

Decentralizing Rent-seeking: Water and Power in Pakistan's Indus Basin*

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Abstract

Does decentralizing public resource allocation reduce rent-seeking or merely change its venue? We study a governance reform in Pakistan's vast Indus basin irrigation system. Using canal discharge measurements across all of Punjab, we find that water theft increased on channels taken over by local farmer organizations, compared to channels that remained bureaucratically managed, leading to substantial wealth redistribution. This increase in water theft was also sharper along channels with larger landowners situated upstream. These findings are consistent with a model in which decentralization accentuates the political power of local elites by shifting the arena in which water rights are contested.

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1 Introduction

Perceived corruption and lack of accountability associated with top-down public service delivery has led to calls for greater decentralization in developing countries. Indeed, participatory or grass-roots governance, in which resource control resides with local elected bodies rather than with centralized bureaucracies, has gained currency among international agencies and donors (see, e.g., World Bank 2004), even though communal authority is by no means immune from rent-seeking in its various forms. A key empirical question is, therefore, whether the promise of local governance can be realized in practice and, if so, under what conditions. Yet, empirical investigation is hampered by lack of large-scale ‘controlled’ experiments in decentralization and by the paucity of objective data on rent-seeking behavior.¹ This paper takes advantage of a partial governance reform in the world’s largest canal irrigation system, that of Pakistan’s Indus basin watershed. During the last decade, in an effort encouraged by the World Bank, the management of several large sub-systems in the Punjab was transferred from the provincial irrigation department to grass-roots farmer organizations (FOs) organized at the channel level. Here we assess how this shift from bureaucratic to local control affected rent-seeking in the form of water “theft” along a channel.

Effective management of large irrigation systems has proven elusive in both historical and contemporary experience (Meinzen-Dick, 2007).² In the continuous gravity flow and rotation systems most common in Asia, volumetric pricing and widespread water trading—i.e., market-based allocation—faces daunting technical hurdles (Moore, 1989; Sampath, 1992).³ Instead,

¹See Mansuri and Rao (2013) for a comprehensive and critical review of the evidence. A small literature looks at the impact of decentralization on corruption in cross-sections of countries (most recently, Fan et al. 2009). The difficulties here include heterogeneity in the nature of decentralization and, of course, reverse causation (See Bardhan and Mookherjee 2006b).

²The celebrated writings of Elinor Ostrom take a slightly more optimistic view, arguing that self-governing institutions sometimes arise organically to solve collective action problems, at least in smaller-scale irrigation systems (Ostrom and Garner 1993).

³Surface irrigation systems are distinct from other public utilities, such as piped water networks, in that property rights are vastly cheaper to enforce in the latter case; canal water thus has an important common property dimension.

irrigation bureaucracies have been established to operate and monitor centralized systems for the allocation of water as it makes its way down from the rivers and main canals to the network of distributaries, minor and sub-minor canals, and, finally, to the watercourse outlets, where it is distributed to individual farms. In such quota-based systems, users have a strong temptation to bribe local officials to “look the other way” as they use various means to illicitly enhance their water entitlement. Invariably, such water theft benefits farmers at the head of the channel, where water is first to arrive, at the expense of farmers at the tail (see Bromely et al. 1980, Wade 1982, and Chambers 1988). As even a cursory internet search reveals, canal water theft garners enormous media attention in Pakistan, where it is often portrayed as pitting large landlords at the head against multitudes of poor tail-enders.

While decentralization strips authority from unelected irrigation department bureaucrats, farmer organizations may also be subject to capture by these upstream elites and, hence, may sanction as much (if not more) water theft than the irrigation department functionaries they replace. In this sense, irrigation reform and, more broadly, decentralization could merely change the venue for rent-seeking without ameliorating its underlying causes.⁴ To think about the implications of decentralizing irrigation management, we set out a simple model of water allocation, corruption, and rent-seeking along a canal system. Given the locational asymmetry, corruption and theft are concentrated at the head of a channel. However, theft induces rent-seeking by coalitions of gainers (farmers at the head) and losers (farmers at the tail); these coalitions have varying degrees of political influence. Under irrigation department control, lobbying effort is directed “over the head” of the local official involved in the corruption whereas, under decentralized control, it is directed toward the FO. The model

