "holdout" problems where strategic behavior among excluders delays or blocks transactions (Fennel 2004). In such circumstances, prospective water buyers such as cities and environmental groups must exert greater effort in designing water transfer deals, thereby dissipating potential net gains. Thus, the presence of both multiple use rights and multiple exclusion rights without individual ownership rights tends to promote overutilization internally and underutilization externally.

Based on the prospect theory proposed by Tversky and Kahneman (1991), IDs might be less willing to transfer water because of their loss aversion, thereby placing more weight on the perceived losses relative to gains. As the individual benefits of external transfers are more uncertain because of the absence of individual water rights, members and their elected boards might throw more weight to the immediate costs of water rights transfer relative to the overall gains. The managers and employees of IDs might also harbor biased perspectives because worries about job security overwhelm the potential for heightened income.

Management boards and managers of public enterprises like IDs might manipulate prices in favor of political support, thereby introducing inefficiency (McDowell and Ugone 1982). While studying the political behavior of public utilities, Peltzman (1971) argued that managers of public enterprises are willing to trade owners' wealth for political support and sustained tenure. McDowell and Ugone (1982) have expanded and applied that theory in the study of IDs in Arizona.

When there are divergences in political support and revenue support groups, ID management can manipulate prices to favor politically powerful groups at the cost of revenue support groups. One method of manipulating prices is to increase the land-based charges and decrease the water-based

[1] The distinction between anti-commons and commons is often tenuous due to "conceptual overlaps and resemblances" between the two terms (Fennel 2004). A number of examples exist where a resource seen as common can be regarded as anti-common and vice-versa depending on perspective (Fennel 2004). Yet, unfortunately-designed privatization used to solve commons problems can create anti-commons problems, for example, the empty storefronts problem in post-communist Moscow described by Heller (1998).

charges in such a way that the number of net gainers exceeds the number of net losers. If there is a majority of small landowners in IDs and the costs of delivering water to their lands are higher compared to that of larger landholders, it can be politically wise for the ID management team to subsidize small landholders at the cost of large landholders. For IDs supplying water as well as electricity, power users might be subsidizing water users because of power's weak political coalition (McDowell and Ugone 1982). In acreage-based voting districts where political support and revenue support groups overlap well, such pricing tactics may not be applicable.

McDowell and Ugone (1982) report that 28.6% of operating revenues were obtained from property taxation in one-landowner one-vote districts as opposed to only 9% in property-weighted voting districts in Arizona. McCann and Zilberman (2000) argued that managers of popular voting districts tend to keep the property charges higher and water-based charges lower because of the electoral influence exerted by tenant farmers, local businesses, and suppliers. When water charges are kept lower, farmers are encouraged to use more water, leaving less for reallocation to higher-valued uses.

In popular voting IDs, the likelihood of blocking or delaying the decision of permanent water transfers might be higher if the majority members' perceived net payoff from the transfer is less than the minority members' net payoff, even though the transfer produces a substantial aggregate gain to the economy. In a nonprofit cooperative setting where a median member does not have the average member's preferences, Hart and Moore (1998) contend that "the inefficient majority gangs up on the efficient minority and thwarts a good investment opportunity." The principle may well be applicable to popular voting IDs where decisions are made on a majority voting basis.

Study Site and Water Transfer Procedures

Many IDs in the western states are dependent on Bureau of Reclamation-owned water rights, so voluntary transfers are limited. However, almost all IDs in Texas are independent from the Bureau in that this federal agency has no water right entitlements and districts have repaid their original loans. This helps to make Texas a compelling study region. Moreover, the Texas IDs in our sample are very similarly organized and managed. The study site comprises 10 counties with IDs and non-IDs in the Rio Grande Valley of Texas, which is located in the southernmost part of the state (figure 1). Both IDs and private holders of irrigation water rights operate in this region. The origins of privately held, non-ID rights is normally associated with physical proximity to the river, thereby permitting affordable irrigation works by individual farms. More distant properties warranted shared pumping and conveyance facilities, thereby motivating the establishment of irrigation cooperatives, especially when federal subsidies became readily available one century ago under the Reclamation Act (Griffin 2012b). Water marketing in the Rio Grande Valley (RGV) commenced in the early 1970s, soon after water rights became transferable. As one of the faster growing areas in Texas, the RGV has witnessed substantial industrial and agricultural growth (mainly maquiladora and tourism; Jarvis 1991). In its lower flood plain, the RGV contains highly fertile alluvial soil ranging from sandy and silty loam to clay loam. The introduction of irrigation networks in the late 1800s and road infrastructure in the early 1900s paved the way for the valley's economic development.

Texas has applied various surface water laws over its history because of the changing governmental and economic landscape (Kaiser 1996; Jarvis 2008). In the early 1600s, Spanish settlers adopted the Spanish Civil Law, which included features of both the riparian and prior appropriation systems (Jarvis 2008). After 1836, when the Republic of Texas was established, the riparian system was officially practiced. Riparian law continued to be applied until 1888, providing water rights to riparian landowners on a reasonable use and correlative basis. Drought spells in the late 1880s motivated Texas legislatures to replace riparianism in favor of the appropriative system then practiced in some western states (Kaiser 1996). Subsequently, Irrigation Acts were enacted in 1889, 1895, and 1913, all of which advanced some sort of priority system for adjudicating appropriative water rights.

As a result, the state of Texas maintained a dual system of riparian and prior appropriative water rights from 1889 to 1966. The dual system of water rights (one based on

Figure 1. Study Site

an administrative and another based on a judicial system) worked acceptably in an era of sufficient water supply. However, the system posed a great challenge to water right administrators attempting to reconcile the competing claims of water rights when water became scarce as a result of population growth and cyclical weather. With a prolonged drought during the 1950's, the incompatibility of the dual system was exposed, giving rise to the "Valley Water Suit" (*State of Texas v. Hidalgo County Water Control and Improvement District No 18*). This legal action involved more than 3,000 parties, 42 special water districts, more than 90 lawyers, around $10 million expenses for courts and attorney fees, and took more than a decade to finalize (Kaiser 1996; Jarvis 2008; Templer 2011).

Another result of these difficulties was the parallel creation of the 1967 Water Right Adjudication Act, which established a single permit system for administering all surface water rights in the state except the RGV (due to the in-progress litigation). The purpose of the Adjudication Act was to inventory and uniformly establish all surface water rights in the state except those resolved by the Valley Water Suit. Because of the resulting judicial discretion, water rights in the Valley are now correlative in the sense that the "first in time, first in right" appropriations doctrine does not apply as it does in the rest of Texas. In the RGV, all municipal rights are on equal footing with one another, as are agricultural rights with one another. Irrigators cannot lease irrigation water to municipalities because of the priority disparity between irrigation and municipal waters, but permanent transfers are allowed; municipal rights are more senior. Permanent transfers can convert shares of the agriculturally available pool of water to the fixed quantities of relatively secure municipal water rights.

