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# INSTITUTIONS, THIRD-PARTIES AND WATER MARKETS

## AN ANALYSIS OF THE ROLE OF WATER RIGHTS, THE NO-INJURY RULE, AND WATER CODE 386 ON WATER MARKETS IN CALIFORNIA COUNTIES

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Given the apparently large potential gains from the trade of water, why do we observe so few market transactions? This paper argues that policy-driven transaction costs stemming from two common water laws are an important trade-hindering factor. It examines the allocation of property rights under the No-Injury Rule, which gives rights to riparian users, and Water Code 386, which gives quasi-blocking rights to third-parties, making water rights less clear. The results for the No-Injury Rule indicate that for the average county, a one standard deviation increase in the ratio of riparian rights holders to the total population will decrease the likelihood that the county will have an active export market by 30 percent and will decrease the ratio of exports to appropriations in counties with active markets by 7.4 percent. This suggests that if California's goal is, as stated in the 1970's, to reallocate water to its highest valued use via water markets, the current allocation of property rights may be creating policy-driven costs that hinder reaching that goal.

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## 1. INTRODUCTION

According to World Bank estimates, approximately 1.1 billion people in developing countries have inadequate water supplies and 700 million people in 43 countries live without enough water to meet their basic needs. In the United States, cities around the country are facing falling water tables and drought conditions that have been costly to state and local economies. In North Carolina, for example, city officials estimate lost crop revenues in 2007 to be $500 million due to insufficient water supplies (Roberson 2008).

In the past, governments have responded to growing water demands by damming major rivers and implementing water storage projects like the California Water Project, which began in the 1950s. These historic options, however, have "long-since been exploited" and the potential for conservation measures alone to meet growing water demands around the world is limited (Libecap 2005, 1). As a result, there has been mounting pressure in regions with severe constraints on water usage to re-allocate water from its dominant historic uses in agriculture[2] to more pressing urban uses and environmental purposes (e.g., to protect species and riparian lands).

Studies suggest that there are significant social gains from the creation of water markets that move water from its current historic allocations to the highest valued uses in the region (Carey and Sunding 2001; Howitt and Sunding 2003). The potential for such gains is made evident by the large price differences observed between the highly subsidized agricultural users and the urban and environmental demanders. For example, from 1970 to 1990, municipal and commercial buyers in the Rio Grande Valley budgeted up to $600 per acre-foot to purchase

[2] For example, 84 percent of California's water supply is used for agricultural irrigation, most of which is used to produce highly subsidized, low profit crops (Howitt and Sunding 2003, 1).

water from farmers who were paying as little as $15 per acre-foot (Griffin and Boadu 1992, 274-275).

Economists predict that because of these observed price differentials between water uses, the gains from trade would create incentives for a substantial water market. In such a market, (given zero or low transaction costs) higher valued water users could simply contract around the historic allocation of water rights, thus reallocating water through market transactions (Anderson and Lueck 1992, 436). Contrary to expectations, however, the number of water markets and the activities within established water markets are not as prevalent as was predicted (Libecap 2005, 2). One potential explanation is that the transaction costs associated with the trade of water are so large that they greatly inhibit exchanges.

The key issue for policy decisions is whether the apparently high transaction costs are, at least in part, an artifact of the way policy has been set (e.g., see Demsetz 2003, 282-300). As the Coase Theorem shows, if transaction costs are present the initial allocation of property rights may influence how resources are allocated among alternative uses (Hirshleifer and Hirshleifer 2005, 513-514). In fact, according to Anderson (2004, 461), certain configurations of property rights "may make transaction costs so high that bargaining is impossible without redefinition". Moreover, Lueck (1995, 644) reminds us that this outcome may occur even when the value of the resource is high, as is the case for water in some regions.

In Section 2, this paper provides background regarding the effects of two common laws observed in water trading states. Using Libecap's (1989, 21-28) framework for transaction costs sources, Section 2 demonstrates that these laws allocate water rights in such a way that increases the number and heterogeneity of competing claimants in the water transfer process and, in some cases, weakens tradable water rights. Specifically, the assignment of property rights via the No-Injury Rule, which gives instream flow claimants (i.e., riparian rights holders[3]) rights in the water transfer process, and California Water Code 386 (W.C. 386), which makes prior appropriative rights[4] less clear by giving third-parties (i.e., those not directly involved with buying or selling) the ability to protest (and potentially block) beneficial trade, creates added information and negotiation costs that would not exist if the property rights were assigned exclusively to the seller. Thus, regions that allocate property rights in this manner should export less water relative to the first-best outcome (i.e., less than the ideal quantity indicated by a theoretical benchmark).

Section 3 develops a model that combines the effects of the No-Injury Rule and W.C. 386 on a farmer's decision to trade water and presents estimated equations based on this model. The model shows that as the number of claimants who can block trade increases, the information and negotiation costs associated with trade increases. In California's case, claimants come in two forms: instream flow claimants and undefined third-parties. Through the No-Injury Rule, a prior appropriator wishing to sell water that he or she has a right to use incurs a higher cost of negotiating with an instream flow claimant than negotiating with another prior appropriator. Through W.C. 386, there is a higher cost for a prior appropriator to negotiate with third-parties than to negotiate with another water rights holder. Moreover, because the law fails to clearly

[3] Riparian doctrine requires that surface water entitlements (i.e., instream flow claims) stem directly from landownership and do not pertain to stored water or water originating from other watersheds. Because these instream flow rights are coequal, riparian water ownership is not quantified in acre-feet or cubic meters and the amount of the water right changes according to the time of year and water supply. These water rights are not transferable apart from the land.

[4] Prior appropriation doctrine sets a clear order of priority to use a certain quantified volume of surface water. This implies that, unlike riparian doctrine, in times of limited water supply, junior appropriators are forced to yield all or part of their water use to senior appropriators. In this way, prior appropriation doctrine allows for the creation of well-defined, enforceable and transferable water rights.

define what type of harm is protected under the law, there are differing degrees of negotiating costs associated with different types of third-party groups. Under both laws, the prior appropriator has a clear and exclusive right to use his water (and can do so without incurring transaction costs), but not a clear right to sell his water without incurring transaction costs because the right to sell is not exclusive to the prior appropriator. This should result in both a decrease in the volume of water exported within a given water market and a decrease in the probability a region will have an active water market[5] for exports (i.e., water transfers in which the seller and the buyer did not reside in the same county).

Because California has a unique blend of water rights, along with cross sectional variation in the number of third-parties, the data presented in Section 4 provide a unique opportunity to test if the property rights distribution under these two laws is facilitating or deterring water trades. Section 5 reports the results from empirical models that test the effects of riparian rights holders (representing costs from the No-Injury Rule) and third-parties (representing cost from W.C. 386) on the volume of water exported and traded locally in each county in California from 1990 to 2001.

The final section summarizes the paper's main conclusions drawn from the empirical results. The effect of the No-Injury Rule has the predicted impact on water exports; however, the evidence on the effect of W.C. 386 is inconclusive. The combined two stage least squares and

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[5] With respect to exports (local sales), active water markets within a county are defined as any county with at least one recorded export (local) transaction from 1990 to 2001. Although it is possible that an unrecorded market transaction may occur if, for instance, the seller and the buyer are neighbors, it is unlikely that even these transactions would not be recorded. This is because any change in diversion or use of water must be approved by the SWRCB or the seller risks losing his or her water rights permanently. In consideration that most of California's watercourses are fully appropriated, it is unlikely that an informal, unapproved transfer would go unnoticed by neighboring users.

tobit (IV-TOBIT) specification shows that for the average county, a one standard deviation increase in the ratio of riparian rights holders to total population will decrease the likelihood that the county will have an active water market for exports by 30 percent. Furthermore, in counties with export markets, a similar increase in the ratio of riparian rights to total population will decrease the annual ratio of exports to appropriations by 7.4 percent. For the county with the median level of prior appropriations this would be equivalent to 219,551 acre-feet of forgone exports. This suggests that if California's goal is, as stated in the 1970's, to reallocate water to its highest valued use, the current allocation of property rights may be creating policy-driven costs that hinder reaching that goal.

