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ABSTRACT
Surface water irrigators in arid regions confront public good issues for building and maintaining shared infrastructure as well as common-pool resource issues to appropriate the surface water. Drawing on the unique history of New Mexico, I explore how the transition in the early 20 th century from the original small decentralized communal Spanish irrigation systems (acequias) to centralized quasi-public irrigation districts altered agricultural development and production. My results confirm that that irrigation districts can significantly improve outcomes when investing in costly infrastructure to expand irrigated acreage, increasing farmland values up to 33 percent. However, I find no broader evidence that the centralized control of water distribution provides any gains to acreage previously under irrigation by the decentralized acequias.

JEL **classifications: N52, O13, Q15, Q25**
Keywords: common-pool resources; transaction costs; externalities; governance structure

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INTRODUCTION

Irrigation water is of great value for farmers cultivating land in the arid regions. Due to the elusive flow of water and disparities between the optimal sizes for farms and irrigation enterprises (Bretsen and Hill 2006), the endeavor requires coordination among irrigators to avoid the pitfalls of misaligned incentives that can lead to a "tragedy of the commons" (Hardin 1968). In particular, the need for shared infrastructure, whether physical or institutional, creates a public good problem prone to free-riding while water's fugitive nature makes it costly to define property rights to provide exclusion, leading to issues of over-appropriation. Plenty of evidence exists that communities, most often small and homogenous, can cooperate and develop a mix of trust and rules that staves off the tragedy of commons (Ostrom 1990). But even where irrigators are similar along all other dimensions, biophysical differences, including spatial distribution on a stream or canal, creates heterogeneity. Upstream irrigators, for example, can more readily appropriate additional water and shirk canal investment and maintenance. This relationship can also impede voluntary cooperation to achieve efficient and equitable allocation of the water as has been found in Kenya and India (McCord et al. 2017; Ray and Williams 2002).

Centralized government control can avoid numerous bargains and even more numerous opportunities to shirk any resulting agreements, but centralized decision-making is not without its own problems (Coase 1960; Hayek 1945). Many government-ran systems in developing countries perform poorly (Suhardiman and Giordano 2014; Adams 1990; Ostrom and Gardner 1993). For example, larger government systems often impose simple and inflexible rules, resulting in inefficient and inequitable benefits accruing to the irrigators (Ferguson 1992). In other instances the governments presence may erode the irrigators' willingness to collectively engage in other needed maintenance efforts (Lam 1996). Still, current efforts to move from centralized organization to decentralized natural resource management offers only mixed success (Andersson, Gibson, and Lehoucq 2006; Larson and Soto 2008; Nagrah, Chaudhry, and Giordano 2016; Meinzen-Dick, Raju, and Gulati 2002) and it remains important to study past examples of drastic shifts in resource governance structure to better understand how the resource and the local users may be impacted by the nexus and mode of decision making.

Because of its aridity, development of the American West, delineated by the 100th meridian, dealt with similar irrigation challenges. Throughout the 19th and 20th century a number of farmers and policymakers attempted to overcome these obstacles and develop irrigation through various laws and organization forms with mixed success.[1] R. H. Whitbeck, (1919) echoes this sentiment stating Western irrigation was neither a success nor failure, highlighting the 55,000 some non-federal projects – communal ditches, incorporated and unincorporated mutual companies, and commercial companies – as successful but the US Bureau of Reclamation projects struggling at the time. However, with greater hindsight it appears that Irrigation Districts (henceforth "IDs"), often in tandem with the Bureau of Reclamation, created significant irrigation growth compared to other irrigation organizations in the latter portion of the 20th century (Bretsen and Hill 2006).[2] Their attractiveness and success of these quasi-public government entities has been attributed to their institutional innovation to overcome free riding and accumulate external capital—reducing a number of transaction costs (Bretsen and Hill 2006; Hutchins 1931; Leshy 1982; Libecap 2011). While the 17 Western states expanded irrigated acreage by an average of 1 percent annually from 1910 to 1978, ID acreage in particular grew by 4 percent annually—adding some 10,000,000 irrigated acres.

In this article, I assess the impact IDs have on agricultural development and production in New Mexico. The choice of New Mexico lies in its unique history among the Western States. Long before Anglo-Americans sought to irrigate the West, Spanish settlers colonized this region. No less dependent on irrigation than later settlers, they established irrigation beginning around 1600, some 240 years prior to the Mormons irrigating the soils of Utah. The Spaniards success stemmed from their transplantation of their communal *acequia* systems developed in the arid regions of Spain and many remain today serving as counter-examples to the oft-prescribed tragedy of the commons (Cox 2014; Smith 2016). However, successful avoidance of the "tragedy" is not indicative of efficiency or optimality. In fact the US found the systems lackluster, stating of New Mexican farmers in 1890, "The average small farmer, especially of Spanish […] descent, has shown little energy or skill, and as a consequence the returns have been small" (US Census Office, 1894, p. 193). Following an overhaul of irrigation legislation in the

[1] A fundamental shift in water law during the 19th century was the rejection of the Riparian Doctrine and the adoption of the Prior Appropriation Doctrine in the 17 Western States. The former defines correlative water rights to landowners abutting a body of water and is used in the more humid east. The latter provides absolute rights independent of land location based on first-come-first-serve. Designed to and able to safeguard investment (Leonard and Libecap 2016), the doctrine introduces some economic inefficiencies in the division of water (Burness and Quirk 1979; Smith 2014). With deeper Spanish roots, New Mexico itself was (and is) slow to adopt and implement this law. The focus of this paper, however, is on organizational form and not the use of prior appropriation.

[2] Though popular, they were not universally successful; from 1890-1928, the number of districts formed in the US grew from just 17 to 801, though by 1928 nearly 300 were inactive (Hutchins 1931).

early 20th century, IDs formed within New Mexico, compelling a number of *acequias* to join the larger entities. Many of the 1400 historic *acequias* have been subsumed by one of the 14 IDs throughout the state, though over 700 *acequias* remain. This historic analysis provides a new perspective to the current irrigation development debate by considering a process of centralization rather than decentralization.

Not only do IDs possess governmental authority to tax, they often centralize decision power as well. Often quite large, IDs are able to internalize externalities in water appropriation along a stream as they often control multiple diversion points and provide many irrigators with water. Because many IDs own the appropriative water rights (Hutchins, Selby, and Voelker 1953), the centralized formal governance structure avoids countless bilateral and multilateral contracts between ditches and can reallocate irrigation water though administrative decisions, reducing the transaction costs associated with market-type transactions (Carey and Sunding 2001). Alternatively, IDs can forego administrative reallocation and instead facilitate an internal market for water users with fewer institutional barriers than formal state statutory transfers (Carey and Sunding 2001; Bretsen and Hill 2006) sometimes with great success; see for example the vibrant water market in the Northern Colorado Conservancy District (Howe and Goemans 2003).

I use New Mexico's partial transition to address three related questions. First, because the choice is not random, who is more likely to adopt an ID? Second, and most directly, how did the transition to IDs impact the agricultural economy of New Mexico? Because the motivation to adopt IDs (at least from legislative records) was economic growth, it is important to understand if IDs delivered. And third, taking advantage of the pre-existing irrigation, I assess whether IDs improve on the intensive margin rather than just the extensive margin. Often the success of IDs is attributable to their expansion of irrigated acres and improvement of infrastructure—the public good issues. This last question assesses whether a change in organization, from many decentralized systems to a larger centralized system, improves upon the common-pool resource issue of efficient division of the resource for those already irrigating.

The first question, concerning who in New Mexico is more likely to adopt an ID, is assessed from a theoretical standpoint, considering the organization differences and those facing the largest transaction costs. Both social and biophysical factors matter. The theory is then tested using 1910 US Agricultural and Irrigation Census data at the county level and provides important background information. To address the second two questions, counties that make the transition (n=13) are compared to counties where smaller communal systems persist (n=13) in a Difference-in-Difference framework using US census data spanning from 1900 to 1978. The primary analysis is grounded in the Hedonic pricing methodology, relying on the assumption that agriculture land prices will capitalize the net value provided by the ID, though other outcomes are considered as well. My findings suggest the irrigators found IDs were valuable on average, driving farmland values up 12-33%. The gains come primarily through improved crop yields due to additional land being brought under irrigation. These gains, however, are nearly all attributable to the Elephant Butte Irrigation District in Dona Ana County, where extensive federal investment nearly quadrupled the land under irrigation from 1900-1945. In contrast, when limiting the analysis to counties where IDs largely subsumed existing *acequias,* other than increased irrigation costs, the transition produces no detectable economic changes. On net the evidence suggests IDs provided economic growth to New Mexico to the extent that they were utilized to overcome the public goods issue and finance large infrastructure improvements and irrigation expansion, but little was gained where IDs did not expand irrigation and simply centralized control over the previously decentralized *acequias*.

NEW MEXICO IRRIGATION

New Mexico's Development

Spanish colonization of *La Provincia del Nuevo México* began in 1598 with a settlement effort led by conquistador Capitán General Juan de Oñate. Following a brief native uprising, the Spanish colonization resumed in full force from 1695 until 1821, at which point Mexico gained its independence from Spain. The settlements were guided by the Laws of the Indies issued by the Spanish crown, stating access to water as essential for the formation of a community. Once officials inspected the land, confirming its promise to provide for the settlement, a land grant would be conferred and the settlers would begin work. The irrigation canals were essential to the survival of these early pioneers traveling miles into the arid climate and were typically the first undertaking, even prior to building the local church or government buildings (J. a Rivera and Glick 2002). Growth and development of irrigation continued through the Mexican period (1821-1848). Sovereignty of the region transferred to the United States of America with the

Treaty of Guadalupe Hidalgo, ending the Mexican-American War in 1848.[3] Initial legislation in the territory focused on water law and codified many *acequia* customs into statute allowing the organization to continue to thrive and grow through the 19th century. But as more Anglos migrated to the region, they began to alter irrigation legislation to favor new institutions and organizations, often at the *acequia's* expense (Smith 2014).

Acequias are similar in purpose and size to mutual ditch companies found in other states, but maintain a distinct heritage and mode of operation. In New Mexico, they also persist within a distinct legal space as political subdivisions of the state rather than a corporation. The communal irrigation system typically relies on diverting streams via simple earthen head gates and utilizing flood irrigation prior to letting the excess water return to the stream for other downstream users. The communal ditches tend to serve relatively small group of neighbors who joined together to dig and maintain the ditch. A *mayordomo*, elected by members, oversees the operation and irrigation schedule, often delivered on rotation. Those that remain operate in a similar fashion still today.

At the turn of the 20th century New Mexico was working to "modernize" its water laws, most markedly with the 1905 and 1907 water code with an eye towards large-scale irrigation projects with federal assistance. The water code adopted the prior appropriation doctrine, in which water rights are private, severable from the appurtenant land, measured by volume and based on seniority—conceptually orthogonal to Spanish practice of communal water in which water is divided by time on a basis of need.[4] Additionally, the water code established the Office of the State Engineer, charged to adjudicate and administer the newly created water rights. The desire to transform the water laws was based on a perceived impact on economic growth. Governor Miguel Otero requested the legislation in 1905, stating:

> ***"[…] the future growth and continued prosperity of our people as a whole, must depend to a great degree upon the extent and success in the development of our agricultural***

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[3] US military occupation began as early as 1846, but the Kearny Code of that year claiming the area was legally dubious.

[4] For instance, (Wilkinson 1992) quotes Lucy Moore saying, "Prior appropriation is a newfangled idea forced on a system that already worked. It does not fit into New Mexico's web of land-based peoples—mostly Hispanics and Indians. The current process of stream adjudications has broken down the social fabric that has existed for generations. The old system's spirit of cooperation has been replaced by competition. Old friend are now enemies." (p. 273). In practice some regions have avoided the priority system and *acequias* along a stream may or may not have formal water-sharing agreements that divides the stream water proportionally among the ditches. For instance, in Taos Valley, New Mexico 24 of 51 acequias have longstanding agreements, known as *repartimiento.*

resources. In this region, where the natural rainfall is insufficient to assure a full crop from year to year, it becomes necessary to resort to irrigation."