For the purposes of this study, water transfer is defined as changes in the purpose and/or place of water uses that may or may not involve ownership change. An amendment of water rights is generally necessary to change the place of water use, purpose of use, point of diversion, rate of diversion, acreage to be irrigated, severance/combinations of water rights, or any other alterations in the conditions of water rights (Willatt 1996; 30 Tex. Admin. Code §295.158). Public notice is necessary if the proposed amendment might have an adverse impact on other water right holders in the basin as per Section 295.158 of the Texas Administrative Code and Section 11.132 of the Texas Water Code. There are exceptions where the public notice may not be needed for an amendment of water right. According to Chapter 303 of the Texas Administrative Code, a mailed and published notice is not necessary for the amendments and transfer of water rights within and between the mainstream of the Lower Rio Grande, Middle Rio Grande, and the Amistad reservoir (30 Tex. Admin. Code § 303.42); the reason is that third party and return-flow effects in the Lower and Middle Rio Grande Valley are negligible due to a unique topography that directs most return flow away from the river (Chang and Griffin 1992).

An Economic Model

To gain insight on how the collective type ownership structure of IDs coupled with local interdependencies between internal water delivery and external water transfers may urge IDs to keep more water in agricultural uses, we develop an economic model. Miller's (1987) presumption about the possibility of positive spillover effects of neighbors' seepage and runoff in IDs' water use is expanded by incorporating a differentiated price structure for internal water delivery and external water transfers, and incorporating a breakeven constraint. We use various prices for internal and external water uses because the internal price or rate structure is determined by IDs and the external price for water transfer is determined by a more regional market. Because IDs are nonprofit organizations, a breakeven constraint is a compelling model component.

When water is applied to farmlands, a portion may be available to neighboring lands in the form of seepage or run-off, thereby producing "local spillover effects" (Miller 1987). Consequently, some water may be actively or passively reused by farmers before it exits the service area. Return-flow increases the water available to down-gradient farmers both internal and external to the ID. When water is transferred to external parties, canal flow is reduced and the average costs of internal water delivery increase due to increased average conveyance losses (Miller 1987). When individual water users are free to transfer water rights, such interdependencies may not be taken into account by profit-maximizing individuals. Thus, two economic models are specified: one for individual ID members and the other for IDs, and comparisons are made regarding internal water uses and external water transfers.

Our model is constructed as follows. A self-interested irrigator with water right entitlement (e) maximizes net benefit from internal water uses and external transfers, and makes decisions about how much land (m) to cultivate, how much water (w) to use, and how much water (t) to lease to nonagricultural uses. In making such decisions the individual also faces the constraint that summed water uses (w) and water transfers (t) cannot exceed the entitlement (e). The irrigator may also benefit from a proportion of neighbors' water use as seepage or runoff. The individual benefits of water use is denoted by $B_i(m_i, w_i + k_i \sum_{j \neq i} w_j)$, where subscript $i = 1, 2, \ldots, n$ refers to individual ID members and k_i is the positive externality of neighbors' water use. Let p be the uniform price of internal water delivery set by the ID, and r be the uniform land charge per unit of irrigated land. With an exogenous market price of s for transferred water and transaction costs of $c(t_i)$, an individual irrigator's profit maximization problem can be written as

$$(1) \qquad \underset{m_i,w_i,t_i}{Max}\ B_i\left(m_i, w_i + k_i\sum_{j\neq i} w_j\right) - rm_i - pw_i + st_i - c(t_i)$$

$$(2) \qquad s.t.\ w_i + t_i \leq e_i.$$

First-order conditions with respect to m_i, w_i and t_i are

$$(3) \qquad m_i : \frac{\partial B_i}{\partial m_i} - r = 0$$

$$(4) \qquad w_i : \frac{\partial B_i}{\partial w_i} - p - \lambda = 0, \text{ and}$$

$$(5) \qquad t_i : s - c'(t_i) - \lambda = 0.$$

Our interpretation of these optimality conditions is as follows. The marginal benefit of cultivated land should be equal to uniform land charge (r). The marginal benefit of water use equals the water delivery charge, p, plus the opportunity costs of water, λ. Lastly, s, the marginal benefit of water transfers, equals the opportunity costs of available water, plus marginal transfer costs ($c'(t_i)$).

On the other hand, a benevolent ID management team choosing policies on behalf of its members might strive to maximize overall net benefits by making decisions about how much to charge for water delivery to members, how much to charge land for irrigation service, and how much water to transfer (T) to external parties, leading to the problem given by equations (6)–(9):

$$(6) \qquad \underset{r,p,T}{Max}\sum_{i=1}^{n}\left[B_i\left(m_i, w_i + k_i\sum_{j\neq i} w_j\right) - rm_i - pw_i\right]$$

$$(7) \qquad s.t.\ \sum_i w_i = E$$

$$(8) \qquad E + T + L(E) \leq W, \text{ and}$$

$$(9) \qquad r\sum_i m_i + p\sum_i w_i = F + V(E) + C(T) - sT.$$

Equation (7) is an identity indicating that the sum of individual internal deliveries should equal total internal delivery entitlements (E). Equation (8) observes that total internal delivery entitlements, total transfers, and conveyance losses should not exceed the total water availability or endowment (W) of an ID. Equation (9) is the breakeven constraint: total revenue should offset fixed costs F, variable costs $V(E)$, and the total costs of conducting water transfers $C(T)$.

Replacing E in equations (8) and (9) with Σw_i and forming the Lagrangian equation,[2] the following first order conditions with respect to r, p, and T are generated:

$$(10) \qquad r : -\sum_i m_i - \sigma\sum_i m_i = 0$$

$$(11) \qquad p : -\sum_i w_i - \sigma\sum_i w_i = 0, \text{ and}$$

$$(12) \qquad T : -\lambda_d + \sigma C'(T) - \sigma s = 0.$$

Equations (10) and (11) redundantly infer $\sigma = -1$, meaning that overall net benefits to ID members decrease by a unit for each unit increase in the total cost of ID operations including transfer costs, and together with equation (12) indicate that $s\text{-}C'(T) - \lambda_d = 0$. Here, σ is the Lagrangian multiplier associated with constraint (9) and λ_d (the opportunity cost of available water) is the Lagrangian multiplier associated with constraint (8). Together, equations (5) and (12) indicate that the marginal benefit of water transfers under ID management differs from that under individual management if respective marginal costs and opportunity costs (λ and λ_d) differ.