## 2. BACKGROUND

The No-Injury Rule is a common water law affecting water markets. Although the law differs slightly by state, generally, the No-Injury Rule states that any water transfer must not injure or adversely affect the legal rights of any other water rights holders. Through this law, a farmer's right to sell his or her quantity of water is reallocated to include other water rights holders, thus increasing the number of claimants that must be addressed in the water transfer process. As shown by Anderson and Lueck (1992), when multiple parties have rights to a single resource, engaging in transactions can be more costly partially due to the added negotiation costs to obtain an agreement among all claimants. Applying this to the water market context, we would expect fewer trades in regions with a higher number of potential claimants granted rights through the No-Injury Rule (compared to the case where the right to sell is exclusively with the seller).

In addition, in states, such as California, that recognize a blend of riparian and prior appropriative rights (i.e., dual doctrine states), the different types of water doctrine in the region, coupled with the No-Injury Rule, raise the costs associated with trade by increasing the information asymmetries among the claimants. Through the No-Injury Rule, prior appropriators wishing to trade their rights in dual doctrine regions incur a higher cost to negotiate with riparian rights holders than to negotiate with other prior appropriators. This is because unlike prior appropriation rights, riparian rights are not defined in acre-feet and change rapidly according to the time of year and availability of water. Because of this, prior appropriators incur a cost to determine any potential harm to riparian rights holders that may result from a water transfer. This increase in information costs should result in less water exported relative to the first-best outcome.

In many states the courts and local water codes have expanded those protected from unreasonable injury to include third-parties (i.e. individuals who are potentially negatively affected by water trades and reside in the transferor's county, but do not hold water rights and do not participate directly in the water transfer). This is the case with California Water Code section 386, which states that "water transfers must not unreasonably affect… the overall economy of the area from which the water is being transferred" (State of California's Legal Information Division). In practical terms, the law gives all third-parties in the county of origin a right to protest any water trade that negatively affects them in an unreasonable manner, but fails to clearly define which groups can successfully claim harm (and therefore have blocking rights).

To understand the implications of these types of laws, it is beneficial to briefly analyze California's water transfer process (SWRCB 1999). In order to obtain permission for a short-term transfer, the transferor must submit a petition with investigation fees, which depend on the volume of water proposed in the trade and the complexity involved, to the State Water Resource

Control Board (SWRCB).[6] Notice of the proposed transfer is then published in newspapers within all affected counties, and letters are sent to other water rights holders and any parties that may be protected under W.C. 386. Any third-party individual in the county of origin may file an objection to the proposed transfer at no charge within thirty days after the notice.

The transferor and the protestors have approximately 35 days to negotiate a resolution, perhaps through compensation or a change in the proposed time of the transfer. If the transferor cannot successfully come to an agreement with all protestors, the SWRCB will hold a hearing to rule on the petition. Most hearings will likely delay temporary transfers to the point that they would not take place in the proposed year (SWRCB 1999, section 6). If the buyer is a farmer looking to fill a short-term need, a one year delay might be enough to block the transfer altogether. This is one way that this law effectively gives third-parties quasi-veto rights (i.e., rights to protest and perhaps block trade).

As this process shows, W.C. 386 makes a prior appropriator's selling right less clear by substantially increasing the restrictions associated with water ownership (Barzel 1997, 3). In addition, the law raises the negotiating costs associated with trade by expanding quasi-veto rights to an undefined group of third-parties in the county of origin. Thus, in regions with a higher number of third-parties, we would expect a lower volume of water traded within a given water market.

Water Code 386 also forces transferors to negotiate with a more heterogeneous group of potential protestors than the No-Injury Rule does, thus making the costs of contracting for resource uses systematically higher (Anderson and Lueck 1992, 434-437). Under the No-Injury

[6] Any change in diversion or use of water must be approved by the SWRCB or the seller risks losing his or her water rights permanently.

Rule, transferors are forced to negotiate with other water rights holders, who are often other farmers. Conversely, under W.C. 386 transferors may be forced to negotiate with diverse groups including bureaucrats, teachers, and tractor dealers and therefore, information asymmetries among these groups will be greater. For example, a farmer can more credibly confirm the losses to a neighboring farmer because of low irrigation flows than the decrease in sales to a tractor dealership because of a reduction in agricultural output. Furthermore, it would be even more costly for the farmer to confirm losses due to a decrease in school enrollment or losses due to a decrease in the demand for diesel at the local truck stop. In sum, the necessity of negotiating with these heterogeneous groups will likely entail high transaction costs and, therefore, may lead to fewer water exports.

## 3. THE THEORETICAL FRAMEWORK AND ESTIMATED EQUATIONS

### 3.1 Theoretical Framework

Consider a farmer's decision to export water given both his legal and physical constraints on water usage. The first legal constraint is the type of water doctrine: the farmer must have a prior appropriative right in order to export. The second is the potential quasi-veto power held by both harmed riparian rights holders and harmed third-parties; this requires the exporting farmer to incur information, negotiation and compensation costs. Figure 1 graphically depicts the export outcomes from the perspective of a farmer who owns a prior appropriative water right. We assume that any given farmer is a price taker in the water export market (but not necessarily in the local water market); this is depicted by the horizontal line labeled $P^*_{export}$. Moreover, the farmer can live in a county with no riparian water rights holders or third-parties or both, few riparian water rights holders or third-parties or both, or a large number of riparian water rights holders or third-parties or both. Finally, the farmer has three income sources in any given period

– income from agriculture (which is a function of the water used), income from local water sales (i.e., water transfers between a buyer and a seller who both resided in the same county), and income from water exports.

In Figure 1, the marginal cost line, labeled $MC_{farmer}$, represents the farmer's cost per acre-foot of water exported if there is no third-party resistance, no resistance from other riparian water rights holders and no SWRCB fees. In other words, this line reflects the farmer's opportunity cost of exporting the water, which includes forgone crop revenues or forgone revenues from local water sales or both. Also included in $MC_{farmer}$ are any legal fees and costs associated with the buyer and seller negotiating for the export. Therefore, a profit maximizing farmer would export $Q_0$ in a county with all water rights well-defined and transferable (i.e., no riparian water rights), no third-party resistance, and no SWRCB investigative fees.

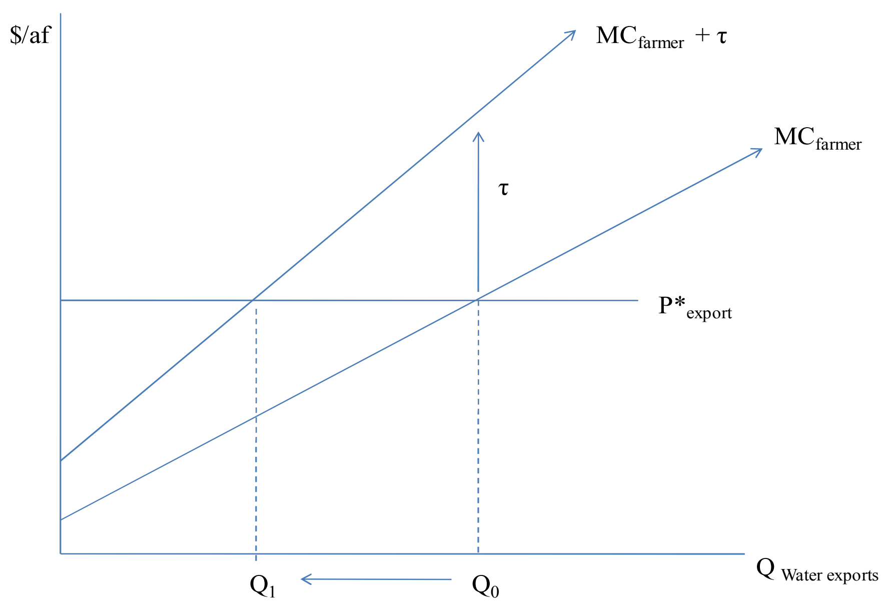


**Figure 1. Model of One Farmer's Decision to Export Water.**

In regions with laws that recognize other rights holders or give third-parties quasi-veto rights or both, the cost to export each acre-foot of water is higher by $\tau$, which is a function of the quantity of water exported, where

$$\tau = \alpha + \beta \cdot (Q_{\text{exports}}) \text{ where } \alpha \geq 0 \text{ and } \beta \geq 0. \quad (1)$$

With $\alpha > 0$ and $\beta > 0$, the marginal cost line is higher and steeper, as shown by $MC_{farmer} + \tau$ in Figure 1. The magnitude of $\tau$ will reflect the farmer's additional costs as a direct result of riparian water rights holders and third-party rights in the water transfer process, as well as SWRCB's investigative fees.