⁴Rijsberman (2008) elaborates on the view that so-called water users associations are not a panacea. Punjab’s irrigation reform exemplifies what Meinzen-Dick (2007) terms “externally initiated programs...[with] top-down imposition of a rigid structure of user groups and uniform rules that would allow state agencies to recognize and interact with [them].” Such irrigation management transfers, according to her review of the evidence, have had mixed success. Vermillion (1997), considering much the same body of country case-studies, concludes that “the literature on irrigation management transfer does not yet allow analysts to draw strong conclusions about...impacts, either positive or negative.” p29.

has several empirical implications for the impact of decentralization and how this impact interacts with asymmetry in political influence.

The centerpiece of our analysis of Pakistan’s irrigation reform is an administrative database maintained by the Punjab Irrigation Department and consisting of readings taken from water discharge gauges installed at the head and tail of each channel of the entire system. These data arguably provide an objective measure of water theft along a channel. Moreover, water discharge data are available over the years 2006-2014, a period encompassing significant devolution of irrigation management to FOs. Importantly, we are also able to match villages along each irrigation channel back to unit record landownership data from recent Agricultural Censuses. This allows us to construct measures of *differences* in political power, proxied by landholdings, between head and tail villages and thus establish whether irrigation reform has had heterogeneous impacts along this dimension.

In a companion paper (Jacoby and Mansuri 2017), we study the allocation of canal water in the presence of rent-seeking farmers and of corruptible irrigation officials with career concerns. Using data from several hundred distributaries in Punjab that were *not* subject to irrigation reform, we find that, under bureaucratic control, the extent of water theft is substantially affected by the distribution of political power along a channel: where political influence is relatively concentrated at the head of a channel, water allocations are more favorable toward the head as reflected in land value differentials between head and tail. In this paper, by contrast, we focus on how inequality interacts with decentralization. Although the literature recognizes that local governance is more likely to serve the interests of elites where political power is more asymmetric (see Mansuri and Rao, 2013), empirical support for this proposition has up to now been lacking.

We adopt two strategies for constructing a control group against which we compare the changes in canal water allocations following decentralization. Since FOs were phased-in starting in 2005, our first strategy is to look solely at variation in outcomes across distribu-

taries with early and late FO formation while controlling for channel-level fixed effects. In this ‘pipeline’ approach, we only focus on the administrative zones where FO formation has been sanctioned; those FOs that became operational later serve as controls for those that became operational early. Our second, and ultimately preferable, strategy uses geographically matched controls drawn from *adjacent* administrative zones in which provincial authorities have not (yet) called for FOs to be established. That is, control channels are chosen on the basis of being within a geographical *buffer* zone of given distance around a particular FO channel. In this case, and in contrast to the pipeline strategy, we compare changes in discharges over the same time period between FO and non-FO channels.⁵

To summarize our empirical results, we find strong evidence of an economically important *decrease* in the relative allocation of water to the tail of a channel once an FO becomes operational. Moreover, this decline is greater along FO channels where large landowners are more heavily concentrated at the head vis à vis the tail. This latter finding implies that, where power asymmetry is in the same direction as the inherent locational (head versus tail) asymmetry, decentralization leads to greater inequity in allocations. By contrast, where the power asymmetry and the inherent locational asymmetry work in opposition, the negative impact of decentralization is muted.