(New Mexico State Records Center and Archives (NMSRA), 1971, Roll 6)

New Mexico then enacted its first ID law in 1909, modeled after the California Wright Act of 1887, followed by two more in 1919 to offer more structure to those wishing to contract with the Federal Government.[5] This was followed in 1923 with legislation to form conservancy districts. Though conservancy districts provide broader services than IDs, I treat them together here for their similar function for irrigation and because they are often treated under the same legal umbrella (Getches 2009). Wells Hutchins, (1931) defines IDs as a "public or quasi-municipal corporation organized […] for the purpose of providing a water supply for the irrigation of lands embraced within its boundaries" (p. 2). They have well defined geographic boundaries and are formed under authority of State legislature with the consent of a designated fraction of the landowners. With the ability to place assessments on the land, once formed it is possible to extract funds in order to invest in large infrastructure, providing a mechanism by which farmers can engage in larger irrigation projects by compelling dissenting minorities to pay (Hutchins 1931; Leshy 1982).[6] Furthermore, they have the ability to issue (tax-exempt) bonds, providing a mechanism to take on debt for such projects. Ultimately these legal powers led the Bureau of Reclamation to prefer contracting directly and exclusively with IDs.[7] Indeed, while early districts were formed to secure internal financing through assessments, later districts often formed to secure external financing through bonds (Leshy 1982). Overall, they served to reduce many transaction costs confronted by irrigation projects (Bretsen and Hill 2006; Libecap 2011; Carey and Sunding 2001).

Irrigators in New Mexico adopted IDs quickly. Table 1 presents the 14 IDs in New Mexico, their dates of formation, and acres included.[8] From 1910 to 1950, acreage irrigated by IDs grew

[5] The ability to form irrigation districts and their exact form vary by state, but generally follow the California Wright Act. By 1917 all 17 Western States permitted the formation of IDs (Hutchins 1931).

[6] The right to do so was held up in 1896 when the US Supreme Court confirmed its legality, arguing the development of the private land being of public interest: Fallbrook Irrigation Dist. v. Bradley, 164 US 112 - Supreme Court 1896

[7] In 1922 the federal government strengthened the power of IDs by allowing them to be the local contracting party for Bureau of Reclamation Projects. In 1926, they became the only legal contracting party. Now a Reclamation Project often required the formation of a district while in other instances the district already existed and could contract for water from government projects under the Warren Act.

[8] Evidence of 5 other districts have been found but are not included in the analysis. Pecos Valley Artesian Conservancy District addresses groundwater use, not surface water. There also exists a Pecos Valley Surface Water

at an average rate of 6.8 percent per year, accumulating 190,518 acres by 1950.[9] The expanded ID irrigated acreage is partially due to service of additional land. However, in New Mexico the adoption of IDs often marked a change in organization for many of the existing *acequia* irrigators rather than new irrigation. Of the six IDs operating in New Mexico in 1929, all had taken over irrigation systems already in place and only one of which formed for principally new development (Hutchins 1931). Figure 1 provides an illustration of both impacts. Following the initial expansion of total acreage from 1910 to 1920 – largely due to the Elephant Butte ID (EBID) – the total acreage remains stagnant through 1950 and the growth in ID acreage compensates for the loss of cooperative ditch acreage. Table 2 presents evidence that the ID gains and cooperative losses are related phenomena. Using New Mexico 1987 county level data, the results presented are from regressing the percent of historic *acequias* no longer in existence on a dummy variable indicating the eventual presence of an ID. [10] While 35 percent have vanished on average, counties now with an ID lost an additional 26 percent of their historic *acequias*. Though some *acequias* may have failed, these results suggest that often the physical diversion and irrigated acreage still exist but the management has shifted from cooperative enterprises to centralized IDs.

Furthermore, 50 irrigation enterprises noted on their 1930 Irrigation Census Schedules that they would soon become a part of the newly formed Middle Rio Grande Conservancy District (MRGCD).[11] In his 1936 report of human dependence on the entire Rio Grande Watershed, Hugh G. Calkins specifically states of the MRGCD: "The program was carried on, not to attract new settlers, but to rehabilitate land already fully owned but partially or ineffectively productive" (pg. 57). While the MRGCD did construct new canals, about half of the canals under its control – or 214 miles worth – were simply subsumed from the pre-existing *acequias* and management

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District, but this is an administrative designation by the State Engineer, not an ID formed by the users. The Hondo Project was an early failure of the Bureau of Reclamation, serving only 1,300 acres in 1910 and shuttered by 1915. Sunshine Valley Conservancy District was short lived and never irrigated any acreage. The unknown district in McKinley is likely due to a self-reporting error in the 1950 Irrigation Census and not truly an irrigation district. See Tables A2 and A3 in the Appendix for full details on sources of data. Hillsdale Irrigation District is itself included in the La Plata Conservancy District.

[9] ID acres are combined with Bureau of Reclamation acreage, as the latter are usually turned over for management by the IDs they contracted with (Wozniak 1997).

[10] Historical acequias in each county is tabulated from Dos Rios Inc. (1996) while 1987 totals were tabulated from Saavedra (1987) – a report by the New Mexico Office of the State Engineer. The regression is simply: $(Historic\ Acequias_i - 1987\ Acequias_i)/(Historic\ Acequias_i) = \alpha + \beta \cdot District_i + \varepsilon_i$

[11] These records are held at the National Archives in record group 29.8.3: "Miscellaneous nonpopulation schedules and supplementary records Textual Records: 1930; drainage and irrigation." My gratitude to Paul Rhode for bringing their existence to my attention.

centralized to district officials in Albuquerque (J. A. Rivera, 1998, p. 215). In total, the evidence supports that, in New Mexico, IDs often marked a change towards a centralized public governance structure by supplanting and combining the previously independent communal ditches rather than developing new systems.

Additional qualitative evidence suggests the change was not always welcome.[12] Charles Wilkinson, (1992) reports, "[T]he MRGCD was formed by a small group of businessmen who wanted to improve the local economy and enhance the value of their investments," while, "Hispanics tried to fight the MRGCD by filing court protests against the district's formation and by physically resisting construction" (p. 272). In the end, the small number of organizers succeeded in compelling the many objectors to join the MRGCD. Drawing on the five northern counties and their experience with formed and defeated districts, Jose Rivera (1998) recounts the concerns small *acequia* farmers had. In fending off a district in Taos County, Rivera captures the irrigators' concerns by quoting the Tres Rios Association's Conservancy District Position Paper:

> ***"'If a conservancy is formed in Taos, the board will have the power to plan and regulate all water development and conservation activities throughout the district; foreclose on land and dispose of it for non-payment of conservancy taxes; alter water allocations and distribution in times of shortage without regard to legal water rights or priorities'"***
>
> *(Rivera 1998, p. 157)*

Rivera goes on to summarize that irrigators fear that "not only would acequia self-government be circumvented by a superimposed board from the conservancy district, but the economic risks could bankrupt the irrigators individually, as had happened after the construction of Elephant Butte Dam in southern New Mexico" (p. 157).[13] Similarly, Calkins (1936) suggests efforts by Spanish-American landowners to block the organization of the MRGCD a half-century earlier were no less concerned with the "dangers inherent in the imposition of cash costs and liens on their hitherto unencumbered land" (pg. 39). Whereas these concerns were unable to prevent the MRGCD, they resonated sufficiently in Taos County years later to defeat the

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[12] With much effort, and frustration, I have been unable to locate voting records that could quantify the percentage of eligible voters for or against any particular district formation other than for the Santa Cruz ID. Requiring four-fifths of each ditch, the total tally was 417 for, 75 against (Calkins, 1937, p. 3).

[13] Calkins (1936) provides some contemporaneous evidence that this did occur within the EBID: "Bankruptcy and loss of farms became the first time during those years not only a possibility but a constant threat for many farmers. While specific quantitative data are not available, there exists evidence that many of the original Spanish-American farmers, in the process of commercialization, were removed from their land through foreclosure." (pg. 102)

formation of the Rancho del Rio Grande Conservancy District and *acequias* maintained local control of water decisions.

Distinctions between Irrigation Enterprises

The old *acequias* and newer IDs are organized substantially different from one another, though both ultimately aim to deliver water to irrigators. The differences stem from the statutory distinctions of their legal authority. To quantify the differences between the organizations, I present data from the 1950 Irrigation Census (US Bureau of the Census, 1952, p. 12-5, State Table 3) selected for its extensive presentation of data by organization.[14] As an organizational tool, I provide parenthetical references to variables corresponding to the Elinor Ostrom's (2009)SES framework. Table 3 summarizes the designed differences based on the institutional structure and also presents what may be seen as outcomes, though, the static nature of the data precludes any causal inferences.

Infrastructure

Acequias do not have the power of inclusion, they cannot tax, and they cannot issue debt, making it difficult to finance large cash expenditures. Instead, *acequias* rely on savings and individual contributions, often in the form of sweat equity rather than cash. This is the most marked financial advantage the IDs have over *acequias* (GS7) (Hutchins 1931; Leshy 1982). The ability to raise capital both internally and externally results in advantageous infrastructure financing. With the ability to tax all users in a large area, they tended to undergo projects that altered the resource system beyond the capability of smaller local organizations (Wozniak 1997). Often, canals were expanded, head gates upgraded to concrete structures, and dams constructed for both flood control and storage (RS4 and RS8), providing more predictability of the system (RS7). With larger storage capacity, the irrigated land within IDs had access to more stored reserves. Diversion structures were more likely to be constructed out of concrete. These

[14] 1950 was chosen largely on data limitations, as spelled out here, but it sufficiently captures the distinctions between the types of irrigation organizations. While the 1959 Irrigation Census reports similar figures, a large portion of the relevant ID data in New Mexico are withheld in tandem with the "commercial" category to protect the privacy of the latter organizations. The 1969 and 1978 Irrigation Census inexplicably reports 23 and 28 districts in New Mexico respectively. No other records, including New Mexico's own surveys of surface water organizations in 1987 and 1969 report support this number. Likely caused by incorrect self-classification by the organizations, the figures in these censuses appear somewhat unreliable. I have also collected the New Mexico population of irrigation districts in 1930, but only a partial and non-random sample of non-district irrigation enterprises, precluding a fair comparison.

improvements were not without their own issues, as the districts often struggled to maintain the expanded infrastructure, raising fees often (Wozniak 1997).

Management

Often trying to garner economies of scale, IDs tend to be much larger than *acequia* systems (RS3). This drastically increases the number of users (U1), often being magnitudes larger. Arguably, the larger boundaries resulted in clearer system boundaries by including a number of diversion points on a single stream previously operating independently. The scale of the operation is telling, as the communal ditches average 14 users while the IDs average 420. This is unsurprisingly related to the difference in coverage, with IDs serving 19,052 acres on average while communal ditches cover only 278. Taken literally, this means a single ID is controlling water for what would otherwise be managed by 68 individual communal ditches. The democratic process also differs, as IDs vote similar to a corporation where power is more likely to be proportional to land holdings. *Acequia* members customarily vote only once per person (GS6). The decision process is more centralized with the member-to-board member ratio much larger among the IDs.

Water Delivery

Whether due to natural supply advantages, infrastructure improvements, or more efficient delivery systems, IDs delivered nearly twice as much water per acre than communal *acequias* as of 1950 (RS5). Division of that water differs as well (GS5). For *acequia* farmers, delivery is almost always done on a rotational basis in which they receive the full flow for a given amount of time. Amongst *acequias* on the same river, either priority or some sharing agreement divides inter-*acequia* water use. The latter – sharing agreements – are more common because the water rights pre-date US sovereignty meaning: 1) it is difficult to establish accurate historical diversion dates and 2) the Treaty of Guadalupe Hidalgo committed to respect existing property rights. Accordingly, many of the independent *acequias* throughout New Mexico have agreed to forego the Anglo priority system during adjudication processes (Richards 2008). This yields a decentralized administration and self-monitoring of water division. In contrast, water division in IDs is administratively determined. In practice, irrigators often place an order for water and then it is delivered as soon as hydrologically possible, often simultaneously with other farmers. Whereas *acequias* are often defined by single diversion point, IDs oversee multiple diversion points, providing internal management and monitoring across them. Any flouting of the division rules across diversion points are more readily enforced within IDs than across *acequias* as IDs have the authority to levy fines, which if unpaid, can result in a lien on the associated land (GS8).

ADOPTING IRRIGATION DISTRICTS

The main analysis draws on the facts that 14 IDs identified in Table 1 are only present in 13 of the 26 counties, formed at different times, and are of various sizes. Figure 2 illustrates all three components with two maps. In 1920 only six counties had formed IDs, but by 1940 the thirteen counties all had adopted at least one ID. Measured as a percent of total farmland, the map also shows that the counties adopting IDs did so to a varying extent. The adoption of IDs, however, does not appear random – at least spatially – partially due to IDs extending beyond county borders. Before considering what factors influence the adoption of IDs, it is worth noting other information in Figure 2 first. Primarily, counties that never form IDs are able to, and often do, irrigate. Surface water can be found in all counties and was developed to some extent by 1910. This can be seen in the 1920 map by the percentage of farmland irrigated and, more importantly, by the varying number of *acequias* that once existed in both ID and non-ID counties alike shown in the 1940 map.