To further investigate the issue, we can optimize the Lagrangian equation derived from (6)-(9) with respect to w to obtain

$$(13) \qquad \frac{\partial B_i}{\partial w_i} + \sum_{j\neq i} k_j\frac{\partial B_j}{\partial w_i} - p + \lambda_d(-1 - L') + \sigma(V' - p) = 0.$$

Here, L' and V' represent marginal conveyance losses and the marginal cost of internal water delivery in IDs, respectively.

[2] $L = \sum_{i=1}^{n}[B_i(m_i, w_i + k_i\sum_{j\neq i} wj) - rm_i - pw_i] + \lambda_d(W - \sum_i w_i - T - L(\sum_i w_i)) + \sigma(F + V(\sum_i w_i) + c(T) - sT - r\sum_i m_i - p\sum_i w_i)$.

Substituting $\sigma = -1$ results in

$$(14) \quad \frac{\partial B_i}{\partial w_i} + \sum_{j \neq i} k_j \frac{\partial B_j}{\partial w_i} - \lambda_d (1 + L') - V' = 0.$$

Comparing equations (4) and (14) indicates that the marginal benefit of internal water use is higher under ID management than with individual management if any $k_j > 0$, if L' is small, and if $V' \leq p$. Under these conditions, optimal water use under ID management (in equation 14) will be higher than that under individual management (in equation 4). If Miller (1987) is right about $k_j > 0$ or if there are increasing returns to scale in the delivery of irrigation water (as IDs can reduce L' by increasing water deliveries), it would be optimal for IDs to transfer less water. Even in the case where $k_j = 0$, optimal water use under equation 14 could be higher than that under equation 4 because of the breakeven constraint and presence of returns to scale in internal water delivery.

This implies that optimal ID transfers (T^*) should be less than the aggregated individual transfers ($\sum_i t_i^*$). Alternatively, if any of the conditions ($k_j > 0$, L' close to zero, and $V' \leq p$) are true, λ_d that is $\left(\frac{\partial B_i}{\partial w_i} + \sum_{j \neq i} k_j \frac{\partial B_j}{\partial w_i} - V'\right) / (1 + L')$ becomes greater than $\lambda \left(= \frac{\partial B_i}{\partial w_i} - p\right)$, and the marginal benefit of water transfer under ID management (equation 12) becomes smaller than that under individual management (equation 5) with $C'(T) \geq c'(t)$.

Empirical Model and Estimation Techniques

To investigate the open proposition that IDs are less receptive to external water transfers, we develop an econometric model using water right-weighted transfers as a dependent variable. As there are considerable variations in water right holdings, with IDs generally holding more rights than non-IDs, it is necessary to account for water right endowments when making water transfer comparisons between the two groups. Weighting water transfers by water right holdings enables the meaningful and consistent evaluation of water transfer performance. Following Papke and Wooldridge (2008), a fractional probit model can capture important nonlinearities arising out of the use of the fractional dependent variable. The econometric model is

$$(15) \quad y_{it} = \Phi(\gamma D + \boldsymbol{x}_t \boldsymbol{\beta}) + u_{it}.$$

Here, the conditional mean of response variable y_{it} can be expressed as

$$(16) \quad E(y_{it} \mid D, \boldsymbol{x}_t) = \Phi(\gamma D + \boldsymbol{x}_t \boldsymbol{\beta})$$

where $y_{it} (0 \leq y_{it} \leq 1)$ is a fractional response variable indicating the proportion of irrigation water permanently transferred to municipal purposes by irrigation entity i in period t. As there are two types of water right owners (districts and non-districts), the proportion is computed separately for each type for each year after aggregating the quantity of water transferred and then dividing the aggregate transfer by the aggregate quantity of owned water that year.

The variable $\Phi(\cdot)$ represents the standard normal cumulative distribution function; D is a dummy variable taking the value of one if a water right owner is categorized as irrigation district and zero otherwise; $\boldsymbol{x}_t$ is $1 \times K$ vector of explanatory variables such as income, population, crop price index, and water availability; u_{it} is an error term; $\boldsymbol{\beta}$ is $K \times 1$ vector of parameters to be estimated; and γ is also a parameter to be estimated. The value of water rights might also impact transfers but is excluded because price data is not available.

The parameter of interest is γ where the intention is to test whether a systematic difference exists in the mean of water rights weighted reallocation between IDs and non-IDs over time after controlling for demographic, economic, and environmental factors. It is hypothesized that $\gamma < 0$. Hypothesized relationships for the variables of interest are listed in table 1.

Water availability, proxied by Amistad reservoir's water elevation, is hypothesized to be negatively associated with external water reallocation, indicating that a higher level of water availability (or lesser water scarcity) at the source triggers lesser water transfers. This hypothesis is consistent with the widely held conjecture that water scarcity produces a favorable environment for water transfers, and the proportion of water transfers to water availability increases as the drier conditions created by high temperature, high solar intensity, and high evapotranspiration rates cause available water at the source to decline. Reduced water availability at the source also

Table 1. Expected Relationship between Key Regressors and Water Transfer

Covariates	Units	Source	Expected Sign
ID dummy (D)	(0,1)	TCEQ	Negative
Amistad water elevation	Meters	IBWC	Negative
Establishments	# Per Year	Census Bureau/UV	Positive
Building *Permits*	# Per Year	Census Bureau	Positive
Personal *Income*	US$	BEA	Positive
Population	# Per Year	BEA	Positive
US crop price index (*USPI*)	Index(1910-14 = 100)	NASS/USDA	Negative

suggests that alternative supply-side water development approaches are more costly and environmentally unfriendly because they commonly require new infrastructure to collect and transport water (Gould 1988).

Increased economic activities and a higher population are postulated to have positive impacts on water transfers. A higher population may also be associated with higher water consumption for increased quantities of homes, jobs, and business activities. Using an 18-sector computable general equilibrium model, Watson and Davies (2011) determined that 5.7% of the water used in agriculture is transferred to municipal/industrial use for every 50% population increase in Colorado's South Platte River Basin.

Crop prices are expected to have insignificant or negative impact on water transfers because transfers are generally driven by municipal and industrial water demand, not by agricultural water demand.