This study contributes to a growing micro-empirical literature on the impact of decentralization. Alatas et al. (2013) and Beath et al. (2017) look for direct evidence of elite capture based on field experiments (in Indonesia and Afghanistan, respectively) in which the authority or accountability of extant local governments is randomly varied (see also Basurto et al., 2015, for a nonexperimental study along similar lines). None of these studies, however, compares local-level to top-down control, the pre-reform scenario considered in this paper. Moreover, as noted by Mookherjee (2015), empirical work to date focuses almost exclusively on intracommunity allocations, although “effects of decentralization on intercommunity al-

⁵Similarly, Holmes (1998) exploits legislative discontinuities at the borders of US states.

locations are no less important,” precisely because much rent-seeking activity is undertaken by *groups* of actors in pursuit of their collective interests. Bardhan and Mookherjee (2006c), using longitudinal data from West Bengal, find that district and/or state allocated development grants to villages are strongly negatively related to the percentage of low-caste poor households in the village. However, neither this study nor any other econometric analysis of which we are aware addresses whether devolution of resource control can exacerbate conflict and inequality *between* communities.

More broadly, this paper is related to, and the results consistent with, Acemoglu and Robinson (2008) who study the interaction between *de jure* and *de facto* political power: “A change in political institutions that modifies the distribution of *de jure* power,” they argue, “need not lead to a change in equilibrium economic institutions if it is associated with an offsetting change in the distribution of *de facto* political power.” Our question, in particular, is whether an institutional change (decentralization) reduces economic inequality or is instead thwarted by increased investments in political capture. We also follow Baland and Robinson (2008) and Anderson et al. (2015), among others, in associating land ownership in developing countries with political power or influence, although our mechanism (rent-seeking) is distinct from theirs (clientilism).

The next section of the paper presents the institutional backdrop and data for our analysis. Section 3 develops the model of corruption and rent-seeking along a canal system. Section 4 lays out the empirical methodologies and presents the main impacts of irrigation management reform in Punjab. Section 5 turns to the empirical analysis of power asymmetry along a channel and how it interact with decentralization. Section 6 concludes the paper.

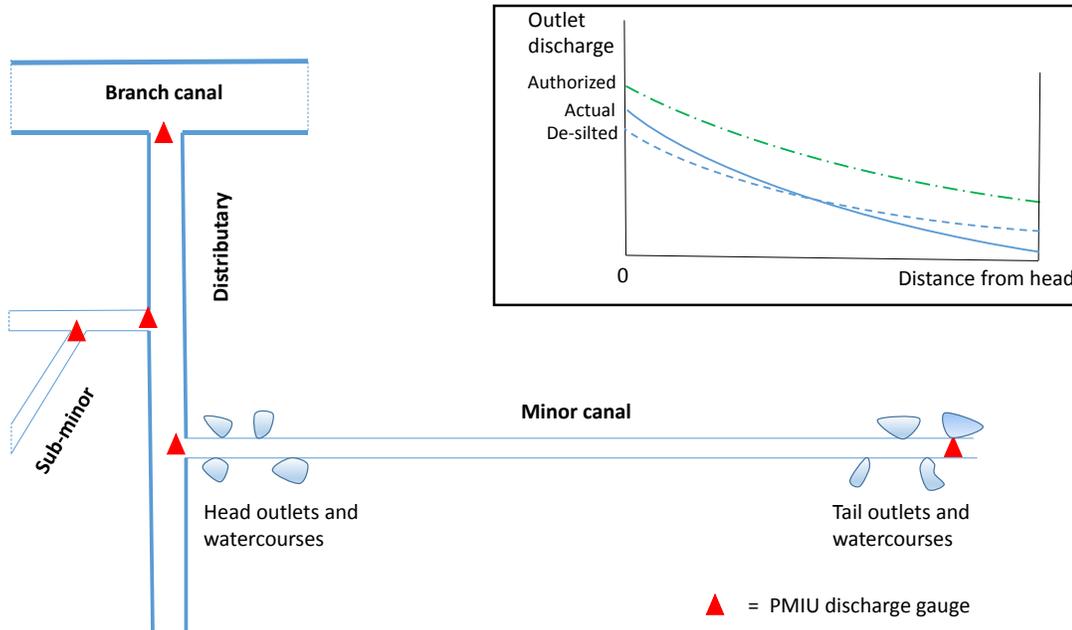


Figure 1: CHANNEL SCHEMATIC WITH DISCHARGE GAUGES

2 Context and Data

2.1 Indus Basin irrigation system

The Indus Basin irrigation system, which accounts for 80% of Pakistan’s agricultural production, lies mostly in its most populous province, Punjab, wherein it encompasses 23 thousand miles of canals and irrigates about 21 million acres. From the Indus, Jhelum, Chenab, Ravi, and Sutlej rivers, issue a dense network of main canals, branch canals, distributaries, minors, and sub-minors, ultimately feeding 58 thousand individual watercourses in Punjab alone (See Figure 1 for a schematic of the canal hierarchy.).