Now consider more specifically how $\alpha$ and $\beta$ are influenced by the water transfer process. The value of $\alpha$, which affects the location of the y-intercept on $MC_{farmer} + \tau$, depends on the SWRCB's investigative fees and any other *per unit* costs that do not vary with the quantity of water traded. The value of $\beta$ affects the slope $MC_{farmer} + \tau$. It depends on the number of riparian rights holders in the county and the number of third-parties with legal standing in the county of origin, as well as their expectations about the potential harm caused by the water export. At low levels of export, there may be little or no resistance from third-parties (or, similarly, riparian rights holders) because the stakes are so low; individual participants lack a sufficient incentive to act. As the quantity of water exported rises, however, more third-parties are likely to act. In addition, they may put up more resistance per unit of exports because the magnitude of injury per acre-foot increases as more acre-feet are exported.

To demonstrate the impacts of these costs on trade, consider Lueck's 1995 model of establishing property rights for wildlife. In it, Lueck shows that resource outcomes will depend primarily on the interaction of the resource's values (i.e., prices) with owner contracting costs (a component of τ in our model). Figure 2 illustrates Lueck's idea in the context of markets for water exports using three possible export prices a farmer might face ($P_{low}$, $P_{middle}$, or $P_{high}$). If the price is $P_{high}$, the farmer would trade $Q_0$ in a county with well-defined and transferable water rights, no third-party resistance and no SWRCB investigative fees. If, however, the farmer faced additional costs to trade in the amount of τ, at a price of $P_{high}$, the quantity of exports would decrease from $Q_0$ to $Q_1$. Thus, if $MC_{farmer} + \tau$ shifts up (as a result of τ increasing), the quantity of water exported will decrease.

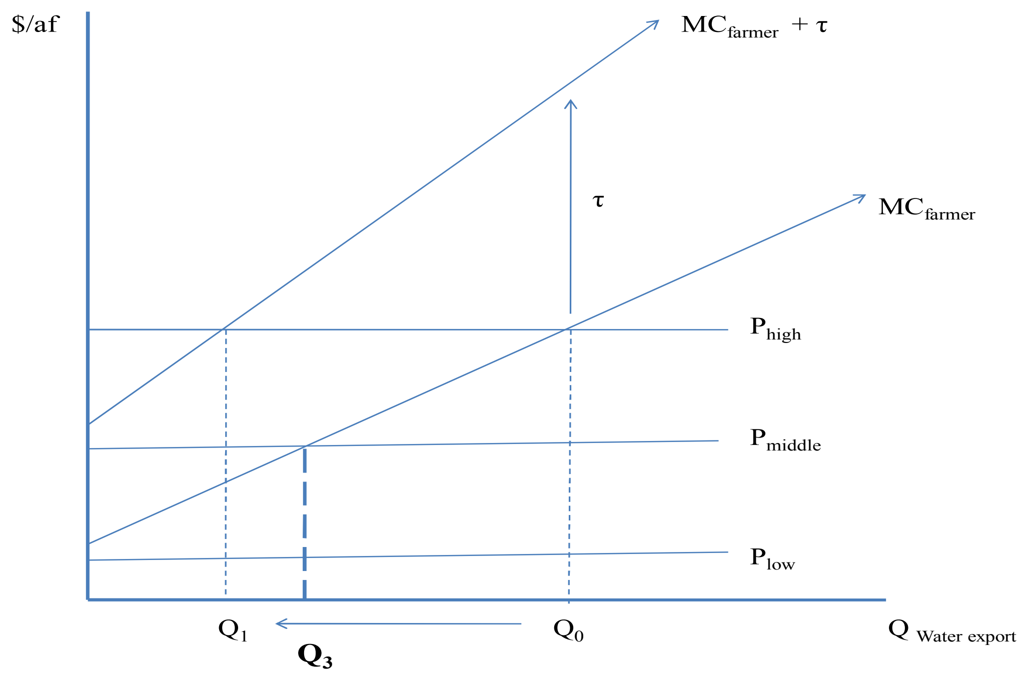


**Figure 2. Possible Export Outcomes.**

Figure 2 also illustrates the potential for corner solutions especially at relatively lower export prices or higher values of τ. If, for example, the farmer faced $P_{middle}$, the quantity of water exported would be $Q_3$ in a county with well-defined and transferable water rights, no third-party resistance and no SWRCB investigative fees. Yet, if τ were positive in the way depicted in

Figure 2, at a price of $P_{middle}$ the marginal cost to trade would outweigh the gains to export and there would be no water exported. At a price of $P_{low}$, the cost for the farmer to trade would be higher than the gains even in a county with well-defined and transferable rights, no third-party resistance and no SWRCB investigative fees.

Overall, Figure 2 generates two testable predictions. First, at any given export price, real world factors analogous to a high $\tau$ will generate a lower volume of trade. In this way, these legally driven contracting costs act in the same way as a tax on potential water sellers, decreasing the volume of trades relative to regions without these same laws. Second, given an export price (e.g., perhaps $P_{high}$ or perhaps $P_{middle}$) factors analogous to a high $\tau$ will lead to a lower probability of observing trades. This is because when the gains from exporting water are overwhelmed by the costs of contracting, no water will be exported.

Finally, consider how these legally driven transaction costs affect a farmer's water allocation decision, keeping in mind that the water not exported is then divided between crop production and local sales. There are three key factors that influence a farmer's reallocation decision. First, as the export price declines relative to $P_{local}$ and crop prices, one would expect the individual farmer to allocate more to crop production or local sales or both. Second, conditional on the level of exports, the allocation of water between local trades and own-farm use is unaffected by third-parties, because W.C. 386 cannot be applied to local trades.[7] Third, conditional on the level of exports, the allocation of water between local trades and own-farm

[7] Note that Water Code 386 cannot be applied to local trades because a local trade necessarily produces an increase in local productivity. A local farmer who trades with another local farmer does so only if the value of water on the buyer's land is greater than the value of water on the seller's land. Thus, any local trade produces more output than would occur if trade was blocked and therefore, cannot "unreasonably affect the overall economy".

use is most likely unaffected by riparian rights holders. This is because the injury that normally is claimed by riparian rights holders – a decrease in return flows – would theoretically not occur as often with most local trades. Thus, ceteris paribus, at higher values of $\tau$ or low export prices or both, the farmer will choose to sell more water locally if $P_{local}$ minus the costs to trade locally, which may be affected by the No-Injury Rule, is greater than the value marginal product of own-farm water.

Overall, this model shows that the amount of water exported will depend on the interaction of export price with variables influencing costs, primarily $\tau$. If the price is low relative to $\tau$ (i.e., the transaction costs) it may not be beneficial to export water. Therefore, water will be used locally or for own-farm use.

**3.2 Estimated Equations**

To test the implications of this model, we would ideally analyze water exports and local trades at the farm level in each county. Such data are, however, unavailable. In place of farm level observations, a dataset containing all water trades from 1990-2001 in 57 California counties is used, excluding San Francisco as an outlier. This dataset is an aggregated measure of all farmers' decisions in the county to consume, sell locally or export their water allotments. Because California counties recognize a blend of riparian doctrine, prior appropriation doctrine, and an influential water code, when the state of California decided to adopt policies and infrastructure to encourage water markets across the state, each county's potential transferors faced differing participation costs. The summation of each individual farmer's choices in regards to water use will then be reflected in the volume of water exported and sold locally in each county.