Equation (15) can be estimated using nonlinear least squares (NLS) or quasi-maximum likelihood estimation (QMLE) techniques. As the dependent variable here is the proportion of water transfers, using a linear functional form for the conditional mean might produce misleading results. The linearity and homoscedasticity assumptions of ordinary least squares will be violated when using proportion as a dependent variable (Paolino 2001). Papke and Wooldridge (2008) have shown that the Bernouli QMLE is computationally simpler than NLS. These authors argue that a traditional solution of log-odds ratio to a fractional response variable can lead to biased estimates, especially when the fractional responses are close to zero or one. Strong independence assumptions might be needed to recover the expected value of a fractional response even if the proportion might be strictly within a unit interval. A two-limit (censored at 1 and 0) Tobit model may not be used, as we do not have observations in both limits. Further, boundary observations in the response variable are natural outcomes rather than a consequence of any kind of censoring. Normality and homoscedasticity assumptions for the response variable in a Tobit model are stringent, thereby disqualifying the model in such circumstances (Ramalho, Ramalho, and Murteira 2011). A two-part model may also be less appropriate, as most observations are between 0 and 1 rather than at a boundary. Thus, the QMLE technique with adjusted standard errors becomes a natural candidate. Quadratic/cubic polynomials or the interaction terms of regressors can also be used to capture some of the possible nonlinear relationships among the variables of interest (Greene 2004).

Water Transfer Data

To gather information about permanent water transfers from irrigation to municipal purposes, amendments to water rights were obtained from the central files of the Texas Commission on Environmental Quality (TCEQ). Peculiar to the RGV, IDs and non-IDs may hold water rights in two broad categories: Agricultural and Municipal. Agricultural water rights include irrigation, mining, and recreation water rights with either a class A or a class B priority. Municipal water rights include domestic, industrial, and livestock water rights with a class M priority. There is no A over B seniority difference, whereas class M is senior to both agricultural classes. Class A water rights were granted to statutory holders of certified water rights as per the 1913 Irrigation Act, or any proof of water rights issued by the state water agency (Schoolmaster 1991). Class B water rights were granted to those who could not furnish a certified water right, but whose claim to having a history of water use was upheld. For regulated amendment transfers, an acre-foot of class A irrigation right converts to 0.5 AF of municipal water rights, and an acre-foot of class B irrigation right converts to 0.45 AF of municipal rights (30 Tex. Admin. Code §303.2(24) (A) and (B)).

The water right accounts for municipal, domestic, and/or industrial (MDI) purposes are identified in TCEQ's water rights database. Using water rights currently listed as MDI use is an efficient way to search for transfers because most current MDI water rights were originally irrigation rights, and therefore required amendment at some point since 1970. One hundred water right accounts[3] that use water for MDI purposes in the RGV were found to have at least one amendment, while 480 amendments were found for the identified 100 water right accounts. More than three-quarters (362) of the amendments are related to transfers of water from irrigation to MDI uses. The amendments, the source of water transfer data, are obtained from microfilms, microfiches, and paper files stored with the TCEQ.

Water rights data for IDs and non-IDs used for constructing the dependent variable for 1971 are adopted from the published work of the TCEQ and its predecessor agencies, while water rights for subsequent years are computed. Because of the unavailability of annual water right entitlement data, two approaches (constant and changing water right approaches) are used to generate the data.

In the constant water rights approach, annual water rights holdings by IDs and non-IDs are computed from the 1971 water rights using an iterative procedure.[4] This approach assumes that water is transferred from agriculture to municipal uses through an amendment, but even after the transfer, the rights remain with the respective entities (i.e., IDs and non-IDs), thereby eliminating the possibility of ownership changes between IDs and non-IDs. However, ownership changes within IDs and non-IDs are allowed. A thorough investigation of the amendments indicates that there are very few incidences of ownership changes between IDs and non-IDs, thereby making this assumption reasonable. Thus, the aggregate water rights holdings of IDs and non-IDs remain constant over time, allowing individual holdings to change. Any new adjudication and appropriation of water after 1971 is excluded.

In changing water rights approaches, the water rights database in the TCEQ is used to compute water rights for different years based on the issue date. In this approach, water rights issued at different dates are summed cumulatively to determine water right holdings in the later dates. Though it does not make strong assumptions, the changing water right approach might have some limitations because of the way in which water rights are recorded in the water right database. An issue date generally indicates an issuance of a water right account not a detailed transaction of the water. The water right database lumps all transactions together by issue date, as if they were occurring in 1971. As the water right database does not identify market transactions in each period, if some transactions with ownership changes are not accounted for in the database, we may miss them, thereby over- or underestimating actual water rights holdings in a year. Despite some limitations, the two approaches generate similar results because the aggregate water right holdings have not been altered significantly since 1971.

Covariate Data

Data for private housing (building) *permits*, number of nonfarm *establishments*, *population*, and personal *income* in the selected counties (Hidalgo, Cameron, Starr, Willacy, Zapata, Kinney, Maverick, Presidio, Webb, and Brewster) were obtained from the U.S. Department of Commerce, Bureau of Economic Analysis, and the U.S. Bureau of the Census. Specifically, nonfarm establishment data for 1973–1981 were obtained from the County Business Pattern reports and an online University of Virginia Library source (U.S. Department of Commerce, U.S. Bureau of the Census 1976b, 1977b, 1978b, 1979b,

[3] A few water rights account numbers (27, 263, 313, 807, 844, 2,697, and 2,727) with current industrial water uses records are not included in the analysis because their information is either missing or not recorded.

[4] Denoting agricultural rights as A, municipal rights as M, aggregate rights as W, and agriculture to municipal transfers as T, then agricultural ($A_{k,t}$), municipal ($M_{k,t}$), and aggregate ($W_{k,t}$) water right holdings of agent k at time t are given, respectively, by $A_{k,t} = A_{k,t-1} - T_{k,t}, M_{k,t} = M_{k,t-1} + T_{k,t}$, and $W_{k,t} = A_{k,t} + M_{k,t} = A_{k,t-1} - T_{k,t} + M_{k,t-1} + T_{k,t}$ where subscript k (1, 2) indicates ID/Non-IDs, and subscript t indicates year (1972, 1973,..., 2010). Thus, agricultural water right holdings decrease by T, municipal holdings increase by T, and aggregate water right holdings remain constant over time. Appropriate conversion factors are applied before combining agricultural and municipal water rights holdings.

1980b, 1981; University of Virginia Library 2012). Data for 1981–2010 were obtained from online U.S. Counties data maintained by the U.S. Department of Commerce, U.S. Bureau of the Census (2011). Nonfarm establishments in the 10 examined counties are summed to obtain the total number of establishments for a particular year.

Building permits data from 1973–1979 were provided by the U.S. Census Bureau (U.S. Department of Commerce, U.S. Bureau of the Census 1974, 1975, 1976a, 1977a, 1978a, 1979a, 1980a). Permits data from 1980–2010 were obtained from the online U.S. Counties data source. Private housing units are summed across counties for each year. Personal income and population data are obtained from the Regional Economic Profile online data maintained by the U.S. Department of Commerce, Bureau of Economic Analysis (2011).

Personal income for the selected 10 counties is averaged for each year, and the population of the selected counties is summed to obtain total population. Water availability data expressed as the elevation of water level in Amistad reservoir (meters) were obtained from the U.S. International Boundary and Water Commission. Daily elevation data are converted into yearly averages for the analysis.