Each watercourse outlet or *mogha* supplies irrigation to typically several dozen farmers according to a rotational system known as *warabandi*. Tracing its origins to British colonial rule and to the early development of irrigation in the Indus basin, the institution of *warabandi* (literally “fixed turns”) embodies a modified principle of equity: to each irrigator in propor-

tion to his cultivated area. As discussed below, adherence to *warabandi* leads to an efficient allocation of canal water. At each level of the canal hierarchy in this continuous gravity-flow irrigation system, “authorized discharge” is allocated in proportion to cultivable command area (CCA). At the main canal level, irrigation department staff operate a series of gates regulating flow into the off-taking distributaries according to a rotational schedule. However, since *moghas* are ungated, discharge into tertiary units, the watercourses, is determined by the width of the outlet; the greater the watercourse CCA, the greater the authorized outlet width (for a given canal discharge), and thus the greater the water in-take each week. Over the course of a week, proceeding from the head to the tail of the watercourse, each farmer takes his pre-assigned turn at using the entire flow to irrigate his field, with the length of turn proportional to the size of the field.

Although design discharge at any point along a channel accounts for seepage and conveyance losses and is therefore a declining function of distance to the head (see Figure 1 inset), tail outlets should, in theory at least, receive their full water entitlement. In practice, however, discharge at the distributary head is often too low (Bandaragoda and Rehman 1995), or the canal is too silted up, for water to reach the tail outlets. Over-silting also results in higher water levels at the channel head and, consequently, greater discharge at head outlets (Van Waijjen et al. 1997). Lack of canal maintenance, therefore, tends to favor head outlets, which may give rise to lobbying of the irrigation department by farmers at the tail outlets to increase maintenance and by those at the head outlets to suppress it. Although such manipulation is difficult to confirm,⁶ pervasive “direct” forms of water theft – i.e., tampering with outlets to increase width, siphoning off canal water with pipes, breaching of the canal banks, all undertaken with the connivance of corrupt irrigation officials – have been documented in the Indus basin (Rinaudo 2002; Rinaudo et al. 2000).

⁶Yet, one apparently widespread practice having the same effect is placing large boulders or other obstructions in the bed of a minor canal to increase flow at the head.

2.2 Irrigation management reform

Administratively, Punjab’s irrigation System is divided into 17 Circles (see Appendix Figure B.1). As part of the reform, Area Water Boards (AWBs) were established at the Circle level with the responsibility of promoting the formation of FOs covering every water channel within the Circle, with the FOs themselves tasked with the operations and management of distributaries and their off-taking channels. In particular, an FO is responsible for monitoring the rotational system to ensure equitable allocation along the distributary, for mediating and reporting water-related disputes among its irrigators, and for collecting water taxes to fund canal operations and maintenance. Five AWBs in what we will refer to as “FO Circles” were initially sanctioned to form FOs. Subsequent roll-out to the remaining 12 Circles has been indefinitely delayed by concerns about FO performance.

The formation of an FO involves the following steps: First, an outlet level chairman is elected by all landowners in each watercourse. Second, a secret ballot election is held at the level of the distributary (including off-taking channels), through which a nine-member management committee (president, vice-president, secretary, treasurer, and five executive members) is selected from among the outlet level chairmen. The management committee exercises all powers of the FO. Once elected, an FO does not start operations until its members are trained and it is registered with the AWB.⁷ Once operationalized, the FO membership remains in office for a tenure of three years, after which new elections are due. In practice, this electoral system has not functioned smoothly. Several incumbent FOs initiated legal action to remain in power and their first tenures have been extended beyond the 3-year term under court stays.