Because ID adoption is not random, it is important to consider where and by who they are more likely to be adopted. Ultimately the decision to form an ID falls to eligible voters within the proposed borders usually requiring a majority to approve the ID, though this can vary and the votes may be counted on an acreage basis. In theory, the decision should driven by the expected net gains of internalizing decisions compared to the current transaction costs of decentralized management (Coase 1937; Libecap 1993). Those subject to larger externalities and/or facing greater transaction costs to cooperatively address the externalities should favor reorganizing as an ID. For instance, the potential gains may be driven by the existing extent of irrigation, though not in an unambiguous way. On the one hand, if the shared infrastructure is the primary issue, than areas with less development – emblematic of their inability to overcome the public goods issue – should favor the adoption of an ID. On the other hand, where irrigation is more developed and water division is problematic, IDs might be favored to address the common-pool resource issues.

Of course centralized control is not necessary to address CPR and public good issues: As an illustration of the Coasean bargaining in action, many of the decentralized *acequias* have addressed the issues by negotiating agreements. Negotiation and cooperation are predicted to become increasingly difficult with more users in general (Olson 1965; Ostrom 1990; R. H. Coase 1960) and this is empirically true for *acequias* (Smith 2016). For provision of public goods, free riding incentives are exasperated by an increased number of beneficiaries. Therefore, one would expect counties with more farmers to have greater desire to form an ID, though this should be qualified at the county level: Irrigators are only impacted by those who share a water source. Having more creeks reduces the need to organize into a centrally managed regime, as the resource itself is geographically separated. Beyond the cooperative dynamic of physical connection, the gains of infrastructure improvements are larger where water is more centralized, meaning counties with more disperse surface water is also less attractive for the type of storage projects IDs may be well-suited to build.

To the extent that IDs were expected to successfully mediate the CPR and public good issues, areas with other favorable factors of production would stand to gain more. For instance, areas with good soil and topography suitable for crops would more likely adopt IDs. Greater non-farm populations may also increase the proclivity to favor IDs in at least two ways. First, more people would mean greater access to labor and a larger market for the farm produce. Second, because IDs are able to tax all those who benefit, which can easily be defined to include non-irrigators benefitting from flood control, irrigators may be able to subsidize their needs, especially when voting is quantified on a per-acre basis.

Empirical Support

Using time-invariant physical data and data from the 1910 Census, the above predictions are tested empirically at the county level in New Mexico.[15] Strictly speaking, no IDs were formed in New Mexico as of 1910 (recall the enabling legislation only passed in 1909), though the Bureau of Reclamation Carlsbad Project that eventually spawns the Carlsbad ID had been completed in 1907. With that caveat in mind, the 1910 data is used as a pre-treatment baseline. Utilizing a linear probability model, I test what factors alter the probability of the later forming of an ID. Given the even mix of treatment (13 non-district to 13 district counties), the use of the linear

[15] The data used is more fully described below in the data section.

model can be expected to perform well, though alternative logit results are also provided in columns (3) and (4).[16] Specifically, I estimate:

$$DistrictAdoption_c = \beta_1 \times \ln(1910value_c) + \boldsymbol{\gamma} \cdot \mathbf{1910Ag_c} + \boldsymbol{\delta} \cdot \boldsymbol{Physical_c} + \epsilon_c \qquad (1)$$

With an eye towards the main hedonic analysis below, I have included the 1910 value per acre to test specifically for any selection into treatment based on this variable. $\mathbf{1910Ag}$ is a vector of agricultural variables in 1910 including the fraction irrigated (land and farms), farms per creek, and acres per farm. $\boldsymbol{Physical}$ is a vector of physical characteristics that could influence the desire to adopt IDs. The results, presented in Table 4a, largely support the predictions. Counties with more farms per creek are more likely to form an ID. A county with more irrigated farms, as a fraction of all farms, is more likely to organize an ID. Interestingly, more irrigated acres as a fraction actually decreases the odds of forming an ID. Combined, these two results indicate that when many irrigating farmers are currently irrigating relatively few acres, they see an opportunity to expand and the ID can overcome the externalities. The fraction of farm acreage in the county increases the odds, as this increases the set of beneficiaries.

The remaining factors are not statistically significant. Importantly, the land valuation in 1910 does not serve as a good predictor. I provide additional evidence, but this supports ID formation as exogenous to the primary outcome considered below. The total population is imprecise providing no evidence of large farms capable of adopting IDs to compel non-farmers to pay. The number of historic *acequias* also provides little predictive power. The empirical result is not surprising; more *acequias* indicate more irrigation but possibly more opposition to alternative irrigation organizations. Finally, geographic position (general north/south and east/west position) offers no additional predictive power.

DATA AND METHODS

Data

To test the impact of IDs in New Mexico, I utilize agricultural outcomes gathered from the publicly available records of the US Irrigation and Agricultural Censuses from 1890-1987,

[16] The alternative logit model is qualitatively similar but limited in the number of regressors included due to the small sample and statistical methodology. It predicts 84.62% of the observations correctly as seen in Table 4b.

though the regression relies on 15 Censuses, both agriculture and irrigation censuses, from 1900-1978.[17] Initial collection of census data came from manual entry from the original county reports (US Department of Agriculture 2013; US Census Bureau 2011). Additional census data was added from the Interuniversity Consortium for Political and Social Research (Haines 2010; Gutmann 2005). Historic county shapes come from the National Historical Geographic Information System (Minnesota Population Center 2011). To measure treatment, a broad swath of resources were utilized and cross-referenced to identify IDs, their location, their date, and their geographic reach.[18] Additional data for controls, detailed below, come from a variety of sources.[19] A complete summary of data and sources are provided in the appendix, Tables A1-A3.

Method: County Level Difference-in-Differences

The main analysis tool is a hedonic valuation utilizing a Difference-in-Differences (DiD) framework at the county level to leverage the quasi-experiment. The specification is as follows:

$$Y_{ct} = \beta_1 \times PostDistrict_{ct} + \beta_2 \times District_c + Census_t + \boldsymbol{\varphi_c} + \boldsymbol{X_{ct}} + \epsilon_{ct} \qquad (2)$$

In the specification above, subscript c refers to the county and t refers to the year.

The primary outcome (Y_{ct}) considered is the logged farm value per acre.[20] The methodology follows a number hedonic value studies, relying on a related market to back out the value put on a component that does not have a market itself. With the inclusion of numerous other variables that likely affect agriculture land value, the remaining portion is attributed to the presence of the ID. The method has been applied to agriculture land for water rights (Crouter 1987; Faux and Perry 1999; Petrie and Taylor 2007), groundwater access (Hornbeck and Keskin 2014), and groundwater heterogeneity (Edwards 2016). I also consider crop value sold, irrigated acreage, irrigation costs, debt levels, and tenancy rates. The measure of debt pertains to the farms themselves, not the irrigation organization.

[17] Census years are 1900, 1910, 1920, 1925, 1930, 1935, 1940, 1945, 1950, 1954, 1959, 1964, 1969, 1974, and 1978

[18] Autobee, 1994; Clark, 1987; Elephant Butte Irrigation District, n.d.; French, 1914; Glaser, 2010; Middle Rio Grande Conservancy District, n.d.; New Mexico State Engineer, 1969; Rogers & Gahan, 2013; Saavedra, 1987; US Bureau of the Census, 1952, 1913; Drainage and Irrigation Textual Records, 1930

[19] These include Frye, 2015; PRISM Climate Group, 2004; USDA NRCS, 2006; USGS, 2003, 2014

[20] Because farm acreage itself could be endogenous, I utilize the maximum observed farm acreage across time for each county so that the denominator is constant through time. Therefore the outcomes may be viewed as per "potential" farm acre.

β_1 is the coefficient of interest, capturing the impact of the interaction term, $PostDistrict_{ct}$, indicating the county has a district formed. Rather than a discrete indicator variable, I utilize a continuous treatment measure based on the fraction of irrigated acres by the districts in the county compared to the total number of acres in farms. IDs never encompass an entire county or even the farmland, let alone all the irrigated land, causing a simple indicator variable to drastically overstate the extent of treatment at the county level. In the cases where a county has numerous IDs, the continuous measure is also able to capture the increase in treatment as the ID acreage increases over time. Acreage assigned to each ID in each county is taken from numerous sources, summarized in Table A2. Because IDs may impact farm acreage, I use the maximum observed farm acreage as the denominator.[21] On average, for counties that have IDs, 1.43 percent of farmland is treated.[22] Though some irrigators are compelled against their wishes to be part of an ID, as discussed above the overall adoption is not random. Accordingly, I interpret the estimated coefficients only as the treatment-on-treated effects.

$District_c$ is a dummy as to whether the county received an ID or will do so in a later period. $Census_t$ represents a series of dummy variables for the various census years, capturing macro shocks: crop prices, inflation, available technology, and general weather conditions. $\boldsymbol{\varphi_c}$ are county level controls and coefficients that may impact agricultural outcomes that do not vary over the sample period. These include soil quality, elevation, ruggedness, longitude and latitude, and proximity to railroads and major interstates. In addition, the presence of an aquifer within a county is included with an interaction term for observations after 1940 to account for the expanded and valuable use of groundwater in Western agriculture (Edwards and Smith 2016). Because the number of creeks is an important factor in predicting where IDs form, I also include this measure as a covariate. X_{ct} contains variables that change over time and their coefficients. This includes general population, which may impact land scarcity and provide farmers with greater access to local markets. It also includes average precipitation over the prior 10 years.

Conducting historic, county level analysis in the Western United States presents issues due to shifting borders of counties as more were added. Today New Mexico boasts 33 counties, but as of 1900 the same geographic area was divided into only 19 counties. Much of the dynamic

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[21] In robustness checks I have also scaled the variables by current farm acreage and total county acres.

[22] As a fraction of irrigated land in a county, the ID acreage is relatively more substantial with a mean of 58 percent for ID counties. With outcomes primarily reported for all farm acreage in the county, using farm acreage as the denominator remains a more appropriate measure of treatment.

process ended by 1925, but many IDs formed prior to this time.[23] The main analysis is based on the 26 counties as drawn in 1910 and shown in Figure 2. As commonly done, the census data from other years are reweighted to reflect these borders (e.g. Hansen, Libecap, & Lowe, 2009). In instances of a county being divided in two, the process is clearly valid. When two counties become three, the validity rests upon the assumption that the agricultural data is uniformly distributed geographically. A somewhat tenuous assumption given the size of counties and clumping of agriculture near streams, a series of robustness checks considers alternative county aggregations.

Difference-in-Difference Assumptions

In order for estimates of β_1 to have a causal interpretation, it is necessary to satisfy the assumption that the two sets of counties, those with and those without districts, would have shared an overall trend absent the intervention. Inherently unknowable, often this assumption is validated through showing treated and untreated observations were similar beforehand. As discussed above, in New Mexico much of the irrigable area had been developed across the State by *acequias* during Hispanic settlement. Looking at Figure 2, prior development by *acequias* appears well dispersed across ID and non-ID counties: Rio Arriba and Taos both had many *acequias* but only Rio Arriba adopted an ID; Quay and Curry counties had very few *acequias* but Quay eventually formed an ID. Therefore, in this setting, it seems reasonable that absent the intervention of IDs, both types of counties would have continued to govern irrigation through the culturally embedded *acequias.* As documented by Calkins (1936) and Rivera (1998), many of the irrigators, in number if not in acreage, desired to do so.

Additional statistical explorations of the data indicate no reason to dismiss the equal trends assumption either. First, Table 4 showed no statistical relationship between the total number of *acequias* and whether or not the county formed an ID, suggesting IDs neither favored nor shied away from pre-existing irrigation development. Perhaps more importantly, 1910 agricultural land values did not predict the eventual locations of IDs either, meaning selection was not occurring based on the main outcome of interest.[24] As further evidence that no drastic distinctions between

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[23] Los Alamos formed in 1949, but is quite small and has a miniscule agriculture sector. Cibola County formed from Valencia County in 1981.

[24] This is only verifiable at the county level. Within counties it is not clear if selection was occurring. Regressions in the Appendix (Table A4) for inclusion in the MRGCD based on 1930 census responses in the four counties suggest *acequias* were more likely subsumed if they had more irrigators, had invested more in irrigation, and were older.

ID and non-ID counties exist pre-treatment, I present sample means for outcome and control variables, as well as additional variables, from 1910 in Table 5. None of the outcome variables are statistically distinct. ID counties, however, are more likely to eventually have an interstate (primarily due to I-25's proximity to the Rio Grande) and slightly better soil quality. Though on a scale of 1-8, the magnitude of the difference (1.08) is not great. Other farm characteristics are similar as of 1910: number of farms, acreage (total and by crop), number of active and historic irrigation enterprises, and storage infrastructure. It is worth noting, however, that ID counties had developed longer irrigation systems and had more land capable of irrigation. Therefore ID counties may have had greater potential gains in an absolute sense, but in terms of relative performance, both sets of counties manage to irrigate 65 percent of their capability on average.