In the absence of time series crop price data for the RGV or Texas, the U.S. annual crop price index (1910-14 = 100) is used. The data are obtained from agricultural prices reports maintained on the USDA/NASS website.[5] Annual U.S. crop price indexes received by farmers are marketing-year average prices received at the point of first sale for all grades and qualities of the commodity sold. Average prices at the state and regional levels are computed by weighting monthly prices by the estimated proportion of marketing season or calendar year sales made each month (USDA/NASS 2009). State prices are weighted by estimated quantities sold in each state to compute average U.S. price index. In computing all crops price indexes, food grains, feed grains, hay, cotton, tobacco, oil bearing crops, fruit/nuts, commercial vegetables, potatoes/dry beans, and other crops are included. Opportunities for strengthening the price index by using only regionally applicable crops were not possible due to the several decades of regional data required.

Water Transfer Findings

Altogether, 362 water transfers were made in the RGV from 1973–2010 with a total transfer of about 0.121 million AF (expressed as a municipal water equivalent) from irrigation to MDI uses. The IDs transferred about 46% of the transferred water, while the remaining 54% was transferred by non-IDs (table 2). When IDs convert agricultural water to MDI water, they have the option of either

Table 2. Annual Water Transfers (AF)

Year	Non-IDs	IDs
1973	1760.0	0.0
1974	0.0	0.0
1975	129.0	1250.0
1976	0.0	587.5
1977	0.0	0.0
1978	0.0	3000.0
1979	144.0	0.0
1980	0.0	8000.0
1981	1119.4	0.0
1982	472.0	756.2
1983	25.5	980.0
1984	1125.3	0.0
1985	1003.0	0.0
1986	3513.2	1525.0
1987	775.1	3162.5
1988	3707.1	0.0
1989	1371.2	5000.0
1990	1597.0	7620.0
1991	1700.7	0.0
1992	2968.1	0.0
1993	2368.0	0.0
1994	3657.6	0.0
1995	3055.0	2020.0
1996	3452.1	1500.0
1997	1109.8	37.7
1998	1038.8	0.0
1999	2404.3	4566.0
2000	2372.1	5000.0
2001	3166.7	1250.0
2002	5858.2	2569.0
2003	671.3	951.5
2004	1420.1	3236.9
2005	960.6	250.0
2006	8081.8	0.0
2007	1964.4	392.0
2008	1324.9	0.0
2009	166.6	1500.0
2010	1031.9	0.0
Total	65514.6	55154.2
Mean	1724.1	1451.4

[5] Please see: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do;jsessionid=F154BA78C7C50C021C8CA924EDB72FD5?documentID=1003.

delivering water directly to MDI clients or selling water to an intermediary (e.g., a city) for further processing and transport.

The IDs' water transfers are smaller than those of non-IDs when weighted by their water right holdings; IDs possess over 0.8 million AF of water right holdings (municipal water equivalent) while non-IDs possess about 0.2 million AF. Thus, IDs possess four times more water than the non-IDs in the RGV, and the transfers relative to water rights holdings are comparatively smaller.

The pattern of water right-weighted transfers over time by IDs and non-IDs in figure 2 shows that IDs' shares of water transfers are less for most years than those of non-IDs. This appears to be consistent with the assertions about IDs' water transfer responses made by some researchers (e.g., Griffin 2006, 2012a; Libecap 2011).

There are also differences in the size of transfers made by IDs and non-IDs. Average transfer size defined as the ratio of group-wise total water transfers from 1973–2010 to the total number of transfers for IDs is 1,379 AF compared to 202 AF for non-IDs. The IDs transfer larger quantities of water less frequently than non-IDs. Also, there are differences in the class of irrigation water rights being transferred by IDs and non-IDs; 35 of the 40 transfers made by IDs involved class A irrigation water rights, while the majority of transfers by non-IDs involved class B water rights (57%). On average, IDs hold 1,568,730 AF of class A water rights and 8,977 AF of class B water rights. Non-IDs hold 29,719 AF of class A and 244,992 AF of class B water rights as of 2010. Thus, IDs are largely equivalent to class A and non-IDs equivalent to class B water right holders; these class distinctions apply to water quantities, not seniorities.

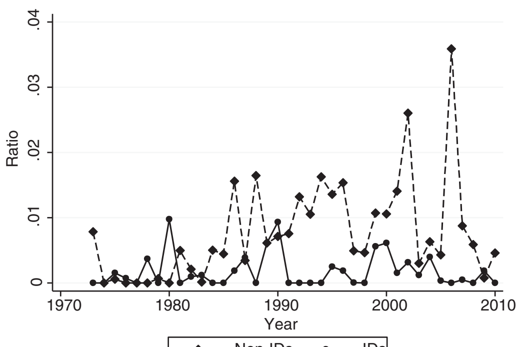

Figure 2. Ratios of Water Transfers to Owned Water

Estimation Issues and Models

As time series data generally suffer from unit root and nonstationarity problems, covariate data are checked for stationarity using the Augmented Dicky Fuller (ADF) test (table 3). The test uses the null hypothesis that the data contain a unit-root against the alternative that data are stationary. The dependent variable, water right-weighted reallocation, is found to be stationary and thus no transformations are made for the variable. Independent variables *Amistad, Establishments, Income, Permits, Population*, and *USPI* are found to be nonstationary with unit-roots. Thus, all the explanatory variables except the ID dummy are converted into logs and first-differenced. Converting data into their logs reduces the noise level in the data, thereby smoothing the data and also helping to remedy the heteroschedasticity issue. As there were no recorded water transfers in 1974 and 1977 for either IDs or non-IDs, these two years are excluded in the estimation. First-differencing eliminates an additional one year of data for IDs and non-IDs, thereby establishing a sample size of 70.

Interaction and quadratic terms of explanatory variables are used to generalize the empirical analysis to allow nonlinear effects. As water transfer is a complex phenomenon, it is expected that economic, demographic, and environmental variables affect the dependent variable (the share of water transfer) in a nonadditive or nonlinear fashion. Friedrich (1982) and Berry, Golder, and Milton (2012) argue that including interactive terms may increase the efficacy of parameter estimates in the presence of interaction among regressors. Greene (2004) argues that quadratic/cubic polynomials or interaction terms of regressors can also be used in regression analysis to capture some of the possible nonlinear relationships among the variables of interest. However, some of the interaction and quadratic terms may be highly multicollinear, thereby producing imprecise estimates of correlated variables (Baltagi 2011). Including all interaction and quadratic terms also consumes valuable degrees of freedom when sample size is limited. Because of these concerns,

Table 3. ADF Test Statistics for Unit Root

Variables	Test Statistic	1% Critical Value	5% Critical Value	P-Value	Optimal Lags
Weighted water transfer	−5.777	−3.668	−2.966	0.000	0
Amistad	−2.159	−3.675	−2.969	0.221	1
Establishments	−0.258	−3.675	−2.969	0.931	1
Permits	−2.042	−3.682	−2.972	0.269	2
Population	2.181	−3.689	−2.975	0.999	3
Income	2.659	−3.689	−2.975	0.999	3
USPI	−1.183	−3.675	−2.969	0.681	1

variables that are highly correlated (correlation coefficient ≥ 0.80) are excluded from the analysis.