Starting from the universe of 2902 irrigation channels in the Punjab, dropping cases that either had zero discharge at the head throughout the 2006-14 period or in which the

⁷In theory, FO members were to acquire formal training related to the daily operations and management of the system and be provided with ongoing institutional support. However, despite detailed rules and regulations to this effect, training and capacity building efforts stalled after the pilot phase in LCC East.

overseeing FO included a larger branch canal (3 FOs in all), leaves 2860 channels. Of these, 1007 are in FO Circles, covered by 394 FOs, and 1853 are in non-FO Circles. The excess of channels over FOs in the former case reflects the fact that most distributaries have off-taking minors (and sub-minors) for which we also have discharge data. A distributary-level FO manages all of these minor canals as well. Appendix Table B.1 presents descriptive statistics for all channels by FO status of the Circle. Across design features (number and location of outlets, position along parent channel), FO and non-FO circles look quite similar.

Table 1: Timeline of FO Operationalization

Circle	Number of		Proportion of channels in Circle								
	Channels	FOs	2006	2007	2008	2009	2010	2011	2012	2013	2014
LCC East	229	84	0.96	0.96	0.96	0.96	0.96	0.73	0.84	0.85	0.68
LCC West	195	73	1.00	1.00	0.97	0.97	0.98	0.98	0.98	0.98	0.74
Bahawalnagar	140	67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.59
LBDC	221	52	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00
Derajat	222	120	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Notes: Figures in the shaded cells are the proportion of channels in a Circle-year under the predominant form of institutional control (by *majority* of channels). Colors of shading indicate predominant institution; i.e., Red=Irrigation department, Blue=FO (first tenure), and Green=FO (second tenure). Thus, for example, in 2011 167 (73% of 229) channels in LCC East were in their second FO tenure.

Table 1 gives a timeline of FO operationalization in each of the Circles where they have been formed. From 2006 to 2014, FOs in LCC East and LCC West had completed one full tenure and started their second tenures, while FOs in Bahawalnagar, LBDC, and Derajat were in their first tenure. We do not have pre-reform data for LCC East because FOs there began their first tenure just prior to 2006. Also, because of delays in the election process, there was an interregnum between the two FO tenures in both LCC East and West. During this period, control of the channels reverted back to the irrigation department under a caretaker administration. Finally, note that legal action (court stays) extended the first tenure of 27 FOs (82 channels) in Bahawalnagar and extended the second tenure of 41 FOs (117 channels) in LCC East. An empirical concern addressed below is that these extensions may have occurred precisely in FOs where rent-seeking was intensifying.

2.3 Canal water discharge data

Punjab Irrigation department’s Program Monitoring and Implementation Unit (PMIU) has maintained daily records of authorized (designed) and *actual* discharge at the head and tail of each channel since 2006. Figure 1 illustrates the typical location of PMIU discharge gauges. Since tail discharge is measured at the last watercourse outlet of the channel, design discharge at the tail is never zero; all sanctioned outlets are entitled to off-take canal water. We construct a version of the *delivery performance ratio* or DPR (see, e.g., Waijjen et al. 1997) for the economically most important *kharif* (summer) season, which runs from mid-April to mid-October. During *rabi* season, from November to March, 42% of channels in Punjab are dry. Letting d index days and t index year, define

$$DPR_{it}^j = \frac{\sum_{d \in t} Q_{id}^j}{\sum_{d \in t} \bar{Q}_{id}^j} \quad (1)$$

for $j = H(ead), T(ail)$, where Q_{id}^j is daily discharge at position j of channel i and \bar{Q}_{id}^j is the corresponding authorized daily discharge.