Last, and perhaps the best test for a shared trend, regressions are used to test for distinct trends prior to treatment. Specifically, I estimate equation (2) but in lieu of $PostDistrict$, each year fixed effect is also interacted with the $District$ indicator. An ID county is dropped from the sample once the ID is formed, leaving observations only from 1900-1930. Results are available in the Appendix, Tables A5 and A6. In short, across the six outcomes, none of the interaction terms are statistically significant other than for irrigation costs per acre and the evidence suggests that these costs were actually rising more substantially for non-ID counties. With no distinguishable difference in pre-treatment trends, save for irrigation costs, the different counties could be expected to continue to share a trend absent intervention.

RESULTS

Did IDs provide substantial economic growth in New Mexico's agricultural sector? The answer is both yes and no. In Table 6, I present the coefficients on the ID variables of interest from estimating equations (2) both without and with county level fixed effects. Qualitatively similar, fixed-effect regressions yield estimates generally smaller in magnitude. In short, IDs appear to greatly increase agricultural land value, suggesting IDs did in someway outperform irrigation via the older decentralized *acequias*. The magnitude of the coefficients are not immediately interpretable and severely overstate any observed effect at the county level as even the most extensive ID only accounted for 9 percent of farm acreage in a county. Accordingly,

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Although in this case these factors are likely correlated with being nearer to the Rio Grande and not themselves the direct driver of ID inclusion.

Table 7 scales the coefficients by the observed average treatment (1.43 percent) to provide a better sense of the observed effect. In addition, means of the outcomes are provided for reference. With no fixed effects, the IDs are estimated to increase county level farm values by 34.7 percent. The effect is more muted when considering only within county variation, but still an economically important 11.5% increase in farmland values.[25]

The gains can be linked the large gain in yields. On average, ID counties gain, when scaled appropriately in Table 7, 82.7 percent in the per farm acre market value of crops. Given the advantages to irrigated production mentioned in the 1910 census, the jump in productivity is not surprising. And to the extent water was being delivered to previously non-irrigated land, 82 percent may be reasonable. Fixed-effect regressions find only a 14.8 percent increase in market value of crops. The large difference in magnitude between the models is no doubt related to the relative increases of the fraction irrigated estimated by the two models. With no fixed effects, IDs nearly doubled the fraction of irrigated acreage, which would align well with large percentage increases in crop production. The expansion of irrigated acreage is again more muted with the inclusion of fixed effects.

The gross gains delivered by IDs, though on net positive based on the land value estimates, did not come without costs and potential downsides. Most apparently, irrigation costs, measured only through 1950, increased by 16 to 35 percent depending on the model. Recalling that irrigation had actually been cheaper in eventual ID counties and were trending even relatively cheaper pre-intervention, this about-face change is even more striking. And just as Hugh Calkins (1936) reported in regard to the EBID, my statistical analysis suggests the increased irrigation costs were associated with more farm mortgage debt and higher tenancy rates.

Though the magnitudes of all the outcomes are significantly different enough across the models to warrant consideration as to which one is more appropriate, I forego that discussion to focus on a more important point: the results, regardless of fixed effects, are driven solely by EBID in Dona Ana County, largely due to its success in expanding irrigated acreage. EBID accounts for the large uptick in irrigated acreage by IDs shown in Figure 1 from 1910 to 1920. When excluding that acreage, the growth of 136,000 ID irrigated acres from 1910 to 1959 was

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[25] Robustness checks provided in the Appendix (Tables A7) show that the results are unlikely driven by omitted variables influencing the local economies more generally as there is no statistically significant effects on manufacturing output nor residential values and rental rates. The results are also robust to alternative ways to scale ID treatment as well as alternative ways to reweight census data to account for changing county borders (Table A8).

almost completely offset by the loss of 117,000 acres irrigated by communal systems, more clearly isolating a change of governance from communal irrigation systems (shown in Figure A1 of the Appendix). Accordingly, I re-estimate equation (2) without Dona Ana and present the coefficients estimates in Table 8. The only statistically significant effect found is that irrigation costs are driven up by IDs, but with none of the other upsides in production or overall value. In general, the point estimates on the other outcomes not only become statistically indistinguishable from zero, but also are smaller in magnitude or even negative in some cases. Therefore there is little evidence that the average effect found with the complete set of counties is representative of the median effect.

DISCUSSION

By enabling the formation of IDs in 1909, New Mexico's agricultural sector benefitted. Back-of-the-envelope-calculation using the fixed-effects coefficient estimates indicates that from 1940 to 1978, IDs added $75.7 million to farmland values on average, peaking at $174 million in 1978, accounting for 5 percent of New Mexico's total farmland values in those years.[26] Similar calculations attribute $43.3 million in additional crop value per year accruing to IDs, or 6.4 percent of New Mexico's total. This share is significant, but as it turns out, they were realized disproportionately in one specific region – the EBID in Dona Ana – and swamped by the gains conjured through groundwater development after 1940. The seeming exception of EBID is explained by investment and expansion. Figure 3 shows the total investment in irrigation infrastructure and water rights by IDs in the 9 counties that had formed one by 1930. EBID in Dona Ana had invested over $6 million (1930 nominal), more than all the other IDs combined.

Most notably, the investment delivered Elephant Butte Dam a reservoir, conceived by the Bureau of Reclamation to be 175 feet deep, 40 miles long, ultimately storing 2 million acre-feet of water (Autobee 1994). The compounded water, in addition to other infrastructure, increased deliveries to existing irrigated land but also substantially increased irrigated land. In Mesilla Valley alone, irrigated acreage, reaching a low of 24,260 in 1903, nearly doubled by 1917 before nearly doubling again by 1945 to 88,714 acres (see Table A9 in the Appendix). In addition, the increase supply and security of water for irrigation (in combination with the increased costs) led

[26] This calculation was done by backing out the average percent gain calculated in Table 7 from the observed value in each ID county each year ($value_{ct} - (value_{ct}/1.115)$) and then aggregating each year over all the treated counties. 1940 was chosen because all ID counties were treated at that point in time and to provide a fairer comparison to groundwater development.

many irrigators to switch to cash crops, primarily cotton (Calkins 1936; Autobee 1994). For New Mexico and landowners in Mesilla Valley, the gains are reflected in my regressions above. However, like other Reclamation projects, some of the gains are attributable to the implicit subsidy through unpaid interest provided by the Federal Government. According to Richard Wahl (1989), EBID, as of 1978, had received a subsidy of $363 per acre, amounting to a 63 percent subsidy (p. 35, Table 2-3). Though not completely a fair comparison, farmland value per acre was only $100.71 for Dona Ana in 1978.[27]

Some additional context can be gained from the flood of groundwater development following technological breakthroughs during the 1940s. Groundwater access, which requires no shared infrastructure to initially develop, expanded irrigation in New Mexico considerably more than the IDs did.[28] To wit, Curry County, irrigating just .001 percent of farmland in 1945, surpassed Dona Ana as the most irrigated county in absolute and percentage terms to be the most irrigated New Mexico County by 1964.[29] Curry and the other counties over the Ogallala aquifer added nearly 350,000 acres of irrigated land after 1940 (Woodward 1997). This expanded irrigation added about twice much value to crop production and farm values in New Mexico post-1940 compared to IDs according to regression estimates.[30]

From the perspective of the Hispanic irrigators IDs did little to improve their outcomes. After the Elephant Butte Dam was constructed crop production and land values rose, "many former Hispanic landholders were paid $1 to $1.50 for a day in the field […] picking cotton [having] faced foreclosure [or] tax sale" (Autobee 1994, 20).[31] Meaning the gains were seldom garnered by the original Hispanic owner. Elsewhere in New Mexico, absent substantial infrastructure investment, there is no evidence found here that the IDs improved upon water management from the previous decentralized communal *acequias.* But also, at an aggregate level, there is no statistical evidence that farm mortgages and tenancy rates increased as had

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[27] The $100.71 is low as it reflects total value divided by all farm acreage while the subsidy is only per EBID acre. Average land values for only land served by the EBID would undoubtedly be higher.

[28] Though free of public good issues for infrastructure, groundwater irrigators are increasingly confronting common-pool issues owing to their shared water source. Water levels for the portion of the Ogallala aquifer in New Mexico generally dropped from 20 feet below the surface to 80 feet below (Woodward 1997).

[29] In 1964, Curry County irrigated 116,125 acres (12.7 percent) while Dona Ana irrigated 91,680 (10.8 percent).

[30] More generally, groundwater access explains the lion share of the growth in agricultural production in the entirety of the West post-1940 while the more costly surface water infrastructure provided just 6% of the growth (Edwards and Smith 2017).

[31] In unreported regressions of equation (2), I also found statistical evidence that hired labor expenditures increased dramatically in ID counties, but again, driven by Dona Ana.

occurred within the EBID.[32] For Hispanic farmers it seems the IDs either improved crop production and land values but they were forced off the land or they were able to stay where the IDs did little to improve outcomes.

The lack of agricultural benefits in New Mexico from centralizing control of irrigation water found here might be due to a number of factors. First, it is possible centralized control would improve outcomes but IDs failed to reach the appropriate scale to address the externalities. The EBID, where benefits were found, stands out as the largest ID and could explain some of the gains beyond the infrastructure investments. But this seems unlikely as other IDs are also often large in absolute terms – the MRGCD covers over 50,000 acres and Carlsbad ID accounts for 25,000 acres – and just as large in relative terms; the EBID covers 86 percent of the maximum observed irrigated land in Dona Ana while IDs in Guadalupe, Quay, Sierra, and Valencia extend over even a larger fraction of irrigated acres. Overall, removing EBID, the other IDs cover an average of 56 percent of irrigated acreage within their corresponding counties. Most IDs take over a significant portion of irrigation within the area.

Second, the IDs may not always be well managed themselves and fail to alter previously engrained practices. For instance, Charles Wilkinson (1992) suggests the expensive San Juan-Chama Bureau of Reclamation project could have been avoided if MRGCD could have increased their efficiency just five percent (freeing up to 70,000 acre-feet annually) instead of continuing their "wasteful uses", referring to flood irrigation (p. 229-230). If true, some of gains garnered by the EBID may be due to better management independent, but because of, expanded irrigation. That is, by delivering new water to new land, EBID had more lateral to impose new water management schemes than IDs superimposed on existing irrigated acreage. This is in some ways similar to Janis Carey and David Sunding's (2001) explanation for the greater reallocation efficiency of the Colorado-Big Thompson Project – not bogged down by prior claims and development – compared to the Central Valley Project.

Third, the *acequias* system of *repartiemento* and reliance on trust and reciprocity for the division of water may have already sufficiently overcome the externalities, leaving little to gain from centralized management. *Acequias* have been widely cited for their successful collective

[32] The EBID are not entirely unique and the regression results only suggest their was no effect on average. Evidence remains that some MRGCD irrigators experienced similar dispossession of their land: Frank Wozniak (1997) reports that 90 percent of the MRGCD lands were delinquent on payments and nearly a third of the irrigable land was confiscated by the state during the 1940s. Though delinquency rates among Hispanic and Anglo farmers were similar, at least as of Calkin's 1936 study (p. 86, Table XIV)

action and avoidance of the tragedy of the commons (Cox & Ross, 2011; Rivera, 1998; Rodríguez, 2006; Smith, 2016). There is even evidence that New Mexico *acequias* and their allowance to circumvent prior appropriations to continue *repartiemento*, have significantly higher marginal returns to surface water than similar *acequias* in Southern Colorado that are subject to Colorado's priority system (Smith 2014).

It is worth considering whether New Mexico's experience with IDs could be construed more generally as the West's experience with IDs. In contracting with the Bureau of Reclamation and investing in large infrastructure, the answer is probably yes and IDs were necessary to bring more acreage under production after 1900. And where they succeeded, undoubtedly the local farms and broader economy improved. However, the investment was not always successful. While the EBID has thrived, the nearby Hondo Project in Chaves County was an early Bureau of Reclamation debacle, completely abandoned by 1916 (Rae and Baker 1971). By 1928, 302 of the 801 IDs in the US were no longer active (Hutchins 1931). These were disproportionately represented by IDs seeking entirely new irrigation or extensive expansion (75 percent). But like in New Mexico, often IDs replaced existing irrigation organizations, 70 percent of IDs active in 1928 began life as something else (Hutchins 1931), sometimes taking over commercial companies, but more often mutual incorporations (Hutchins, Selby, and Voelker 1953). In these instances, it is likely greater gains were garnered than in New Mexico. Whereas former *acequia* ditches were guided by the Law of the Indies to share shortages and surpluses – minimizing the common-pool externalities through collective action – the mutual ditches elsewhere exhibited more competition yielding greater opportunity for centralization to mitigate the common-pool losses. Alternatively, mutual ditch companies, already more market oriented than *acequias*, may be more prepared and apt to implement more efficient systems. These speculations, however, would require additional studies to substantiate.