The estimated model for water exports is as follows:

$$\text{Water Exports}_{it} = \rho_1 + \delta_1 x_{it} + \gamma_1 z_{it} + \lambda_1 w_{it} + \theta_1 v_{it} + a_i + \mu_{it}, \qquad (2)$$

where Water Exports$_{it}$ is the volume of water exported in county i during year t divided by the total volume of water appropriated in county i during year t. Using this ratio allows the analysis to ask, out of the water available for legal trade, how much trade do we actually observe in the county. The term $x_{it}$ is a vector of institutional variables that represent sources of costs generated by the No-Injury Rule, which influences the size of $\tau$. The ratio of riparian rights holders to total population is used to represent these institutional costs. Theory predicts that the effect of the No-Injury Rule on exports, measured by $\delta_1$, should be negative. The term $z_{it}$ is a vector of third-party indicators that proxy for individuals that generate sources of third-party costs, which influences the size of $\tau$. The per capita number of employees in the farm machinery industry plus the number of employees in the irrigation industry, the percent of farm employment to total employment, and the per capita value of agricultural production are used to represent sources of third-party costs driven by W.C. 386. Theory predicts that the effect of W.C. 386 on exports, measured by $\gamma_1$, should be negative.

The remaining variables act as controls. The term $w_{it}$ is a vector of supply and demand measures and proxies that influence $MC_{farmer}$ and the market demand for water. Total water supply in thousands of acre-feet, annual precipitation in inches, and a proxy for transportation costs are used to represent factors that change the location of $MC_{farmer}$. The term $v_{it}$ is a vector of control variables. These include a time trend variable, local laws, the number of employees in the gold and silver mining industry in 1998, and the inverse of total population in the county. The term $a_i$ is the county fixed effect component of the error term and includes the effects of time invariant unobserved variables. The term $u_{it}$ is the idiosyncratic component of the error term.

Local sales within the county provide an additional opportunity to test the implications of the No-Injury Rule, which can be applied to local sales, and W.C. 386, which cannot. This is true because a farmer who faces higher export costs due to these laws should export less water and reallocate his water use between own-farm uses and local sales. Under the current law, the farmer would not choose to leave any water unused because he risks losing that part of his water allocation. Thus, the farmer's decision to trade locally will depend on the costs to trade locally, $P_{local}$ , and the value marginal product of water on the farm . The estimated model for local sales is as follows:

$$\text{Local Sales}_{it} = \rho_2 + \delta_2\, x_{it} + \gamma_2\, z_{it} + \lambda_2\, w_{it} + \theta_2\, v_{it} + a_i + \mu_{it}\,, \qquad (3)$$

where Local $\text{Sales}_{it}$ is the volume of water traded locally in county i during year t divided by the volume of water appropriated in county i during year t. The effect of the No-Injury Rule on local trade, measured by $\delta_{2,}$ could be positive if, as a result of less water being exported out of the county, more water is traded locally. Conversely, the effect of the No-Injury Rule on local trade could be negative if the type of local trade is covered under the No-Injury Rule and, thus, raises the cost for prior appropriators to trade locally. Because W.C. 386 cannot be applied to local trade, the effect of W.C. 386 on local trade, measured by $\gamma_2$, should be positive if, as a result of less water being exported out of the county, more water is traded locally.

## 4. DATA

Summary statistics for all variables can be found in Table 1. Surpassed only by Colorado, California's water market is the second largest water market in the nation, accounting for about fifteen percent of the nation's transactions from 1987-2007. Nevertheless, the data show that despite state-wide efforts to create water markets, only 34 counties have active water markets (i.e., at least one recorded transaction) for exports or local sales or both between 1990 and 2001. In these counties, the yearly acre-feet of water exported and traded locally were recorded for all years with no missing records. In most years, the agricultural sector supplied 90 percent of the water traded (Hanak 2002, 7 and 42). During the period studied there was considerable variation across counties in the amount of trade with acre-feet in exports ranging from zero to 252,377 and acre-feet locally traded ranging from zero to 98,000.

Data for the volume of water exported in county i during year t and the volume of water traded locally in county i during year t were gathered by Ellen Hanak (2005), using a variety of state, federal and local sources on individual water transfers from 1990-2001. Hanak reported data as $\text{exports}_{it}$ and $\text{local sales}_{it}$ where i = 1…58 and t = 1…12. Each category is the summation of surface water and groundwater transfers, as well as short term and long term transfers for water agencies (state or private) within a county for a given year. Where agencies had multiple county jurisdictions and transferred water came from multiple counties, Hanak weighted the acre-feet transferred by area, recording partial amounts of the transfer in different counties.

Data for the volume of water appropriated in county i during year t (the denominator of both the dependent variables) come from the SWRCB's database that documents all public water rights that must legally be registered (SWRCB 1990 and SWRCB 2009). The pertinent section of the database reports the characteristics of each post-1914 prior appropriation water right.[8] From

[8] Note that *pre*-1914 prior appropriative rights are diversion rights established prior to a central agency permitting and documenting appropriative rights in California. According to the SWRCB and the DWR, most pre-1914 appropriative rights were lost during the transition due to a lack of historical documentation and such rights are rare today.

this, the annual number of acre-feet in post-1914 prior appropriative rights in each county is obtained. This variable serves as a proxy for the number of acre-feet in the county that are well-defined and can be legally traded. [9] Dividing exports and local trades by this variable allows us to distinguish counties with few trades because of a small number of tradable acre-feet from counties with few trades because of legal constraints. Note that the variable, acre-feet appropriated, contains only cross sectional variation.

To account for the institutional variation across counties ($x_{it}$ vector and component of $\tau$) the ratio of riparian rights holders to the total population in county i during year t was used. Data for the numerator of this variable come from the Statement of Water Diversion and Use section of the SWRCB database. According to Division 2 of Part 5.1 of the California Water Code, all water diverted under a claim of riparian rights must be reported in this section. From this, I obtain the number of riparian water rights holders in the county. This variable exhibits only variation across counties and the total number of rights per county ranges from 4 and 768. Data for the total population in county i during year t come from the US Census Bureau.

To measure the third-party component of $\tau$ ($z_{it}$ vector) three proxy variables were assembled by the author: per capita number of employees in the farm machinery industry and the irrigation industry, percent of agricultural employment to total employment, and per capita value of agriculture. All variables are in per capita terms to more effectively capture the variation in agricultural employment in the rural exporting counties. Using the 1997 Economic Census, the per capita number of employees in the farm machinery plus the irrigation $\text{industries}_{it}$ is measured

[9] Note that 71 percent of California counties have more acre-feet appropriated than acre-feet in dedicated water supply. This implies that the observable acre-feet in prior appropriations is an overestimate of the true acre-feet available for trade in any given year. To test the implications of over appropriated counties, a binary variable equal to one if the county's water supply is over appropriated was added to the baseline IV-TOBIT specifications (Tables 3 and 4). No changes in the qualitative results occurred.

by adding the number of employees in the farm machinery industry in 1997 to the number of employees in the irrigation industry in 1997 and dividing that summation by the county's population.[10] This variable contains only cross sectional variation.

The percent of agricultural employment to total employment$_{it}$ is measured by dividing farm employment$_{it}$ by total employment$_{it}$ and multiplying by 100. Farm employment$_{it}$, as measured by the Bureau of Economic Analysis (BEA 1990), is the number of workers engaged in direct production of agricultural commodities, either livestock or crops; whether as sole proprietor, partner, or hired laborer. It contains both between and within period variation.

Per capita value of agriculture$_{it}$ (in 2000 dollars) is measured by dividing the county's value of agriculture by the county's population. The monetary value of agriculture by county for each year between 1990 and 2001 includes all farm production (excluding timber) in the county whether it is sold or used on the producing farm (compiled by the California County Agricultural Commissioner's Office). These Annual Crop Reports provide the most detailed annual data available on the gross value of agricultural production by county. Although this is not a direct measure of the potential harm to third-parties in the county, the value of agriculture is an indication of the county's total expenditures on farm inputs.

Choosing proxies for third-party costs is difficult. Under W.C. 386, all residents in the county could potentially be included, some of which may not be directly associated with the agricultural industry and thus, may not protest regarding a loss of income from the transfer. According to Libecap (1989, 19), however, focusing on individuals with the greatest potential for

[10] For disclosure reasons, the 1997 Census often gives a range of employees in these industries rather than the actual number. In these cases, the range was recorded with minimums. Because of this there may be a systematic underreporting of the true number of employees in the farm machinery and irrigation industries (although this will be small because the ranges are not large).

immediate income losses due to the change should increase the odds of capturing the "third-party effect". Therefore, for the purposes of this study, the individuals in the agricultural service industry were chosen because their income streams will be most likely to be affected by the land-fallowing practices that typically accompany transfers and will, therefore, be likely to protest water exports. It is important to note that although the scope of harm caused by land fallowing may stretch beyond a county's borders, the law only recognizes the rights of third-parties from the county of origin.