Figure 2 shows how head and tail DPRs vary across years for all channels in the 5 FO Circles and 12 non-FO Circles.⁸ Two key facts emerge: First, the Indus basin irrigation system consistently under-provides surface water relative to its design parameters; i.e., the ratio of actual to authorized discharge is substantially less than one for the entire 8 year period. Second, the water shortfall is *greater* at the tail than at the head. To understand the greater water shortfall at the tail, recall that under the quota-based *warbandi* system each watercourse gets a share (in terms of irrigation hours) of flow into the channel. Thus, if discharge measured at the head gauge of the channel is, say, 80% of authorized over the whole season, then each outlet along that channel, including the very last one where tail

⁸Even though a channel is in an FO Circle, it may not actually come to be managed by an FO until as late as 2013 (see Table 1).

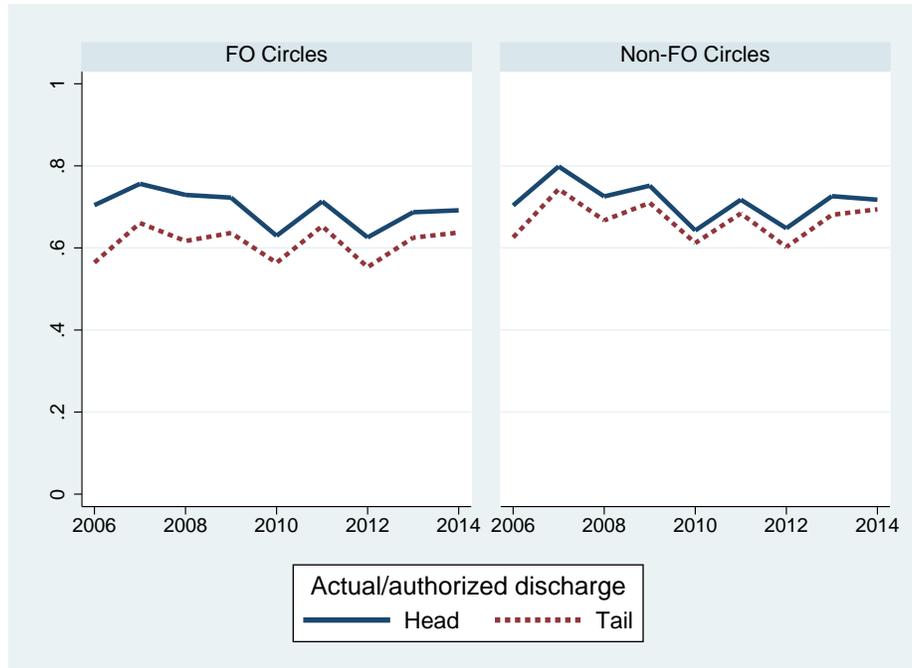


Figure 2: HEAD AND TAIL DPRS BY YEAR FOR FO AND NON-FO CHANNELS

discharge is measured, would automatically receive 80% of its water entitlement or design flow. If, however, upstream outlets are enlarged or the canal is breached or silt is not removed in a timely manner, then off-take per hour at the head is increased and relatively less water makes its way to the tail of the channel over the course of the season; for any given value of DPR^H , there is a lower value of DPR^T .

As noted earlier, however, water theft in its various forms is not the only reason for differential shortages at channel tails. Fluctuation in the flow of water into the channel *during the week* also disrupts the *warabandi* schedule. Absent a continuous discharge throughout the week at the head, the channel would not remain full and tail outlets would not receive water. To examine this issue, we again use the daily data to construct the coefficient of variation (CV) of weekly discharge at the head of each channel. Note that we take the intertemporal variance of weekly discharge *within each kharif* season so that CV varies by both channel and year. Figure 3 shows a strong positive relationship between tail shortage,