CONCLUSION

Surface-water irrigation in New Mexico, like the rest of the arid world, has to contend with both the division of a common-pool resource and the construction and maintenance of shared infrastructure to divert and deliver the water. Though New Mexico's irrigation had developed significantly through communal *acequias* through the 19th century, the State followed other Western States' lead and sought additional agricultural gains through IDs, designed to reduce transaction costs in infrastructure provision and water allocation. Over the first half of the 20th

century, New Mexico formed 14 IDs in half of their counties, often subsuming many smaller *acequias.* Yet many areas fended off IDs, and *acequias* continue to deliver water to irrigators as they historically have. My analysis shows that larger centralized IDs tended to form in counties where the common-pool losses were likely to be larger, primarily where more irrigators share a common source of water.

Where IDs expanded irrigated acreage and made significant new irrigation related investment, the gains to agriculture were substantial. As Bretsen & Hill (2006) point out, IDs were particularly equipped to overcome free-riding issues to construct and maintain irrigation infrastructure through their quasi-government status, ability to tax, and ability to issue tax-exempt bonds. And to this end, IDs were successful in New Mexico, particularly in Dona Ana.

When centralized IDs primarily altered the governance structure of existing decentralized communal irrigation systems and did not seek to substantially increase irrigated acreage, there is no evidence of improved irrigation and related agricultural outcomes. The results support the fact that not only are *acequias* among the types of common-arrangements that can avoid the falling prey to the tragedy of the commons over long time frames, but also that centralized governmental control does not necessarily improve upon the commons-arrangements.

While the well-established presence of *acequias* and only partial transition to IDs across the New Mexico lent itself well to answering how that change impacted the agricultural sector, the results and conclusions are also contextualized by this unique history. The results do add to the cannon of successful cases of common-property type arrangements working, but more analysis is needed to understand the factors in this and other cases that lead to relative efficient governance and why the move to IDs generally did not deliver significant gains. The results also enhance our understanding of how the development of various irrigation enterprises influence agricultural outcomes, but again, more work is needed to understand the impact of IDs more generally as well as the comparative performance of the more prevalent mutual irrigation companies for agricultural development and performance.

Last, the economic impacts should be considered in light of ecological and cultural impact. As Crossland (1990) puts it, *acequia* users "interacted with arid lands instead of dominating them technologically" (p. 278). The summary of Taos County in the 1890 Census of Irrigation echoes this notion, saying the irrigation "is of the most primitive character," but also, that they are not often short of water because they "have learned to adapt their acreage to the probable supply from the streams" (US Census Office 1894, 201). The large use of water for irrigation in the West, often attributed to the effectiveness of IDs and the Bureau of Reclamation are not necessarily socially desirable, even if highly productive for the irrigators themselves. Water is increasingly valued more outside of agricultural but IDs, no matter there importance in developing the water may have been, impede on the reallocation of water outside of the agricultural sector (Libecap 2011). Meanwhile, with the evidence of the environmental costs building up, dams today are more likely to be torn down than constructed in the US. In addition, while the land became more valuable and more productive, significant displacement occurred. The concerns of being priced out of farming by the original irrigators represent a real cultural cost. Overall, there are other outcomes beyond the direct economic output considered here that increased production might be at odds with.

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Figures and Tables:

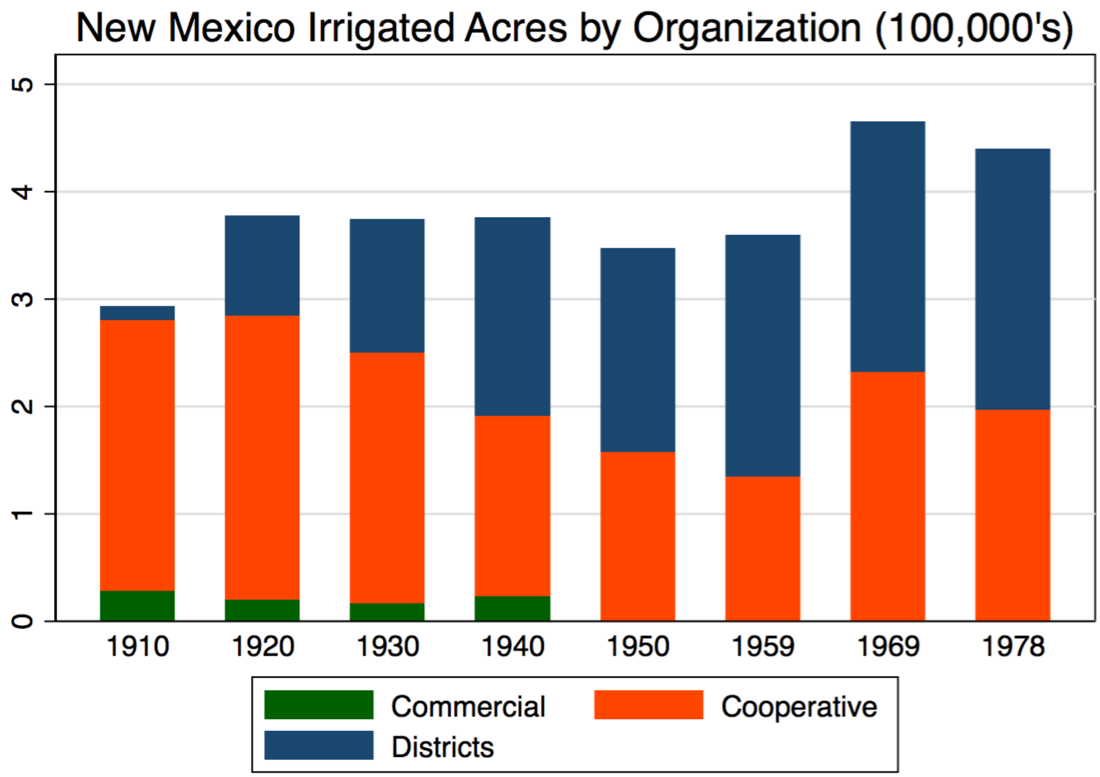

Fig. 1. Notes: Districts combines irrigation districts and bureau of reclamation project acreage. Cooperative includes mutual companies (incorporated and not). Individual systems largely consisting of groundwater users are excluded.

Sources: 1910: 1910 Census of the United States, Chapter 14, Table 4, p. 424.

1920-1940: Sixteenth census of the United States: 1940. Irrigation of agricultural lands.1940, State Table 5, p. 416.

1950: 1950 Census of the United States, Irrigation (ix) Table 60-20, p. 58

1959: US Census of Agriculture 1959, Vol. 3, Table 7, p. 30

1969: 1969 Census of Irrigation, Table 18, p. 85

1978: 1978 Census of Agriculture, chapter 2, Census of Irrigation Organizations. Table 15, p. 192.

1910 New Mexico Counties and Irrigation Districts

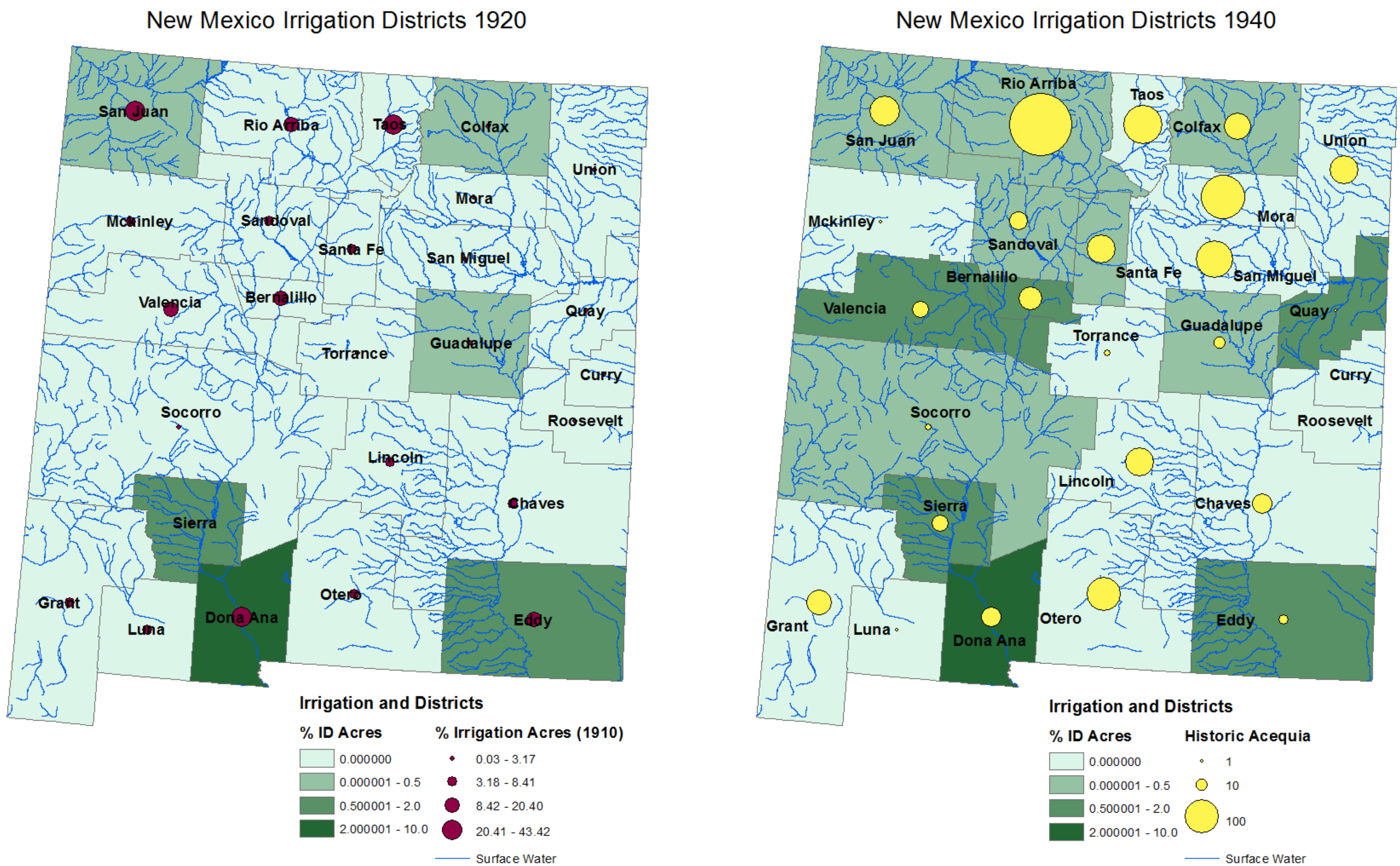

Fig. 2. Irrigation development in New Mexico

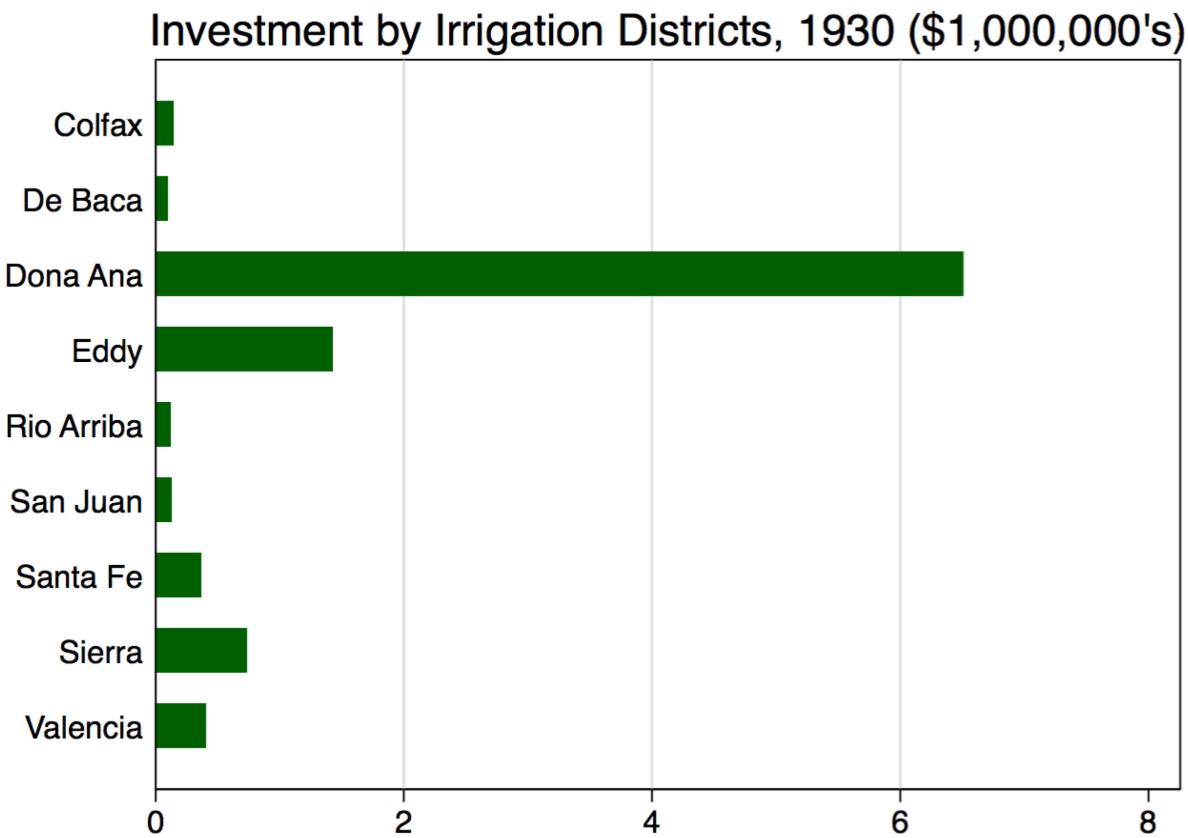

Fig. 3. Investment in irrigation infrastructure by irrigation districts. Source: US National Archives. ***29.8.3 Miscellaneous nonpopulation schedules and supplementary records,*** *drainage and irrigation, 1930****,*** *New Mexico*.