The following are variables that influence the supply and demand of water exports ($w_{it}$ vector). First, I use three variables to represent factors that change the location of $MC_{farmer}$: total water supply in thousands of acre-feet, annual precipitation in inches, and a proxy for transportation costs. The county's available water supply is measured with two variables. The dedicated water supply in 1999 (a wet year and the only year in the time span that can be broken down by county) is taken from DWR's Division of Planning and Local Assistance, which produces a hydrological assessment of California's water usage and supply by county. This variable is a realistic representation of the total water supplied in the county and is composed of agricultural use, urban use, managed wetlands, environmental use and reused water in the county. Including the precipitation rate in inches controls for the variable water supply that is available to the county each year. It was assembled by the author using a program produced by the National Climate Data Center that accumulates historical weather data from each station in a county on a daily, monthly and yearly basis. For the purposes of this paper, the yearly data among all stations in the county were averaged to obtain one estimate for average yearly rainfall in inches in the county. A variable controlling for the relative differences in transportation costs across counties was added because some counties do not have canals or aquifers that are connected to the state's main water distribution system: the Sacramento San Joaquin Delta. To account for this, a binary variable, Canal/Aquifer, was created that is equal to one if the county has a canal or aquifer running through any part of the county and zero otherwise. Because of the way this variable was constructed, there may be attenuation bias in the estimation if some parts of the county do not have access to canals.

Two variables were assembled to represent factors that shift the market demand for water: lagged population growth rate and lagged population growth rate multiplied by precipitation. The variable for lagged population growth rate is based on yearly county population rates taken from the US Census Bureau. This was added to represent shifts in the residential demand for water across counties and time. According to Griffin and Boadu (1992, 275), high population growth rates in regions lead to abnormally large benefits from water trade to municipal buyers. In addition, the interaction of lagged population growth rate and precipitation was added to proxy for the changing relative water scarcity within and across counties, which shifts the market demand for water. The interaction term allows the population growth rate to have a different effect for counties with different variable water supplies. It is important to control for these variables because, as demonstrated by Lueck (1995), when resource values are higher sellers can more easily bear the high transaction costs associated with trade.

The time trend variable was included to control for any linearly trending state-level variables. Examples include the initial government actions aimed at facilitating California's water markets and the effect on potential water traders as they became familiar with water markets (Hanak 2003, 89). In addition, the inverse of population in the county was used to insure that the county's population levels were not driving the results on the ratio of riparian rights to total population.

Finally, three variables were used to test the sensitivity of the results obtained in the next section. The first, county level export ordinance is a binary variable equal to one if the county passed a law restricting water exports by requiring an environmental review of each potential water export. The second, the average number of employees engaged in any form of gold and silver mining in 1998, was gathered by the author using the US Census Bureau's 1998 County Business Patterns. For some counties, for disclosure reasons, a range of employees was used instead of an exact number. When this occurred an average of the range was used. Lastly, year dummy variables from 1990 to 2001 were constructed.

## 5. EMPIRICAL RESULTS

This section presents the results from several specifications that estimate the effects of riparian water rights (estimating the No-Injury Rule) and third-parties (estimating W.C. 386 using three different proxies) on water exports and local trade. Note that all models cluster the $a_i$ error terms by county. This results in more conservative estimates of the standard errors than if this clustering was ignored.

As a baseline for comparison, Table 2 presents OLS estimates of the effect of the No-Injury Rule and W.C. 386 on the volume of exports in a county. The results are consistent with predictions, although imprecise. As a further test of these findings, the model's predictions were checked with the annual volume of local trade. The effect of riparian users and third-parties on local trade lends further support to the model's predictions. The results in Column 2 indicate that the No-Injury Rule raises the cost to trade locally in a way similar to that depicted in Figure 1.

There are two initial problems with the OLS specification. First, because only 34 counties have active water markets and some do not trade in all the years recorded, a maximum-likelihood estimate may better capture the censored nature of these data. Second, there are both theoretical and empirical reasons to believe that riparian water doctrine is endogenous to the model. There may be unobserved historical variables that caused the individuals in the county to choose riparian water rights over prior appropriation rights. If this is the case, then these unobserved and omitted variables not only drove the establishment of different water doctrines in the 1850s, but they may also drive the willingness to use water markets as a solution for water scarcity today. This means that $a_i$ may be correlated with the ratio of riparian rights to total population, thereby biasing the estimates.

I attempt to correct for these two potential sources of bias using the IV-TOBIT model and four instrumental variables, each of which played a historical role in the establishment of the two types of water doctrines in California. The main results are presented in Tables 3 and 4. Table 3 estimates Regression (2) and Table 4 estimates Regression (3). Columns 1-3 of Table 3 (Table 4) report the marginal effects of the explanatory variables, measured at their means, on the probability of exports (local trade). Columns 4-6 of Table 3 (Table 4) report the marginal effects of the explanatory variables, measured at their means, on the ratio of exports (local trades) to acre-feet appropriated for all trading counties. Each column in the tables reports the results from a different proxy for third-parties. Results from robustness tests suggest that the estimates are not sensitive to the addition of local ordinances, mining today, or year fixed effects, although controlling for transportation costs (represented by the canal variable) remains vital.

**5.1 The No-Injury Rule**

There is strong evidence in Columns 1 – 3 in Table 3 to indicate that the No-Injury Rule raises the cost to export in the way depicted in Figure 1. Column 1 in Table 3 shows that, all else equal, a one standard deviation increase from the mean in the ratio of riparian rights holders to total population will decrease the probability that a county will have an active water market for exports by 30 percent. This is statistically significant at the .5 percent level.

To verify these findings, the model's predictions were checked with the annual volume of local trade.[11] The specification in Table 4 indicates that a one standard deviation increase from the mean in the ratio of riparian rights holders to total population will decrease the probability that a county will have an active water market for local trade by 6 percent. This result implies that the local trades we are observing may be moving water within a county in such a way that it decreases the return flows to riparian rights holders in the watershed. In these cases, riparian rights holders would still have standing through the No-Injury Rule to block beneficial local trades.

Consistent with Columns 1-3, Columns 4 – 6 of Table 3 support the model's predictions of the effect of the No-Injury Rule on the volume of exports. Column 4 in Table 3 shows that for counties that have export markets, all else equal, a one standard deviation increase from the mean in the ratio of riparian rights holders to total population decreases the annual ratio of exports to acre-feet in appropriations by 7.4 percent or 47.45 percent of one standard deviation; the coefficient is statistically significant at the .1 percent level. For the county with the median level of prior appropriations (Siskiyou County) this decrease in the acre-feet exported would be

[11] The qualitative findings in Table 4 were unchanged with the addition of the county export ordinance variable. These findings are available upon request.

equivalent to 219,551 acre-feet[12] (assuming the acre-feet in appropriations remains constant in the county at 2,966,902 acre-feet).[13]

As before, to verify these findings, the model's predictions were checked with the annual volume of local trade. The results from Column 4 of Table 4 show that for all locally trading counties, a similar increase in riparian rights to total population leads to a trivial decrease (.03 percent) in local trades to acre-feet appropriated. The results are statistically insignificant and essentially show that the No-Injury Rule has no apparent effect on the volume of local trade for all trading counties. This may imply that $P_{local}$ is less than the value marginal product of water on most of the farm acres in the counties that trade.[14]

**5.2 Water Code 386**

There are three variables used as proxies to control for the number of third-party individuals in the county that influence the size of $\tau$: the per capita number of employees in the farm machinery plus irrigation industries (Columns 1 and 4 of Tables 3 and 4), the percent of agricultural employment to total employment (Column 2 and 5 of Tables 3 and 4), and the per capita value in agriculture (Column 3 and 6 of Tables 3 and 4).