Two types of models are used for the analysis to investigate the sensitivity of coefficient estimates with varying variable combinations. Model I is a basic model incorporating seven variables of interest without their interaction and quadratic terms, and is specified as follows:

$$(17) \quad PWT_{it} = \beta_0 + \beta_1 D + \beta_2 \Delta \ln(Amistad_t) + \beta_3 \Delta \ln(Permits_t) + \beta_4 \Delta \ln(Establishments_t) + \beta_5 \Delta \ln(Population_t) + \beta_6 \Delta \ln(Income_t) + \beta_7 \Delta \ln(USPI_t) + \varepsilon_{it}$$

where $t = 1973, 1974, \ldots, 2010$. As justified previously, in this model PWT_{it} is the proportion of water transfer defined as the ratio of water transfer of an irrigation entity i to total water right holding of that entity at time period t, βs are the parameters to be estimated, Δ is the first difference operator, and ln is the log operator. Covariate D is an indicator dummy variable taking value of 1 for IDs and 0 for non-IDs; ε_{it} is the disturbance term for the model.

Model II (equation 18) is the expanded version of model I containing the quadratic and interaction terms of the variables that are not overly correlated with other covariates. Model II is specified as follows:

$$(18) \quad PWT_{it} = \beta_0 + \beta_1 D + \beta_2 \Delta \ln(Amistad_t) + \beta_3 \Delta \ln(Permits_t) + \beta_4 \Delta \ln(Establishments_t) + \beta_5 \Delta \ln(Population_t) + \beta_6 \Delta \ln(Income_t) + \beta_7 \Delta \ln(USPI_t) + \beta_8 (D * \Delta \ln(Amistad_t)) + \beta_9 (D * \Delta \ln(Permits_t)) + \beta_{10} (D * \Delta \ln(Establishments_t)) + \beta_{11} (D * \Delta \ln(USPI_t)) + \beta_{12} (\ln \Delta Permits_t * \Delta \ln Amistad_t) + \beta_{13} (\ln \Delta Permits_t * \Delta \ln Establishments_t) + \beta_{14} (\ln \Delta Permits_t * \Delta \ln USPI_t) + \beta_{15} (\Delta \ln Permits_t)^2 + \beta_{16} (\Delta \ln Amistad_t)^2 + \beta_{17} (\Delta \ln USPI_t)^2 + \varepsilon_{it}.$$

There are 18 parameters to be estimated, including the intercept. Seven interaction terms and three quadratic terms are included along with the seven base variables.

Results and Discussions

The time series fractional probit regression approach is used to estimate models I and II. As the dependent variable (the proportion of water transfer) is computed using changing and constant water right approaches, models are estimated and presented for both the approaches.

Regression results for models I and II with changing water rights are presented in table 4. Multiple test statistics such as the Deviance (likelihood ratio statistic for model comparison), Pearson residual, AIC (Akaike Information Criterion), and BIC (Bayesian Information Criterion) indicate the relative fit of the models. Lower values of the statistics in both the models indicate that they fit the data well and have good explanatory

Table 4. Fractional Probit Estimates (Changing Water Right, $N = 70$)

	Model I		Model II	
Covariates	Coeffs.	Robust S.E.	Coeffs.	Robust S.E.
ID Dummy	−0.466***	0.098	−0.428***	0.130
Δ Log of *Amistad*	−12.541***	3.626	−13.117***	3.662
Δ Log of *Permits*	0.469***	0.130	−0.154	0.402
Δ Log of *Establishments*	0.789	2.124	4.857**	2.331
Δ Log of *Population*	−10.656***	4.118	−9.165**	4.050
Δ Log of *Income*	−2.327**	1.153	−3.242***	1.091
Δ Log of *USPI*	0.64	0.399	0.935*	0.509
ID × Δ Log of *Amistad*			2.024	10.028
ID × Δ Log of *Permits*			0.217	0.694
ID × Δ Log of *Establishments*			−0.848	4.567
ID × Δ Log of *USPI*			−1.178	1.033
Δ Log Permits × Δ Log *Amistad*			15.811	27.766
Δ Log Permits × Δ Log *Establishments*			33.301***	8.444
Δ Log Permits × Δ Log *USPI*			0.134	3.818
Sq. Δ Log of *Permits*			−1.101	0.770
Sq. Δ Log of *Amistad*			15.282	367.770
Sq. Δ Log of *USPI*			−0.943	5.008
Intercept	−2.019***	0.152	−2.065***	0.184
Deviance	0.232		0.201	
Pearson	0.239		0.212	
(1/df) Deviance	0.004		0.004	
(1/df) Pearson	0.004		0.004	
AIC	0.274		0.559	
BIC	−263.174		−220.721	

*Sig at ≤10%, **sig at ≤5%, and ***sig at ≤1% level of significance. Water right holdings-weighted transfer is used as dependent variable in all the models. Δ is the first difference operator. Sq. stands for the square of a variable. Deviance, Pearson, AIC (Akaike Information Criteria), and BIC (Bayesian Information Criteria) statistics indicate relative fit of the models.

power. Comparatively lower Deviance and Pearson test statistics for model II than for model I recommend model II as the relatively better model. It is not surprising that the AIC value is smaller for model I than for model II as the criterion penalizes higher parameter numbers (Agresti 2007). All coefficient estimates except that of *Establishments* and *USPI* in model I are statistically significant at a 95% confidence interval or better. About 49% of the coefficient estimates in model II are statistically significant at 95% or better confidence level. Coefficient estimates in the models are not directly interpretable as they are probit estimates. The presence of interaction and quadratic terms in model II further complicate the direct interpretation of the parameter estimates. Therefore, marginal effects are computed and presented in table 5. Marginal effects (ME) are computed at both the means and medians of variables. The magnitudes of ME are slightly higher when evaluated at medians than at means, although the directions of the effects are identical.

The negative and significant marginal effect of the ID dummy indicates that IDs are less responsive to water transfers compared to their non-ID counterparts in both models. When evaluated at the means, IDs are likely to transfer 0.5% less water (as a ratio) than non-IDs. The results are consistent with our prime hypothesis and consistent with the arguments of previous researchers.