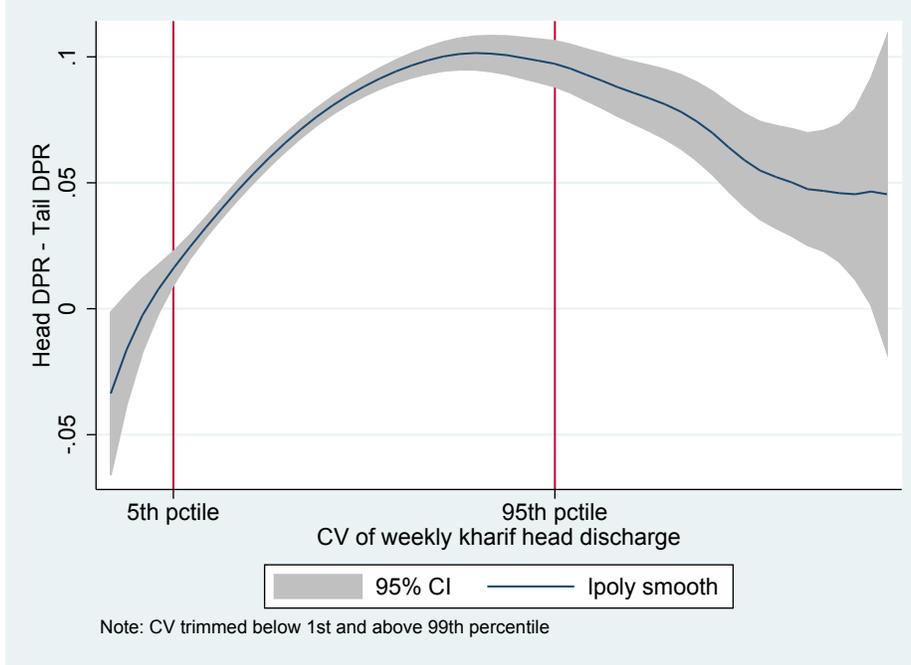


Figure 3: HEAD-TAIL DIFFERENCES IN DPR AS A FUNCTION OF CV

defined as

$$TS_{it} = DPR_{it}^H - DPR_{it}^T \quad (2)$$

and the variability of seasonal discharge across most of the range of CVs. It is, therefore, important to control for CV in the empirical analysis.

Returning to Figure 2, the average tail shortage across all channels and years is twice as large in FO Circles (0.096) as in non-FO Circles (0.048). Since this gap is not attributable to differences in average CVs between FO and non-FO Circles, which are negligible, it appears that water theft is more prevalent in FO Circles. However, inferring anything about the causal impact of FOs is premature. Indeed, the pattern could reflect selection; i.e., reforms may have been initiated in areas where water theft was most pervasive to begin with.

3 Conceptual Framework

3.1 Centralized bureaucracy versus decentralization

Modelling public service delivery *both* under centralized bureaucracy and under local governance using a common theoretical apparatus poses a distinct challenge. In perhaps the only attempt to do so,⁹ Bardhan and Mookherjee (2006a) consider a bureaucratic hierarchy engaged in rent extraction under asymmetric information and compare it against a local elected government captured by elites. Decentralization “shifts control rights away from bribe extractors to those who respond to the interests of local users, owing to electoral pressures. However, they respond with a bias in favour of local elites” (p. 110). Bribe-taking is, consequently, replaced by biased fiscal transfers.

Bardhan and Mookherjee’s conceptualization of bureaucracy ignores the disciplining power of career concerns. In a companion paper (Jacoby and Mansuri 2017), we develop a model of canal water allocation in the presence of corruptible irrigation department officials motivated by a dismissal or transfer threat. Here, we extend the model to cover the case of FO-managed channels. Under either form of management, corruption generates winners (farmers at the head of the channel) and losers (farmers at the downstream outlets) who receive less water than they are entitled to. Rent-seeking arises as these winners and losers lobby the powers-that-be to intercede on their behalf. To highlight the role of institutional structure, the only difference between centralized and decentralized systems lies in the incentive for corruption, which, in equilibrium, affects the incentive for rent-seeking.

⁹Hoffmann et al. (2017) examine political allocations under centralized and decentralized structures when home constituencies are favored. However, there is no bureaucratic hierarchy in the model.