Empirical results from Column 1 of Table 3 show that all else equal, if the per capita number of employees in the farm machinery industry plus the irrigation industry increases by

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[12] Assuming an average price per acre-foot of $234, which was obtained using the Bren School's Western Water Transfer Data Base, the average cost for Siskiyou County in terms of forgone revenue from exports attributable to the No-Injury Rule is $51,374,934 (in 1987 dollars).

[13] Although the assumption that the acre-feet in post-1914 prior appropriation rights remains constant in the county is not a trivial one, it is most likely a realistic assumption. This is because, according to the SWRCB, the majority of available rights were allocated prior to 1950.

[14] As a further test of the paper's main findings, several specifications were run using the number of riparian rights holders in place of the ratio of riparian rights to total population. The point estimates show support for the model's predictions, but the results are smaller in magnitude and less precise. One explanation for this is that the raw number of riparian rights holders does not effectively account for the variation in the number of riparian rights in the rural exporting counties.

one standard deviation from the mean, the probability that a county will have an active water market for exports increases by a trivial amount (.51 percent). Though the coefficient is not statistically significant, it is opposite of the model's predictions. The estimates for the effect on the volume of exports from Columns 3 – 6 in Table 3 were also opposite of the model's predictions and statistically insignificant.

As a further test of the effect of W.C. 386, the model's predictions were checked with the annual volume of local trade. The specification in Column 1 of Table 4 shows that a similar increase in the per capita number of employees in the farm machinery plus the irrigation industry increases the probability that a county will have an active market for local trades by 2.6 percent. The results from Column 4 of Table 4 show that for all locally trading counties, the same increase in the per capita number of employees in the farm machinery plus the irrigation industry would increase the annual ratio of local trades to acre-feet appropriated by 8.5 percent of one standard deviation. These results are consistent with the model's predicted effects of third-parties on local trades. Results are similar when other proxies for third-parties are used (with some changes in statistical significance among different proxies).

Although the estimated effects of the third-party proxies may indicate that W.C. 386 has little effect on exports, it might be that the chosen proxies do not capture all the potential third-party effects. If this is the case, the results understate the true effects of third-parties on exports. There are three reasons to believe this is plausible.

First, some proxies for third-party costs fail to capture the major sources of transaction costs. Specifically, the percent of agricultural employment to total employment does not differentiate between the many types of agricultural employment including farm owners versus farm laborers. Therefore, this variable does not effectively control for a major source of τ: heterogeneous claimants. In addition, the per capita value in agriculture tells us little about who really owns the income stream related to agriculture. Therefore, this variable does not effectively capture two important components of τ: the number of potential claimants in the county and their heterogeneous makeup.

Second, the third-party variables chosen may be proxies for the groups who can most easily negotiate with farmers. Consider that a farmer (and potential transferor) already has some form of contractual relationship with employees in the agricultural service industries. Therefore, it might be that farmers and agricultural service employees act as though rights are clearly defined and successfully contract around one another for the optimal water use. If this is true then the magnitudes of the coefficients on the third-party proxies are most likely being offset by side payments that allow trade. This may explain the positive sign found on all three coefficients on the third-party proxies in Table 3. Thus, the three chosen proxies in the empirical model fail to capture the effects from the most heterogeneous third-party groups influencing exports such as teachers who may be concerned that school enrollment will drop or the local commercial builder who may be concerned that the tractor dealer will put off renovations.

Third, the low variation in the proxies for third-party costs may be leading to large standard errors on the coefficient and imprecise estimations. For example, we observe only a small degree of within county variation in agricultural related employment in the 12 year time span. The variable per capita value in agriculture has the greatest amount of variation, but conveys the least information about the transaction costs to trade.

Overall, it is not surprising that the effect of W.C. 386 is harder to estimate than is the effect of the No-Injury Rule because the very nature of W.C. 386 makes all residents in the county potential claimants. Thus, although the chosen proxies are useful, they do not capture all the potential third-party effects. Note that the proxies for third-parties may be correctly predicting the effect on local trades because these variables are an indication of whether there is agriculture in the county. Naturally, where there is agriculture, there are potential buyers and sellers for local water markets.

### 5.3 Endogeneity of Riparian Water Rights: The Relevance and Validity of the Instruments

The IV-TOBIT estimations use four instrumental variables: population by county in 1850, population by county in 1860, the value of farm products by county in 1900 (county boundaries in 1900 are almost identical to the county boundaries today), and the value of gold and silver production from mining by county in 1880 (the most accurate accounting of historic mining by county between 1850 and 1880). These instruments were chosen because, historically, prior appropriation water doctrine was established to meet the needs of mining camps – and to a lesser degree, farmers – to divert water from riparian lands. In 1852, a new hydraulic mining technology emerged that used large volumes of water to strip the ground and substantially increased the gains from acquiring divertible water rights. This water-intense technology, along with the value of water for agricultural irrigation off riparian lands, led California to recognize, in addition to riparian water rights, a new type of divertible water doctrine called prior appropriation. Thus, the presence of (or lack of) valuable resources, such as gold, silver and fertile farm land, in a county between 1855 and 1900 drove individuals in each county to choose either riparian water rights, if these resources were not abundant, or prior appropriation doctrine, if these uses for water existed. Population levels in 1850 and 1860 were included because even in counties with little or no farming or mining, large populations may have led to a sprawl far from water sources, thus leading to individuals choosing differing water doctrines. Therefore, these instruments should be correlated with water doctrine, but have no direct effect on the existence of active water markets today.[15]

An F-test for the joint significance of the instruments produces an F(3,671) statistic of 22.08 for the OLS specification. This is well over the usual standard for establishing significance (i.e., an F statistic of 10). Similar results were obtained from the IV-TOBIT specification, which rejected the null hypothesis that the instruments were jointly insignificant with a p-value from the $\chi 2$ distribution of .0381. This implies that these instruments are relevant predictors of riparian rights today. The exogeneity of these four instruments was investigated using a Lagrange Multiplier test (i.e., an over identification test), which produced a p-value from the $\chi 2$ distribution of .665 using the TSLS and OLS specifications. This test implies that the correlation of the instruments and the error term from the TSLS specification is not statistically different from zero. These results are consistent with using the IV-TOBIT estimates.[16]

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[15] Note that there is little correlation between the historical value of farm products and the value of farm products today. Specifically, the correlation coefficient between value of $\text{agriculture}_{i,t}$ (in year 2000 dollars) and the value of farm products in $1900_i$ (in year 1900 dollars) is .1825.

[16]It is worthwhile to note that the results from both the Hausman tests and a Wald test for the exogeneity of riparian rights doctrine rejected the plausible endogeneity of riparian rights doctrine and may indicate that an OLS regression is preferred. Specifically, using unclustered OLS and TSLS specifications, the Hausman test for the correlation between the ratio of riparian rights holders to the total population and the error term produced a p-value from the $\chi^2$ distribution of .9967, indicating the standard errors from the OLS and TSLS specifications are similar. This was supported by a Wald test from the clustered IV-TOBIT specification, which produced a p-value from the $\chi^2$ distribution of .5997. There are two possible explanations for the Hausman test rejecting the plausible endogeneity of riparian rights doctrine. First, it might be that the standard errors on the OLS and TSLS specification are so similar that an OLS regression would produce more precise estimates. An alternative explanation for this outcome is that the large standard errors are driving the results. Given the large changes in the magnitudes and statistical

### 5.4 Robustness Tests

The sensitivity of these results was explored under a number of alternative specifications with little change to the main results. First, in consideration of Hanak's 2003 study of the effect of county restrictions on exports, Regression (2) was reestimated using a binary variable equal to one if the county passed a law restricting water exports by requiring an environmental review of each potential water export. If counties with more third-party individuals are more likely to pass such measures, the omission of this variable may bias the estimates on the variables of interest. Second, in consideration of the historical context in which California counties acquired differing water doctrines (i.e., as a direct result of the presence of – or lack of – valuable resources to mine), it might be that gold and silver mining today is highly correlated with the number of riparian rights holders in a county, and that this may bias the estimate on riparian rights if left omitted. Therefore, Regression (2) was reestimated using a county level variable that represents the average number of employees engaged in any form of gold and silver mining in 1998. Finally, because the time trend variable might not be effectively controlling for the growing familiarity with the water transfer process or the initial importance of the government's role in facilitating trades, the variable was replaced with individual year fixed effects. The results from these specifications were similar to those reported in Table 3. This lends additional support to the significance of the No-Injury Rule on trade and confirms the need for better proxies for third-party individuals.