The negative and significant marginal effect of *Amistad* water elevation (table 5) indicates that increased water availability decreases the rate of water transfers. In general, a 10% increase in water availability decreases the rate of water transfers by 1.2% when evaluated at the mean, and by 1.7% when evaluated at the median. The results are better visualized using the predicted value plot of figure 3 and the marginal plot presented in the upper panel of figure 4. The predicted or estimated ratio of water transfers

Table 5. Marginal Effects (Changing Water Right Approach)

	Model I		Model II	
	M.E.	Delta S.E.	M.E.	Delta S.E.
At Mean				
ID Dummy	−0.005***	0.001	−0.005***	0.001
Δ Log of *Amistad*	−0.121***	0.036	−0.125***	0.045
Δ Log of *Permits*	0.005***	0.001	0.008***	0.003
Δ Log of *Establishments*	0.008	0.021	0.05***	0.019
Δ Log of *Population*	−0.103***	0.040	−0.096**	0.047
Δ Log of *Income*	−0.023**	0.011	−0.034**	0.014
Δ Log of *USPI*	0.006*	0.004	0.003	0.005
At Median				
ID Dummy	–	–	–	–
Δ Log of *Amistad*	−0.169***	0.055	−0.179***	0.048
Δ Log of *Permits*	0.006***	0.002	0.009***	0.003
Δ Log of *Establishments*	0.011	0.029	0.062**	0.025
Δ Log of *Population*	−0.144**	0.060	−0.128*	0.067
Δ Log of *Income*	−0.031*	0.016	−0.045**	0.020
Δ Log of *USPI*	0.009	0.005	0.009*	0.005

**Sig at ≤5%, and ***sig at ≤1% level of significance. M.E. stands for marginal effect and S.E. for standard errors. There is no M.E. evaluated at medians for dummy variable ID.

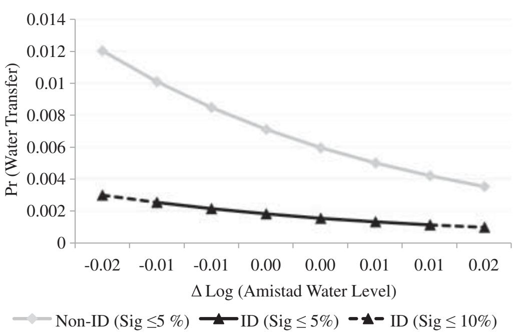

Figure 3. Estimated Ratio of Water Transfers

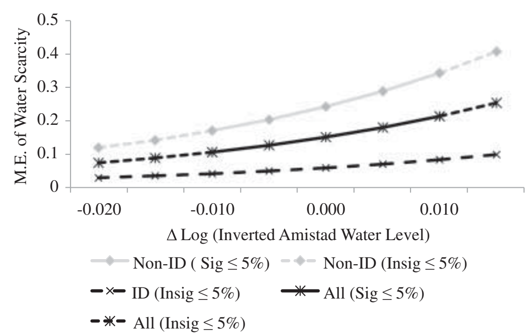

Figure 4. Marginal Effect of Water Scarcity on Water Transfers

is shown on the vertical axis, and *Amistad* water level is shown on the horizontal axis in figure 3.[6] The negative impact of water elevation is significant for almost all observations at 95% confidence interval or higher.

The negative impact of water availability is less for IDs than for non-IDs. Even though the predicted ratios of water transfer for IDs are significant for all data points (at least 90% confidence level), the MEs are not. This can be seen in the marginal plots. We also consider the results by inverting the water elevation data, (1/*Amistad*), which can be taken as an index of water scarcity. The results indicate that scarcity has positive and significant impacts on water transfers. The results are presented in the marginal plot in figure 4. The ME is positive and statistically significant for most of the inverted data points for non-IDs and total sample (all) as indicated by solid lines. Dotted lines indicate that ME is insignificant in that range; the ME is positive but insignificant for IDs for almost all the observations as indicated by the lowermost dotted line. This is an intriguing result that complements the claim that IDs are not as responsive for water transfers, even as scarcity advances. On the other hand, non-IDs continue to be responsive for water transfers as water scarcity increases, except at the highest level of scarcity. Here, the result is consistent with the hypothesis that increased

[6] Unless stated otherwise, all the marginal graphs are drawn based on the model II results of table 4. The dotted lines indicate the MEs are insignificant at specified significance levels for respective variables.

water scarcity encourages external water transfers.

Private housing permits have a significant positive impact on water transfer responses in all the models. The results are exhibited in figure 5 where, again, dotted lines indicate insignificant ranges. *Permits* have a significant positive marginal effect on proportion of water transfers, but the effect is more robust for non-IDs than for IDs. Half of the observations are significant for IDs and about 90% of the observations are significant for non-IDs (based on the data). The positive impact of private building permits on water transfer responses is consistent with the hypothesis set forth previously.

The ME of *Establishments* on water transfers is found to be statistically insignificant in model I and significant for model II at a 5% significance level. The marginal plot shown in figure 6 indicates that the ME of nonfarm establishments is not statistically significant for the majority of establishment data points for IDs, non-IDs, and both (all). The ME is larger for non-IDs than for IDs regarding the housing permits. Thus, increased developmental activities such as private housing permits and nonfarm establishments in the region appear to contribute positively toward water transfers in the RGV and their impact is stronger for non-IDs than for IDs.

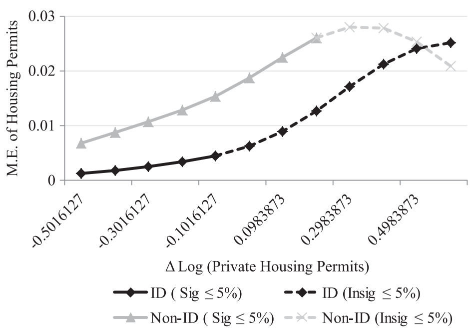

Figure 5. Marginal Effects of Housing Permits on Ratio of Water Transfer

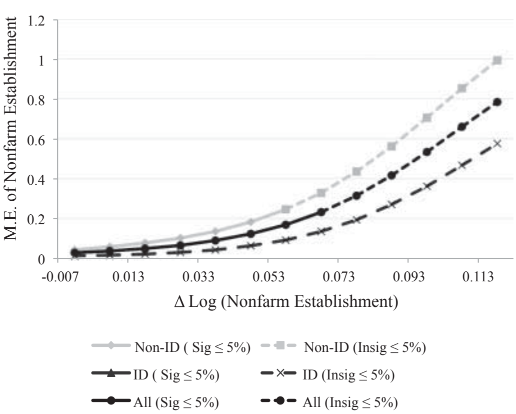

Figure 6. ME of Nonfarm Establishments on Ratio of Water Transfer

However, the impact of *Population* and *Income* on water reallocation oppose earlier hypotheses; the MEs are significantly negative for both the models at the 10% significance levels. The results are inconsistent with the hypothesis set forth in the paper and contrary to general expectations. Perhaps both rising population and income have been accompanied by unmeasured influences upon the demand for reallocation. One can speculate that the emergence of urban water conservation programs and/or water rate increases are possible omitted variables of this sort.