Table 1: New Mexico Irrigation Districts and Counties

District	County(ies)				Year[1]	Acres[2]
Middle Rio Grande Conservancy District[3]	Bernalillo	Sandoval	Socorro	Valencia	1925	50,265
Vermejo Conservancy District	Colfax				1952	7,379
Arch Hurley Conservancy District	Quay				1937	38,760
La Plata Conservancy District	San Juan				1946	5,000
Hammond Conservancy District	San Juan				1956	3,933
Antelope Valley ID	Colfax				1912	10,000
Fort Sumner ID	De Baca	(Guadalupe)*			1919	8,000
Elephant Butte ID (EBID)	Dona Ana	Sierra			1918	88,000
Carlsbad ID[4]	Eddy				1907/1932	25,055
Santa Cruz ID (SCID)	Rio Arriba	Santa Fe			1925	10,000
Bloomfield ID	San Juan				1912	5,500
Bluewater-Toltec ID	Cibola	(Valencia)*			1925	10,000
Farmers ID	San Juan				1954	4,181
Pojaque Valley ID	Santa Fe				1969	2,768

Notes: [1] Year of formation are from various sources (Clark 1987; US Bureau of Reclamation Reports, MRGCD 2013; EBID 2013; 1930 Irrigation Census Schedules). [2]Acres are determined (and cross-referenced when possible) from multiple sources systematically favoring the source by order: (1930 Irrigation Census Schedules; Saavedra 1987; New Mexico 1969; BoR Project History Reports) and cross-referenced to those and others when possible (1950 Irrigation Census; 1912-1914 New Mexico Bienniel Report; 1910 Irrigation Census). Specific sources for both acreage and date are detailed in Tables A2 and A3. [3]Ditches to be included remained independent as of the 1930 Census, so treatment in analysis is from 1935 onward. [4]Carlsbad ID was formed in 1932 but the Bureau of Reclamation Project it tookover began in 1907, so treatment is as of 1910. *County in parentheses indicate inclusion based on 1910 borders, but not current borders.

Table 2: Lost Acequias by County (1987)

	(1)
VARIABLES	Fraction Lost
District	0.255*
	(0.149)
Constant	0.353***
	(0.105)
Observations	28
R-squared	0.102

Note: Fraction acequias lost calculated by comparing historical totals (Dos Rios Inc. 1996) to 1987 counts (Saavedra 1987). Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: New Mexico Irrigation Enterprises (1950)

	Communal ditches	Irrigation districts
Institutional Designed Distinctions		
Owners	Private	Public
Management (GS1)	Users	Elected Board
Water rights (GS4)	Individual	Group/individual
Voting rights (GS6)	One per person	Proportional to land
Bureau of Reclamation projects (GS1)	No	Yes
Formation (GS7)	Voluntarily	Voluntarily or involuntarily
Purpose (RS1)	Irrigation/communal ties	Irrigation/Flood Control/International Obligations
Finance (GS5)	Labor and Fees	Bonds and Assessments
Monitoring and enforcement (GS8)	Within canals: mayordomo, denial of water	Across canals: ID employees, denial of water
Extent and Size		
Total enterprises*	565	10
Total acres irrigated*	156,891	190,518
Average users* (U1)	14.2	420.4
Average acres* (RS3)	278	19,052.00
Finances (I5)		
Capital investment	$5,589,490.00	$34,801,248.00
Total indebtedness	$214,849.00	$18,131,576.00
Indebted enterprises	25	6
Average debt reported	$8,593.96	$3,021,929.33
Infrastructure (RS4)		
Storage (Acre-Feet)	128,430	3,006,800
Percent acres with storage	0.23	0.95
Percent concrete diversions	10.8	72.7
Water (RS5)		
Cost of water	$386,273.00	$1,138,107.00
Cost/acre	$2.46	$5.97
Cost/acre-foot	$1.15	$1.05
Water obtained (Acre-Feet)	461,512.00	1,599,925.00
Water delivered (Acre-Feet)	334,625.00	1,082,096.00
Water/acre	2.94	8.4
Water delivered/acre (O1)	2.13	5.68
Conveyance loss/water	0.25	0.3

Note: Parenthetical text refers to Social-Ecological System Variables as identified in Ostrom (2009). Data is from United States census of agriculture: 1950. v.3., New Mexico State Table 3, p. 12-5. Data for Bureau of Reclamation enterprises are combined with irrigation districts

Table 4a: 1910 Irrigation District Predictors

VARIABLES	(1) District	(2) District	(3) District	(4) District
Land Value per Acre (ln)	0.105	-0.153	0.120	0.012
	(0.151)	(0.158)	(1.563)	(0.153)
Fraction Acres Irrigated	0.0197***	0.0215***	0.381	0.037*
	(0.00451)	(0.00654)	(0.264)	(0.020)
Fraction Farms Irrigated	-0.0250*	0.00737	-0.534	-0.052*
	(0.0125)	(0.0198)	(0.389)	(0.031)
Farms per Creek	0.000288**	0.000407**	0.00500	0.00049**
	(0.000115)	(0.000136)	(0.00328)	(0.00024)
Acres per Farm	-0.00190	0.0131	-0.0302	-0.003
	(0.00901)	(0.0148)	(0.0710)	(0.007)
No. Acequias (Historic Count)		-0.00418		
		(0.00328)		
General Population		-2.10e-05		
		(1.83e-05)		
Fraction Over of an Aquifer		-0.426		
		(0.403)		
Average Soil Suitability		0.309*		
		(0.151)		
Rail Road Access		-0.248		
		(0.292)		
Median Ruggedness		-0.000236		
		(0.000260)		
Median Elevation		0.00177		
		(0.00403)		
Average Precipitation		0.00564		
		(0.00724)		
X-Coordinate		-1.11e-07		
		(2.42e-07)		
Y-Coordinate		7.40e-08		
		(1.83e-07)		
Constant	-0.435	-3.717	-14.20	
	(0.273)	(3.142)	(8.917)	
Observations	26	26	26	
R-squared/Pseudo R-Squared	0.517	0.824	0.574	
Model	OLS	OLS	Logit	MEM of Logit

Note: Dependent variable is an indicator variable equal to one if the county eventually has an irrigation district form within its borders. Column (4) presents the estimated marginal effect at the mean for the logit coefficient estimates in column (3). Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4b: Logit Prediction Matrix

		Actual		
		District	No District	Total
Predicted	District	11	2	13
	No District	2	11	13
	Total	13	13	26

Note: Predictions are based on logit regression in column (3) of Table 4a. Correctly Classified: 84.62%

Table 5: Sample Means

	All	District	Non-District	Difference	
Independent variable of interest					
District (indicator)	0.50	1.00	0.00	1.00	***
Percent Irrigation District Acres	0.72%	1.43%	0.00%	1.43%	**
Outcome Variables (1910)					
Land Value per Acre (ln)	2.25	2.28	2.22	0.06	
Crop Value per Acre (ln)	-1.30	-1.16	-1.44	0.28	
Fraction Acres Irrigated	0.09	0.11	0.06	0.05	
Irrigation Cost per Acre (ln)	0.85	0.55	1.15	-0.60	
Total Debt per Acre (ln)	0.76	0.82	0.69	0.13	
Fraction Tenants	0.07	0.08	0.06	0.02	
Controls (1910)					
No. of Creeks	5.62	5.46	5.77	-0.31	
General Population	12,588.50	13,176.31	12,000.69	1,175.62	
Interstate County	0.50	0.69	0.31	0.38	*
Fraction Over of an Aquifer	0.46	0.51	0.42	0.09	
Soil Quality	5.99	6.53	5.45	1.08	*
Railroad Access	0.81	0.77	0.85	-0.08	
Median Elevation	2,126.19	2,209.57	2,042.81	166.76	
Median Ruggedness	87.31	96.80	77.81	18.99	
Average Precipitation	354.30	339.52	369.09	-29.57	
X-Coordinate	-819,821.20	-986,084.60	-653,557.80	-332,526.80	*
Y-Coordinate	-66,041.35	22,302.16	-154,384.80	176,686.96	
Other Variables of Interest (1910)					
No. Farms	1,372.15	1,271.85	1,472.46	-200.62	
Farm Acres	433,462.30	416,686.80	450,237.90	-33,551.10	
No. Acequias (Historic Count)	56.50	55.85	57.15	-1.31	
No. Irrigation Enterprises	107.15	103.77	110.54	-6.77	
Irrigated Land per Enterprise	336.80	444.16	229.44	214.72	
Main Ditch Length (miles)	179.38	230.83	127.94	102.88	*
Irrigation Capacity (Acres)	24,806.54	33,337.88	16,275.19	17,062.69	**
Fraction of Capacity Irrigated	0.65	0.64	0.66	-0.03	
No. Dams	0.27	0.31	0.23	0.08	
No. Resorvoirs	19.54	19.69	19.38	0.31	
Storage Capacity (Acre-Feet)	17,467.77	24,277.15	10,658.38	13,618.77	
Observations	26	13	13		

Note: Census data limited to the 1910 Irrigation and Farm Census for New Mexico. Aggregated irrigation data for Curry, Quay, Roosevelt, and Torrance Counties are divided evenly for those counties. Nominal dollars are converted to 2007 dollars

Statistically distinct means: *** p<0.01, ** p<0.05, * p<0.1

Table 6: Main Results

VARIABLES	(1) Land Value per Acre (ln)	(2) Crop Value per Acre (ln)	(3) Fraction Acres Irrigated	(4) Irrigation Cost per Acre (ln)	(5) Total Debt per Acre (ln)	(6) Fraction Tenants
Panel A: No County Fixed Effects						
Post x District (fraction of acres)	21.57***	43.67***	0.907***	10.98**	21.38***	1.743***
	(2.100)	(6.745)	(0.0393)	(4.032)	(2.565)	(0.193)
District	0.0403	0.00988	-0.00341	-0.0332	0.160	-0.0206*
	(0.190)	(0.546)	(0.00269)	(0.285)	(0.232)	(0.0106)
Constant	2.657***	1.186	0.0441**	1.121	-1.218	-0.00257
	(0.815)	(2.424)	(0.0213)	(1.575)	(0.976)	(0.0802)
Observations	390	329	363	145	104	389
R-squared	0.811	0.677	0.582	0.781	0.545	0.591
Panel B: County Fixed Effects						
Post x District (fraction of acres)	7.889***	10.00*	0.548***	21.79***	6.037***	-0.448
	(1.791)	(5.636)	(0.0873)	(3.585)	(1.742)	(0.329)
Constant	1.088***	-1.299***	0.0128**	3.534***	0.567***	0.103***
	(0.122)	(0.170)	(0.00617)	(0.416)	(0.142)	(0.0170)
Observations	390	329	363	145	104	389
R-squared	0.869	0.752	0.234	0.817	0.180	0.472
Number of Counties	26	26	26	26	26	26

Note: Coefficient estimates for a linear regression of equation (2). The average fraction of acres in a district is only 0.0143. Additional but unreported controls include number of creeks, population, latitude, longitude, I-25 indicator, railroad indicator, fraction over aquifer (interacted with post 1940), soil quality, ruggedness, elevation, and mean precipitation. Observations vary due to missing data in the census reports, with irrigation costs unreported past 1950 and and debt unreported past 1940. Robust standard errors, clustered by county, in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7: Coefficient Interpretation (1910-1978)

	Mean	Observations	Impact[a] No Fixed Effects	Impact[a] Fixed Effects
Maximum Percent ID Acres	1.43%	13	n/a	n/a
Land Value per Acre	$22.89	390	34.7%	11.5%
Crop Value per Acre	$10.85	329	82.7%	14.8%
Irrigation Costs per Acre	$28.83	145	16.4%	35.1%
Fraction Acres Irrigated	0.015	363	0.013	0.008
Debt per Acre	$2.89	104	34.3%	8.7%
Fraction Tenants	0.122	389	0.024	-0.006

Notes:[a]Impact scales the estimated coefficients for equation 2 presented in Table 6. It is calculated in two ways. For the monetary values (2007 dollars) per acre which were logged, impact = e^(0.0143*Coefficient)-1 and is a percentage change. For the outcomes measured as fractions, impact=0.0143*Cofficient and is a change in that fraction.