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significance of the variables of interest between the OLS and IV-TOBIT regressions, it is likely that the alternative explanation is correct. Thus, these results do not necessarily imply the OLS specification should be used over the IV-TOBIT specification.

The overall results show that the No-Injury Rule, transportation costs, and a time trend variable have a strong, highly significant impact on the probability a county will have an active export market, as well as the volume of exports within a given market. Although precipitation[17], residential water demand (as represented by lagged population growth rate)[18], and relative water scarcity (as represented by the interaction of lagged population growth rate and precipitation) all have a jointly significant effect on exports, the magnitudes of these effects are trivial.

## 6. CONCLUSION

The findings of this study suggest that despite the large potential gains from water market transactions, the No-Injury Rule (and perhaps W.C. 386) may hinder the realization of these gains. This implies that the apparently high transaction costs are, to a substantial degree, an artifact of the way policy has been set and not exclusively inherent to water trade. For regions, such as the southeastern United States, that are considering the potential for water markets to reallocate scarce water supplies, this paper suggests that they need to look carefully at their property rights assignments if they want to realize the potential gains from trade.

More specifically, the findings point to four policy recommendations to promote trade. First, for regions that are just beginning to fully allocate watercourses, define water rights in terms of consumptive use as opposed to divertible acre-feet. For regions whose watercourses are

[17] Column 1 of Table 3 shows that for the average county a one standard deviation increase from the mean in the precipitation rate will decrease the probability the county will have a market for exports by a trivial amount (.38 percent), when lagged population growth rate is evaluated at its mean of 1.36 percent. In addition, column 4 of Table 3 shows that for all exporting counties, a similar increase in the precipitation rate will decrease the ratio of exports to appropriations by a trivial amount (.09 percent), when lagged population growth is evaluated at its mean.

[18] Column 1 of Table 3 shows that for the average county a one standard deviation increase from the mean in the lagged population growth rate will increase the probability that the county will have a market for exports by 2.23 percent, when precipitation is evaluated at its mean of 28.48 inches. In addition, column 4 of Table 3 shows that for all exporting counties, a similar increase in the lagged population growth rate will increase the ratio of exports to appropriations by a trivial amount (.55 percent), when precipitation is evaluated at its mean.

already fully appropriated, limit transfers to historic consumptive use rather than divertible acre-feet. This will lower the probability of a given water transfer reducing the return flows available for other users and thus, decrease the transaction costs to trade by avoiding many protests under the No-Injury Rule. Second, in regions with laws that grant third-parties rights, policy makers should clearly define the type of harm that can be successfully claimed under these laws. For example, a law could specify that claims of harm must demonstrate a substantial and immediate expected decrease in their future income stream in percentage terms. Third, states should have water transfer processes that facilitate negotiations among claimants and the free flow of credible information regarding expected losses to other water rights users and third-parties. Lastly, where protests cannot be successfully settled out of court, state water agencies and courts need to issue prompt, predictable final rulings so that property rights are clearly defined for the future.

Implementing these recommendations to reallocate and redefine rights does not come without costs. Nevertheless, considering the non-trivial losses to a county as a result of forgone exports, such measures should be considered as an effective means to facilitate trade and reallocate scarce water resources.

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## Table 1. Summary Statistics for California Counties, 1990-2001.

| | Sample Mean | Standard Deviation | Min | Max |
|---|---|---|---|---|
| **Dependent Variables** | | | | |
| Exports (acre feet) | 11410.79 | 31403.26 | 0 | 252377 |
| -zero exports | *64.50%* | | | |
| Local Sales (acre feet) | 1916.38 | 7689.036 | 0 | 98000 |
| -zero local sales | *79.31%* | | | |
| Ratio of Exports to Acre-Feet in Prior Appropriation | 0.014 | .155 | 0 | 2.933 |
| Ratio of Local Trades to Acre-Feet in Prior Appropriation | .0004 | .002 | 0 | .024 |
| **Costs influencing the size of τ** | | | | |
| Number of Riparian Holders to Total Population | 0.01 | 0.013 | 1.38E-06 | 0.214 |
| Per Capita Number of Employees in the Farm Machinery Plus Irrigation Industry | 0.00 | 0.003 | 0 | 0.0214 |
| Percent of Agricultural Employment to Total Employment | 5.54 | 5.62 | 0 | 33.25 |
| Per Capita Value in Agriculture (in 2000 dollars) | 2485.96 | 3361.83 | 0 | 19471 |
| **Supply/Demand Proxies for Trade** | | | | |
| Lagged Population Growth Rate*Precipitation | 33.46 | 221.53 | -5509.92 | 814.94 |
| Lagged Population Growth Rate | 1.35 | 3.99 | -90.11968 | 28.8347 |
| Total Water Supply in Thousands of acre-feet | 1790.60 | 2878.66 | 35.5 | 18860.2 |
| Precipitation (in inches) | 28.48 | 21.87 | 1.95 | 274.57 |
| **Controls** | | | | |
| Canal or Aquifer (1= canal) | 0.46 | 0.498 | 0 | 1 |
| Time Trend | 6.50 | 3.45 | 1 | 12 |
| 1/Population | 19809.30 | 87928.55 | 4.67 | 724637.7 |
| Export Ordinance (1= restrictions) | 0.52 | 0.500062 | 0 | 1 |
| Employees in Gold and Silver Mining (average 1998) | 22.89 | 61.7 | 0 | 374.5 |
| **Instruments** | | | | |
| Value of Gold and Silver Production from Mining in 1880 | 322648.90 | 634197.7 | 0 | 3267971 |
| Value of Farm Products in 1900 | 2063501.00 | 1908619 | 61011 | 8029158 |
| Population in 1850 | 1624.51 | 3894.77 | 0 | 20057 |
| Population in 1860 | 5636.65 | 5729.25 | 0 | 24142 |
| Counties | 57.00 | | | |
| Years | 12.00 | | | |
| Sample Size | 684.00 | | | |

**Table 2. Ordinary Least Squares Estimates of Riparian Rights and Third-Parties on Exports and Local Trade.**

| Y: | 1<br>Regression (2)<br>exports/prior appropriations | 2<br>Regression (3)<br>local/prior appropriations |
|---|---|---|
| **Costs influencing the size of τ** | | |
| Ratio of riparian holders to total population | -.24215 | -.0050964 |
| | (.2202941) | (.0044158) |
| Per capita number of employees in the farm machinery plus irrigation industry | -.9252234 | .0465271 |
| | (1.033855) | (.0384405) |
| **Supply/Demand Proxies for Trade** | | |
| Lagged population growth rate*precipitation | 5.23e-06 | -1.23e-06 |
| | (.0000229) | (1.11e-06) |
| Lagged population growth rate | -.0000397 | .0000696 |
| | (.0012987) | (.000066) |
| Total Water Supply in thousands of acre-feet | -1.94e-06 | 1.57e-08 |
| | (2.48e-06) | (2.57e-08) |
| Precipitation in inches | -.0001039 | -1.89e-06 |
| | (.0000977) | (3.57e-06) |
| **Controls** | | |
| Canal or Aquifer | .0277954 | **.0006361**** |
| (binary variable) | (.0232877) | (.0002014) |
| Time trend | .0037953 | .0000153 |
| | (.0033733) | (.000023) |
| 1/population | -1.81e-08 | -9.39e-11 |
| | (2.40e-08) | (4.42e-10) |
| $R^2$ | .0174 | .0548 |

N = 684; T = 12; i= 57

Notes: Clustered robust standard errors are in parentheses and are adjusted by county name. All models are estimated with a constant. Columns report the estimated effects of the explanatory variables on the probability of exports (i.e., Regression (2)) and local trades (i.e., Regression (3)). San Francisco was dropped. For binary variables the coefficient is the effect from a discrete change from 0 to 1. Estimates are significant at the 5 percent (*p < .05), 1 percent (** p < .01), or .1 percent (*** p < .001) level.