The impact of crop prices are positive and marginally significant at a 10% significance level in some models and largely insignificant in others. The results do not provide any conclusive evidence that crop prices are noteworthy factors in water transfers, which agrees with our expectations.

The regression results for constant water rights are presented in table 6 and associated marginal effects in table 7. The results are similar to those found in the changing water right approach discussed above, and further discussion is omitted.

Conclusions and Policy Implications

Overall, the empirical results support prior claims that water reallocation in the ID-dominated western United States may not be occurring as regionally desired (Carey and Sunding 2001; Brown 2006; Eden et al. 2008). Indeed, IDs are less responsive in agricultural-to-municipal water transfers relative to non-IDs in terms of the proportion of transfers to their water right holdings. The IDs' collective-type institutional structure, coupled with local interdependencies (between external transfers and internal water delivery) and the presence of increasing returns to scale can motivate IDs to transfer less and retain more water in agricultural uses.

Table 6. Fractional Probit Estimates (Constant Water Right Approach, $N = 70$)

	Model I		Model II	
Covariates	Coeffs.	Robust S.E.	Coeffs.	Robust S.E.
ID Dummy	−0.486***	0.099	−0.458***	0.128
Δ Log of *Amistad*	−13.253***	3.820	−13.915***	3.921
Δ Log of *Permits*	0.525***	0.135	−0.066	0.416
Δ Log of *Establishments*	0.841	2.214	4.893**	2.463
Δ Log of *Population*	−11.811***	4.420	−10.362**	4.417
Δ Log of *Income*	−2.945***	1.146	−3.794***	1.147
Δ Log of *USPI*	0.692*	0.407	0.969*	0.525
ID × Δ Log of *Amistad*			2.782	9.976
ID × Δ Log of *Permits*			0.164	0.692
ID × Δ Log of *Establishments*			−0.3	4.495
ID × Δ Log of *USPI*			−1.231	1.050
Δ Log *Permits* × Δ Log *Amistad*			12.623	29.436
Δ Log *Permits* × Δ Log *Establishments*			33.143***	8.972
Δ Log *Permits* × Δ Log *USPI*			−0.472	4.025
Sq. Δ Log of *Permits*			−1.15	0.827
Sq. Δ Log of *Amistad*			36.416	391.004
Sq. Δ Log of *USPI*			−1.002	5.316
Intercept	−1.892***	0.159	−1.943***	0.198
Deviance	0.265		0.230	
Pearson	0.279		0.251	
(1/df) Deviance	0.004		0.004	
(1/df) Pearson	0.004		0.005	
AIC	0.278		0.564	
BIC	−263.142		−220.692	

*Sig at ≤10%, **sig at ≤5%, and ***sig at ≤1% level of significance. Water right holdings-weighted transfer is used as dependent variable in all the models. Δ is the first difference operator. Sq. stands for the square of a variable. Deviance, Pearson, AIC (Akaike Information Criteria), and BIC (Bayesian Information Criteria) statistics indicate relative fit of the models.

Table 7. Marginal Effects (Constant Water Right Approach)

	Model I		Model II	
	M.E.	Delta S.E.	M.E.	Delta S.E.
At Mean				
ID Dummy	−0.005***	0.001	−0.006***	0.002
Δ Log of *Amistad*	−0.14***	0.042	−0.143***	0.051
Δ Log of *Permits*	0.006***	0.001	0.009***	0.003
Δ Log of *Establishments*	0.009	0.024	0.059***	0.022
Δ Log of *Population*	−0.125***	0.047	−0.119**	0.058
Δ Log of *Income*	−0.031***	0.012	−0.044***	0.016
Δ Log of *USPI*	0.007*	0.004	0.004	0.006
At Median				
ID Dummy	–	–	–	–
Δ Log of *Amistad*	−0.2***	0.065	−0.211***	0.060
Δ Log of *Permits*	0.008***	0.002	0.011***	0.003
Δ Log of *Establishments*	0.013	0.034	0.072**	0.030
Δ Log of *Population*	−0.179**	0.072	−0.162*	0.084
Δ Log of *Income*	−0.045**	0.018	−0.059**	0.024
Δ Log of *USPI*	0.01*	0.006	0.01*	0.005

**Sig at ≤5%, and ***sig at ≤1% level of significance. M.E. stands for marginal effects and S.E. for standard errors. There are no M.E. evaluated at medians of dummy variable ID.

The tendency of IDs to maintain high levels of agricultural water use, with less water for money-generating transfers, is aggravated by the presence of multiple uses and exclusion rights without individual ownership rights. Such ownership structures create a disincentive for the adoption of water-conserving practices by ID members, increases the transaction costs of water transfers, and creates uncertainty about individual transfer benefits, thereby reducing support for external transfers. The political structure of IDs, especially the popular voting scheme applied by many, may worsen inefficiency because of the opportunity to subtly manipulate water prices for political support, unfortunately ignoring the opportunity costs of water. A stark interpretation is that these systems may be favoring irrigation over irrigators, given the transfer rewards that are being left on the table.

The study has been able to address open questions about whether IDs are able to transfer water in such a way that their participation is matched by their proportion of water right holdings. The theoretical claims of previous studies about the reluctance of IDs in reallocative activities is empirically supported, which is a significant contribution of the present study. It is also clear that the design of IDs promoted water development for agriculture, yet subsequently hindered the movement of water to higher valued uses. The presence of common and anti-common traits in IDs' water poses a serious challenge for achieving water use efficiency as water scarcity mounts. Although the formulated microeconomic model includes a breakeven constraint in the objective function of IDs and uses a differentiated price structure for internal water uses and external water transfers, the political aspects of decision making in IDs remain under-represented in the model.

The findings suggest that theoretical claims of previous studies about the under-participation of IDs in reallocative activities merit public attention. At a time when economic, climate, and environmental change suggest the reallocation of water from lower-valued agricultural to higher-valued municipal uses, the slow response of water-rich IDs in external transfers signals a need to redesign policies. Examples of such policies are to rearrange ownership structures to the mutual IO type (where members own shares of the district and its water), changing voting structures to acreage-based (perhaps a modestly potent option), and redesigning water rates to reflect water's opportunity costs (Griffin 2012a). Such modifications appear unlikely to be advanced via forces internal to IDs.

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