Table 8: Main Results without Dona Ana (EBID)

VARIABLES	(1) Land Value per Acre (ln)	(2) Crop Value per Acre (ln)	(3) Fraction Acres Irrigated	(4) Irrigation Cost per Acre (ln)	(5) Total Debt per Acre (ln)	(6) Fraction Tenants
Panel A: No County Fixed Effects						
Post x District (fraction of acres)	-7.277	17.20	-0.305	47.71	-5.991	-0.323
	(9.427)	(28.88)	(0.508)	(29.96)	(15.87)	(1.645)
District	0.154	0.113	0.00213	-0.116	0.181	-0.0148
	(0.193)	(0.542)	(0.00333)	(0.331)	(0.231)	(0.0110)
Constant	2.280**	-2.417	0.0322	1.775	-1.795*	-0.0628
	(0.847)	(2.425)	(0.0204)	(1.710)	(0.884)	(0.0657)
Observations	375	316	349	139	100	374
R-squared	0.810	0.627	0.388	0.779	0.529	0.602
Panel B: County Fixed Effects						
Post x District (fraction of acres)	-2.775	-7.491	-0.0716	74.39**	-7.306	0.285
	(8.260)	(28.89)	(0.570)	(31.62)	(13.02)	(1.672)
Constant	1.067***	-1.371***	0.0137**	3.540***	0.607***	0.0963***
	(0.126)	(0.172)	(0.00630)	(0.408)	(0.144)	(0.0177)
Observations	375	316	349	139	100	374
R-squared	0.871	0.747	0.174	0.814	0.156	0.471
Number of Counties	25	25	25	25	25	25

Note: Coefficient estimates for a linear regression of equation (2). Without Dona Ana, the average fraction of acres in a district is only 0.00687. Additional but unreported controls include number of creeks, population, latitude, longitude, I-25 indicator, railroad indicator, fraction over aquifer (interacted with post 1940), soil quality, ruggedness, elevation, and mean precipitation. Observations vary due to missing data in the census reports, with irrigation costs unreported past 1950 and and debt unreported past 1940. Robust standard errors, clustered by county, in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix: Additional Figures and Tables

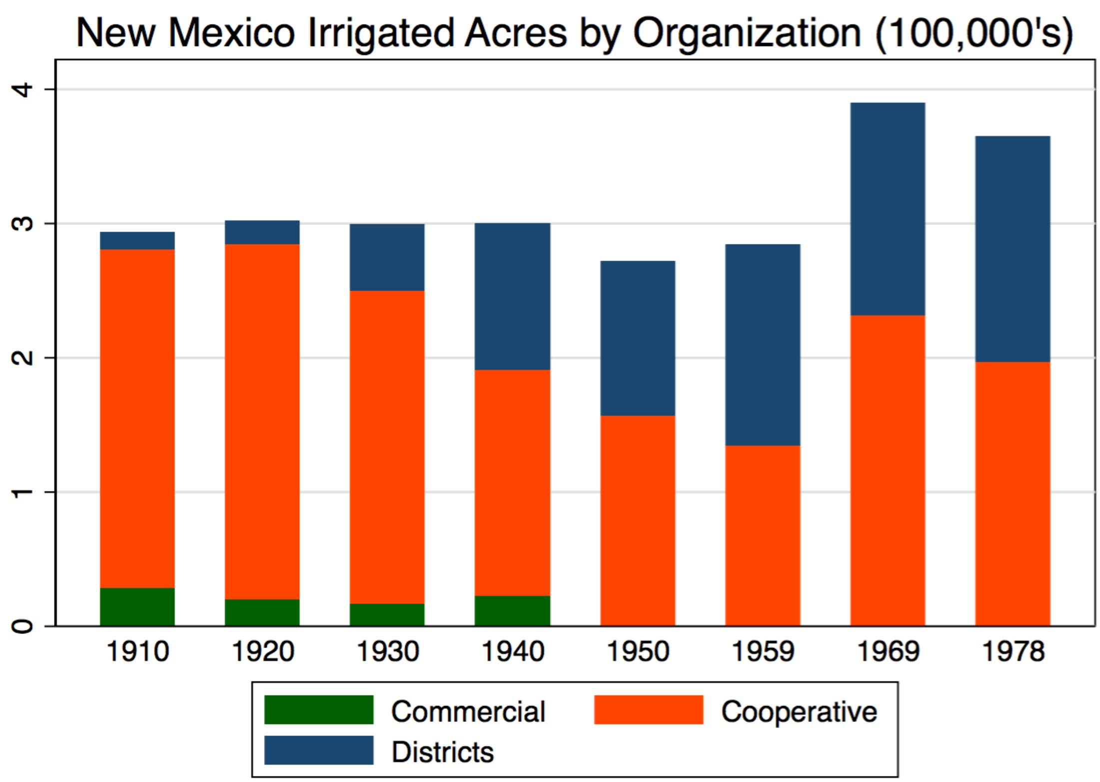

Fig. A1. Notes: Districts combines irrigation districts and bureau of reclamation project acreage. Cooperative includes mutual companies (incorporated and not). Individual systems largely consisting of groundwater users are excluded. ***Excludes Elephant Butte Irrigation District***.

Sources: 1910: 1910 Census of the United States, Chapter 14, Table 4, p. 424.

1920-1940: Sixteenth census of the United States: 1940. Irrigation of agricultural lands.1940, State Table 5, p. 416.

1950: 1950 Census of the United States, Irrigation (ix) Table 60-20, p. 58

1959: US Census of Agriculture 1959, Vol. 3, Table 7, p. 30

1969: 1969 Census of Irrigation, Table 18, p. 85

1978: 1978 Census of Agriculture, chapter 2, Census of Irrigation Organizations. Table 15, p. 192.

Table A1: Data Description Summary

Variable	Description	Calculation	Source
Fraction Irrigation District Acres	Fraction of farm acres within irrigation districts	Divide district acres by the maximum county level acreage in farms	Various (see table AX) and Agricultural Censuses
Land Value per Acre	Value of farm land and buildings per farm acre	Divide value by maximum farm acres	Haines (2010)
Crop Value per Acre	Market value of crops grown or sold per farm acre	Divide value by maximum farm acres	Haines (2010). Unavailable 1900 and 1935. Only crops value is available only through 1950 and crop sold is available only from 1940 onward.
Irrigation Cost per Acre	Investment in irrigation infrastructure and water rights per farm acre	Total costs calculated from average acreage cost and then divided by maximum farm acres except 1950 where total costs are directly used.	New Mexico Agriculture and Irrigation reports. Available only 1900, 1910, 1920, 1930, 1940, and 1950.
Percent Acres Irrigated	Actual irrigated acreage per farm acre	Number of irrigated acres divided by maximum farm acres	New Mexico Agriculture and Irrigation reports. Unavailable in 1925 and only harvested acres reported in 1935
Total Debt per Acre	Total Farm Mortgage Debt per Acre	Debt to value ratio multiplied by value to find total debt, then divided by farm acreage	New Mexico Agriculture and Irrigation reports. Available only 1900, 1910, 1920, 1930, 1940.
Percent Tenants	Share of farms operated by tenants	Number of tenant farm operators divided by number of farms that year	New Mexico Agriculture and Irrigation reports.
Number of Creeks	Number of creeks from which surface irrigation organizations draw water from within a county	Added up tabulation in report	Saavedra 1987
General Population	Total population within a county	For non decadal years, a linear trend foreach individual county is imposed	NHGIS download
Interstate County	Whether or not an interstate is in the county	Binary indicator for I25, I40, or I10	Road Atlas (2014)
Fraction over an Aquifer	Fraction of county overlaying an aquifer	Calculated by Tabulate Area in ArcGIS	USGS 2003
Soil Quality	Soil quality classified 1 (high)-8 (low)	Calculated by zonal statistic (mean) in ArcGIS	USDA NRCS 2006
Railroad Access	Whether or not a major railroad is in the county	Presence of major railroad spur	Frye 2014
Median Elevation	Median elevation in meters	Spatial statistic calculated in ArcGIS	Frye 2014 (https://nationalmap.gov/)
Median Ruggedness	Topographic Ruggedness Index in meters	Spatial statistic calculated in ArcGIS (Riley 1999)	Frye 2014 (https://nationalmap.gov/)
Average Precipitation	Total Annual Precipitation millimeters	Monthly spatial average aggregated to annual and then averaged over time	PRISM (2014)
X-Coordinate	Centroid of the county	County centroid extracted from 1910 Shapefile	NHGIS download
Y-Coordinate	Centroid of the county	County centroid extracted from 1910 Shapefile	NHGIS download

Note: Dollar amounts were convereted to 2007 dollars. The full census sample includes 1900, 1910, 1920, 1925, 1930, 1935, 1940, 1945, 1950, 1954, 1959, 1964, 1969, 1974, 1978

Table A2: Acreage and Source summary for IDs in New Mexico

	Acreage						
	1987 OSE	1969 OSE	1910 Census	1930 Census	1950 Census	BOR	Bienniel (1914)
Middle Rio Grande Conservancy District	50,265						
Bernalillo	10,975	.	n/a	0	.	n/a	
Sandoval	3,530	7,603	n/a	0	.	n/a	
Socorro	14,760		n/a	0	.	n/a	
Valencia	21,000		n/a	0	22,539	n/a	
Vermejo Conservancy District							
Colfax	.	7379	n/a	n/a	n/a	7,379	
Arch Hurley Conservancy District							
Quay	38,760	42,214	n/a	n/a	20,649	41386	
La Plata Conservancy District							
San Juan	.	5,000	n/a	n/a	n/a	.	
Hammond Conservancy District							
San Juan	3,933	3,900	n/a	na/	n/a	3933	
Antelope Valley ID							
Colfax	.	5,000	n/a	10,000	0	n/a	19,500
Fort Sumner ID							
Guadalupe (1910) De Baca (Current)	6,500	6,500	n/a	8,000	4,591	6500	0
Elephant Butte ID	90,640		n/a	88,000	85,196	.	110,000
Dona Ana	87,270		n/a	79,000	82,061	.	
Sierra	3,370	87,500	n/a	9,000	3,135	.	
Carlsbad ID							
Eddy	.	25,055	20267	25,055	.		20,261
Santa Cruz ID	4,400						
Rio Arriba	1,100	4,600	n/a	5,000	.	n/a	
Santa Fe	3,300		n/a	5,000	.	n/a	
Bloomfield ID							
San Juan	.	4,422	n/a	5,500	2,482	n/a	7,000
Bluewater-Toltec ID							
Cibola (current) Valencia (1910)	3,000	5,488	n/a	10,000	22,539		
Farmer's Irrigation District							
San Juan	4,181	4181	n/a	n/a	n/a	n/a	n/a
Pojaque Valley ID							
Santa Fe	.		n/a	n/a	n/a	2,768	
EXCLUDED FROM ANALYSIS							
Pecos Valley Artesian Conservancy District							
Eddy	0		n/a	0	0		
Chaves	0		n/a	0	0		
N/A							
McKinley					601		
Hondo Project							
Chaves	0		10,000	0	0	0	0
Sunshine Valley Conservancy District							
Taos	n/a		n/a	0	0	n/a	n/a
Hillside Irrigation District							
San Juan	800	801	n/a	n/a	n/a	n/a	n/a

Note: Acreage Summary by source, district, and county. n/a is "not applicable" because the relevant districts did not yet exist. "." indicates the data is missing from that source. Highlighted cell indicates the number utilized in analysis. 1987 OSE:(Saavedra, Paul. Surface Water Irrigation Organizations in New Mexico. Santa Fe, New Mexico: New Mexico State Engineer Office. 1969 OSE: New Mexico State Engineer. A roster, by County, of organizations Concerned with Surface Water Irrigation in new Mexico. Santa Fe, New Mexico. 1910 Census: Statistics of Irrigation for the State and its Counties, pg. 631-33. 1930 Census: Tabulated from original irrigation schdedules at the National Archives; 29.8.3 Miscellaneous nonpopulation schedules and supplementary records. 1950 Census: Irrigation of Agricultural Lands, New Mexico County Table 2 (part 1 of 4). BoR: Various project reports from the Bureau of Reclamation with links provided in Table A3 below. Bienniel 2014: New Mexico Biennial Report 1912-1914.