**Table 3. IVTOBIT Estimates of the Marginal Effects of Riparian Rights and Third-Parties on Exports.**

| | **Y: Pr(ratio of exports to p.a. > 0)** | | | **Y: E(exports to p.a.\|exports to p.a. > 0)** | | | |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **Mean of X** |
| **Costs influencing the size of τ** | | | | | | | |
| Ratio of riparian holders to total population | **-24.09542**** | **-25.26959**** | **-25.2422**** | **-5.881654***** | **-6.343829***** | **-6.196608***** | 0.004946 |
| | (8.51997) | (8.94433) | (8.25174) | (1.56357) | (1.52214) | (1.63855) | |
| Per capita number of employees in the farm machinery plus irrigation industry | 1.477851 | | | .360741 | | | 0.002607 |
| | (3.6818) | | | (.8751) | | | |
| Percent of agricultural employment to total employment | | .0028669 | | | .0007197 | | 5.54441 |
| | | (.0026) | | | (.00051) | | |
| Per Capita Value in Agriculture | | | 5.44e-06 | | | 1.34e-06 | 2485.963 |
| | | | (.00001) | | | (.00) | |
| **Supply/Demand Proxies for Trade** | | | | | | | |
| Lagged population growth rate*precipitation | .0005594 | .0005326 | .0006153 | .0001366 | .0001337 | .000151 | 33.4625 |
| | (.00033) | (.00033) | (.00034) | (.0009) | (.00009) | (.00009) | |
| Lagged population growth rate | -.0103445 | -.0105883 | -.0132158 | -.0025251 | -.002067 | -.0032443 | 1.35913 |
| | (.0095) | (.00979) | (.0107) | (.00247) | (.0026) | (.00273) | |
| Total Water Supply in thousands of acre-feet | -5.13e-06 | -4.98e-06 | -6.03e-06 | -1.25e-06 | -1.25e-06 | -1.48e-06 | 1790.6 |
| | (.00001) | (.00) | (.00001) | (.00) | (.00) | (.00) | |
| Precipitation in inches | -.0009361 | -.0008233 | -.000864 | -.0002285 | -.0002067 | -.0002121 | 28.475 |
| | (.00075) | (.00075) | (.0008) | (.00019) | (.00019) | (.00021) | |
| **Controls** | | | | | | | |
| Canal or Aquifer (binary variable) | **.2113694***** | **.1890757***** | **.1924546***** | **.0501182***** | **.0461381**** | **.046165**** | 0.45614 |
| | (.04782) | (.04865) | (.05138) | (.01399) | (.0151) | (.01623) | |
| Time trend | **.0089387***** | **.0086215***** | **.0039904***** | **.0021819** | **.0021644*** | **.0022905*** | 6.5 |
| | (.00222) | (.00216) | (.00228) | (.00097) | (.00099) | (.00101) | |
| 1/population | -2.88e-07 | -2.32e-07 | -2.64e-07 | -7.03e-08 | -5.82e-08 | -6.48e-08 | 19809.3 |
| | (.00) | (.00) | (.00) | (.00) | (.00) | (.00) | |
| Pseudo $R^2$ | .00402687 | .00336916 | .00355045 | .00402687 | .00336916 | .00355045 | |

N = 684; T = 12; i= 57 Notes: Columns 1-3 report the marginal effects of the explanatory variables, measured at their means, on the probability of exports (i.e., Regression (2)). Columns 4-6 report the marginal effects of the explanatory variables, measured at their means, on the ratio of exports to appropriations for all exporting counties. Clustered robust standard errors are in parentheses and are adjusted by county name. All models are estimated with a constant. San Francisco was dropped. For binary variables the coefficient is the effect from a discrete change from 0 to 1. I control for the endogeneity of riparian doctrine using four instrumental variables: population by county in 1850, population by county in 1860, the value of farm products by county in 1900, and the value of gold and silver production from mining by county in 1880. An F-test for the joint significance of lagged population growth rate, precipitation, and the interaction term rejected the null hypothesis that the variables were jointly insignificant with a p-value from the χ2 distribution of .000. Estimates are significant at the 5 percent (*p < .05), 1 percent (** p < .01), or .1 percent (*** p < .001) level.

**Table 4. IVTOBIT Estimates of the Marginal Effects of Riparian Rights and Third-Parties on Local Trades.**

| | **Y: Pr(ratio of local to p.a. > 0)** | | | **Y: E(local to p.a.\|local to p.a. > 0)** | | | |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **Mean of X** |
| **Costs influencing the size of τ** | | | | | | | |
| Ratio of riparian holders to total population | -4.530394 | -6.761188 | -4.939874 | -.0243124 | -.0370959 | -0.0248866 | 0.004946 |
| | (7.02061) | (5.781) | (5.69671) | (.03798) | (.02466) | (0.02627) | |
| Per capita number of employees in the farm machinery plus irrigation industry | 7.654723 | | | .0410791 | | | 0.002607 |
| | (7.09762) | | | (.03616) | | | |
| Percent of agricultural employment to total employment | | **.0058976*** | | | **.0000324***** | | 5.54441 |
| | | (.00293) | | | (.00001) | | |
| Per Capita Value in Agriculture | | | 0.00000746 | | | 3.76E-08 | 2485.963 |
| | | | (.00001) | | | (.00) | |
| **Supply/Demand Proxies for Trade** | | | | | | | |
| Lagged population growth rate*precipitation | -.0001521 | -.0001694 | -0.0001423 | -8.16e-07 | -9.30e-07 | -0.000000717 | 33.4625 |
| | (.00039) | (.0002) | (.00025) | (.00) | (.00) | (.00) | |
| Lagged population growth rate | .0124401 | .0086238 | 0.0081627 | .0000668 | .0000473 | 0.0000411 | 1.35913 |
| | (.01707) | (.01162) | (.01325) | (.00009) | (.00006) | (0.00006) | |
| Total Water Supply in thousands of acre-feet | .0000119 | 7.28e-06 | 0.00000746 | 6.36e-08 | 3.99e-08 | 3.76E-08 | 1790.6 |
| | (.00001) | (.00) | (.00001) | (.00) | (.00) | (.00) | |
| Precipitation in inches | -.0016603* | -.0007119 | -0.0008811 | **-8.91e-06*** | -3.91e-06 | -0.00000444 | 28.475 |
| | (.0008) | (.00041) | (.0005) | (.00) | (.00) | (.00) | |
| **Controls** | | | | | | | |
| Canal or Aquifer | **.3015342***** | **.2306889***** | **0.2594317***** | **.0015562***** | **.0011088***** | **0.0011738***** | 0.45614 |
| (binary variable) | (.06345) | (.05428) | (.06321) | (.00028) | (.0002) | (.00023) | |
| Time trend | .0018634 | .0011921 | 0.0020578 | .00001 | 6.54e-06 | 0.0000104 | 6.5 |
| | (.00299) | (.00248) | (.003) | (.00001) | (.00001) | (.00001) | |
| 1/population | **2.25e-07*** | **2.12e-07*** | **0.0000002*** | 1.21e-09 | 1.16e-09 | 1.01E-09 | 19809.3 |
| | (.00) | (.00) | (.00) | (.00) | (.00) | (.00) | |
| Pseudo $R^2$ | .04640601 | .04966662 | .05528319 | .04640601 | .04966662 | .05528319 | |

N = 684; T = 12; i= 57 Notes: Columns 1-3 report the marginal effects of the explanatory variables, measured at their means, on the probability of local trades (i.e., Regression (3)). Columns 4-6 report the marginal effects of the explanatory variables, measured at their means, on the ratio of local trades to appropriations for all trading counties. Clustered robust standard errors are in parentheses and are adjusted by county name. All models are estimated with a constant. San Francisco was dropped. For binary variables the coefficient is the effect from a discrete change from 0 to 1. I control for the endogeneity of riparian doctrine using four instrumental variables: population by county in 1850, population by county in 1860, the value of farm products by county in 1900, and the value of gold and silver production from mining by county in 1880. An F-test for the joint significance of lagged population growth rate, precipitation, and the interaction term rejected the null hypothesis that the variables were jointly insignificant with a p-value from the $\chi 2$ distribution of .000. Estimates are significant at the 5 percent (*p < .05), 1 percent (** p < .01), or .1 percent (*** p < .001) level.