Table A3: Data and Source summary for IDs in New Mexico

	Date Year	Source
Middle Rio Grande Conservancy District	1925	http://mrgcd.com/uploads/FileLinks/fb113b302b484ed393c31a81377f4849/Fast%20Facts.pdf
Bernalillo		
Sandoval		
Socorro		
Valencia		
Vermejo Conservancy District	1952	https://www.usbr.gov/history/ProjectHistories/Vermejo%20D2.pdf
Colfax		
Arch Hurley Conservancy District	1937	https://www.usbr.gov/history/ProjectHistories/Tucumcari%20Project%20D2.pdf
Quay		
La Plata Conservancy District		
San Juan	1946	Repayment Contract: https://www.usbr.gov/uc/progact/animas/contract_neg.html
Hammond Conservancy District		
San Juan	1956	http://hammondcon.org/
Antelope Valley ID		
Colfax	1912	Clark (1987) and verified in 1930 census
Fort Sumner ID		
Guadalupe (1910) De Baca (Current)	1919	https://www.usbr.gov/projects/pdf.php?id=117
Elephant Butte ID	1918	EBID Website
Dona Ana		
Sierra		
Carlsbad ID	1932/1906	https://www.usbr.gov/projects/pdf.php?id=93
Eddy		
Santa Cruz ID	1925	https://ia801403.us.archive.org/33/items/CAT31289804/CAT31289804.pdf
Rio Arriba		
Santa Fe		
Bloomfield ID		
San Juan	1912	https://www.bloomfieldirrigationdistrict.com/history.html
Bluewater-Toltec ID		
Cibola (current) Valencia (1910)	1925	Clark (1987) 1930 Census verified
Farmer's Irrigation District		
San Juan	1954	http://www.farmersirrigationdistrict.com/
Pojaque Valley ID		
Santa Fe	1969	https://www.usbr.gov/projects/pdf.php?id=186
EXCLUDED FROM ANALYSIS		
Pecos Valley Artesian Conservancy Distric	1932	http://pvacd.com/index.php?option=com_content&view=article&id=47&Itemid=59
Eddy		
Chaves		
N/A		
McKinley		
Hondo Project		
Chaves	1903	https://www.usbr.gov/history/ProjectHistories/HONDO%20PROJECT%20MASTER%20ZLA%2
Sunshine Valley Conservancy District		
Taos	1927	Clark (1987)
Hillside Irrigation District		
San Juan	1967?	New Mexico (1969)

Note: Summary of District Dates and sources of dates.

Table A4: MRGCD Predictions (1930)

	(1)	(2)
VARIABLES	Future MRGCD	Future MRGCD
Number of Irrigators	0.00654***	0.00181
	(0.00163)	(0.00170)
Acres Irrigated	7.48e-05	-0.000104
	(0.000137)	(0.000142)
Investment in Irrigation		6.66e-05***
		(1.39e-05)
Maintenance Cost		9.02e-06
		(3.08e-05)
Canal Capacity (CFS)		0.000885
		(0.00224)
Initial Construction Date		-0.00253***
		(0.000910)
Constant	0.167***	4.872***
	(0.0539)	(1.715)
Observations	117	77
Future MRGCD Ditches	50	44
R-squared	0.314	0.555

Note: Dependent variable is an indicator variable whether or not the ditch was to be included in the MRGCD as of 1930. Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A5: Pre-Trend Test

VARIABLES	(1) Land Value per Acre (ln)	(2) Crop Value per Acre (ln)	(3) Fraction Acres Irrigated	(4) Irrigation Cost per Acre (ln)	(5) Total Debt per Acre (ln)	(6) Fraction Tenants
1910	1.018***		0.00341	1.668***		-0.0442**
	(0.200)		(0.00574)	(0.314)		(0.0168)
1920	1.048***	2.235***	0.00583	2.974***	0.235	0.0404
	(0.192)	(0.218)	(0.00875)	(0.382)	(0.167)	(0.0314)
1925	0.954***	1.271***				0.0690*
	(0.244)	(0.259)				(0.0363)
1930	0.640***	1.734***	0.00416	3.442***	-0.00654	0.105**
	(0.221)	(0.228)	(0.00688)	(0.389)	(0.165)	(0.0447)
1910 x District	-0.0516		0.00375	-1.078**		0.0196
	(0.254)		(0.00568)	(0.497)		(0.0198)
1920 x District	-0.344	-0.422	-0.000663	-1.677**	-0.235	-0.0557
	(0.293)	(0.406)	(0.00845)	(0.679)	(0.247)	(0.0343)
1925 x District	-0.132	-0.423				-0.0756
	(0.347)	(0.454)				(0.0457)
1930 x District	-0.157	-0.283	0.000775	-2.436***	-0.229	-0.0787
	(0.358)	(0.411)	(0.00633)	(0.832)	(0.238)	(0.0762)
District	0.404	0.865	0.00459	0.786	0.505	-0.00377
	(0.322)	(0.560)	(0.00530)	(0.553)	(0.376)	(0.0351)
Constant	-0.0871	-3.246	0.128***	-4.740	-0.576	0.0327
	(1.298)	(2.370)	(0.0171)	(2.790)	(1.361)	(0.148)
Observations	108	82	87	79	62	107
R-squared	0.626	0.698	0.779	0.658	0.496	0.473

Note: Coefficient estimates for a linear regression similar to equation (2). Rather than treatment, year fixed effects are interacted with an indicator for a county that eventually forms a district with observations post-treatment being dropped from the sample. All district counties are treated by 1940. The omitted year is 1900 except where the dependent variable was unavailable until 1910. Additional but unreported controls include number of creeks, population, latitude, longitude, I-25 county, railroad indicator, fraction over aquifer, soil quality, ruggedness, elevation, and mean precipitation. Robust standard errors, clustered by county, in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A6: Pre-Trend Test without Dona Ana

VARIABLES	(1) Land Value per Acre (ln)	(2) Crop Value per Acre (ln)	(3) Fraction Acres Irrigated	(4) Irrigation Cost per Acre (ln)	(5) Total Debt per Acre (ln)	(6) Fraction Tenants
1910	1.030***		0.00368	1.647***		-0.0416**
	(0.203)		(0.00577)	(0.321)		(0.0168)
1920	1.064***	2.241***	0.00617	2.949***	0.239	0.0437
	(0.193)	(0.220)	(0.00878)	(0.386)	(0.169)	(0.0316)
1925	0.970***	1.278***				0.0724*
	(0.247)	(0.260)				(0.0362)
1930	0.658***	1.744***	0.00455	3.414***	-0.000523	0.109**
	(0.223)	(0.230)	(0.00694)	(0.397)	(0.166)	(0.0448)
1910 x District	-0.0785		0.00245	-1.073*		0.0191
	(0.262)		(0.00555)	(0.524)		(0.0206)
1920 x District	-0.258	-0.171	-0.000149	-1.733**	-0.128	-0.0415
	(0.295)	(0.328)	(0.00843)	(0.709)	(0.236)	(0.0320)
1925 x District	-0.0431	-0.167				-0.0609
	(0.342)	(0.383)				(0.0439)
1930 x District	-0.0746	-0.0451	0.00126	-2.500***	-0.126	-0.0649
	(0.353)	(0.345)	(0.00637)	(0.876)	(0.199)	(0.0760)
District	0.275	0.537	0.00344	0.869	0.354	-0.0242
	(0.287)	(0.442)	(0.00524)	(0.594)	(0.325)	(0.0309)
Constant	-1.058	-4.893**	0.113***	-3.953	-1.512	-0.113
	(1.157)	(1.837)	(0.0135)	(3.097)	(1.140)	(0.0852)
Observations	106	81	85	77	61	105
R-squared	0.663	0.756	0.792	0.648	0.548	0.527

Note: Coefficient estimates for a linear regression similar to equation (2). Rather than treatment, year fixed effects are interacted with an indicator for a county that eventually forms a district with observations post-treatment being dropped from the sample. All district counties are treated by 1940. The omitted year is 1900 except where the dependent variable was unavailable until 1910. Additional but unreported controls include number of creeks, population, latitude, longitude, I-25 county, railroad indicator, fraction over aquifer, soil quality, ruggedness, elevation, and mean precipitation. Robust standard errors, clustered by county, in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A7: Non Agriculture Outcomes

VARIABLES	(1) Manufacturing output	(2) Manufacturing output	(3) Median home value	(4) Median rent
Post x District (fraction of acres)	-5.363	-6.258	-0.790	-3.584*
	(4.825)	(6.259)	(2.942)	(1.879)
District	-0.371		0.0911	0.0322
	(0.381)		(0.192)	(0.120)
Constant	9.762***	10.76***	6.608***	2.975***
	(2.178)	(0.381)	(0.866)	(0.574)
County Fixed Effects	No	Yes	No	No
Observations	90	90	130	129
R-squared	0.499	0.292	0.911	0.910
Number of Counties		26		

Note: All dependent variables are logged. Coefficient estimates for a linear regression of equation (2). The average fraction of acres in a district is only 0.0143. Additional but unreported controls include number of creeks, population, latitude, longitude, I-25 indicator, railroad indicator, fraction over aquifer (interacted with post 1940), soil quality, ruggedness, elevation, and mean precipitation. Manufacturing output is available only for 1900, 1920, 1930, and 1940. Home value and rent are only available 1930, 1940, 1950, 1959, and 1969. Robust standard errors, clustered by county, in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A8: Sample and Treatment Robustness

VARIABLES	(1) Land Value Per Acre (ln)	(2) Land Value Per Acre (ln)	(3) Land Value Per Acre (ln)	(4) Land Value Per Acre (ln)	(5) Land Value Per Acre (ln)	(6) Land Value Per Acre (ln)	(7) Land Value Per Acre (ln)
Panel A: All Counties							
Post x District (fraction of acres)	21.57***	8.450***	31.64***	-0.00236	16.73***	17.52***	17.95***
	(2.100)	(1.768)	(11.21)	(0.129)	(4.350)	(2.115)	(1.602)
District	0.0403	0.117	0.0259	0.311	0.297	0.0236	-0.0459
	(0.190)	(0.167)	(0.210)	(0.269)	(0.285)	(0.136)	(0.0930)
Constant	2.657***	5.188***	-0.986	1.766	4.453***	1.431***	2.102***
	(0.815)	(0.861)	(0.908)	(1.760)	(1.295)	(0.371)	(0.485)
Observations	390	389	338	390	233	348	442
R-squared	0.811	0.694	0.824	0.728	0.900	0.900	0.904
Panel B: No Dona Ana							
Post x District (fraction of acres)	-7.277	1.421	-3.405	-0.136	2.057	-12.59	2.135
	(9.427)	(3.477)	(10.67)	(0.0870)	(12.25)	(7.832)	(6.986)
District	0.154	0.102	0.109	0.220	0.354	0.143	0.0457
	(0.193)	(0.178)	(0.201)	(0.221)	(0.318)	(0.144)	(0.118)
Constant	2.280**	2.269**	-0.373	0.975	3.597**	4.515***	5.210***
	(0.847)	(0.840)	(0.935)	(0.846)	(1.560)	(0.293)	(0.431)
Observations	375	374	325	375	219	334	428
R-squared	0.810	0.807	0.816	0.811	0.899	0.903	0.905
Treatment Denominator	**Max Farm Acres**	**Current Farm Acres**	**County Acres**	**ID Acres (Indicator)**	**Max Farm Acres**	**Max Farm Acres**	**Max Farm Acres**
Borders	**1910**	**1910**	**1910**	**1910**	**1910 Consistent**	**1920 Consistent**	**1978**

Note: Coefficient estimates for a linear regression of (2). Column (1) is the main specification for reference. Columns (2)-(4) scale the number of district acres by various measures of land availability. Columns (5)-(7) reweight the census data in various ways. Column (5) keeps 1910 borders but includes only counties that did not subsequently change, only reweighting 1900 observations. Column (6) uses consistent 1920 county borders, only reweighting 1900 and 1910. Column (7) reweights all census data to 1978 county borders. Additional but unreported controls include number of creeks, population, latitude, longitude, I-25 indicator, railroad indicator, fraction over aquifer (interacted with post 1940), soil quality, ruggedness, elevation, and mean precipitation. Observations vary due to missing data in the census reports, with irrigation costs unreported past 1950 and and debt unreported past 1940. Robust standard errors, clustered by county, in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A9: Irrigation in Mesilla Valley

Year	Acres
1880	31,700
1890	27,150
1903	24,260
1917	45,995
1930	65,747
1935	53,591
1938	64,085
1943	71,770
1945	88,714

Note: Irrigated acreage calculated from Wozniak (1997), pages 90, 120, 124, and 129