3.2 Model preliminaries

Assume a continuum of outlets along a channel indexed by $n \in [0, N]$, with $n = 0$ representing the first outlet at the head of the channel and $n = N$ the last outlet at the tail of the channel. Suppose that each outlet has the same command area, normalized to one, and hence the same *de jure* endowment of water w_0 . The *de facto* inflow of water to each outlet is given by the function $w(n)$, which for the channel as a whole is constrained by

$$\int_0^N w(n)dn = Nw_0. \quad (3)$$

Agricultural output depends on water per acre cultivated, but with diminishing marginal product.¹⁰ The demand schedule for water $D(w)$ is, therefore, downward sloping ($D' < 0$ for $\forall w$). Suppose further that $D(w_0) > 0$ and that surplus from off-take w is

$$s(w) = \int_0^w D(w)dw. \quad (4)$$

So, the *de jure* allocation has a positive marginal value and confers a collective surplus or total value of $s_0 = s(w_0)$ to farmers on the outlet.

The efficient allocation of canal water along a channel maximizes

$$\int_0^N s(w(n))dn \quad (5)$$

subject to (3), which requires that $D(w(n))$ be equal across outlets. The *de jure* allocation, with $w(n) = w_0 \forall n$, is thus efficient and deviations from equal per acre allocations, such as those discussed below, create deadweight losses.¹¹

¹⁰Output, of course, also depends on purchased inputs such as seed and fertilizer, but to the extent that these are optimally chosen and that their prices do not vary along a channel, the presence of such complementary (to water) investments will not affect our analysis.

¹¹Chakravorty and Roumasset (1993) point out that equal per-acre allocation along a canal is not necessarily efficient once conveyance losses—i.e., water seepage into the channel itself—are taken into account. They

3.3 Theft and corruption

Assume that canal water at each outlet is appropriated until its marginal value is zero subject to availability. Since water arrives first at the head of the channel, outlets at the head have first-mover advantage; some outlets at the tail must, therefore, get no water. Define outlet off-take \hat{w} such that $D(\hat{w}) = 0$ and the ‘critical’ outlet \hat{n} by $\hat{n}\hat{w} = Nw_0$ (using equation 3). Thus, all outlets $n \in [0, \hat{n}]$ off-take $\hat{w} - w_0$ in excess of their legal entitlement and receive surplus $\hat{s} = s(\hat{w})$, whereas all outlets $n \in (\hat{n}, N]$ receive no water and get zero surplus.

Now, consider the role of an authority, such as the irrigation department or an FO. While the authority could, at some cost, set $w < \hat{w}$ by restricting outlet tampering and other such violations, we assume that the amount of water theft $\hat{w} - w_0$ is, for them, a *fait accompli*. Alternatively, we may suppose that the authority (through its agent) engages in Nash bargaining with each outlet over w , which also yields $w = \hat{w}$.¹² In any case, the official of the authority accepts a bribe from each offending outlet to overlook the infraction.¹³ If the official cannot pre-commit to a bribe amount b for the entire channel, then b would also be determined at each outlet in a Nash bargain (see fn. 12) and thus set to a fixed share of *excess* surplus $\hat{s} - s_0$. However, inability to commit to a channel-level corruption plan implies that political institutions and rent-seeking can have no influence on the official’s actions. Therefore, for the sake of argument, we assume the contrary.

show that, in this case, optimal inflow at each outlet should *decline* with distance to the head. Chakravorty and Roumasset’s simulations, however, indicate that these conveyance loss effects only become quantitatively relevant for outlets at a considerable distance from the head. With a median length of 7 kilometers, the channels that we consider are, in general, too short for conveyance losses to be consequential. Moreover, these simulations overstate the effect of canal seepage in our context by not accounting for the resulting aquifer recharge, which is recovered and used productively by farmers through groundwater pumping.

¹²In particular, w would be chosen to max $[s(w) - s_0 - b]^\eta b^{1-\eta}$, where b is the bribe and η is an exogenous bargaining weight. The necessary condition for an optimum implies that $s'(w) = D(w) = 0$.

¹³Wade’s (1982, p. 297) observations from south India are apposite in this regard: “The distinction between a bribe, offered by farmers to get the [irrigation official] to do something he might not otherwise do, and extortion money, demanded by the officer in return for not inflicting a penalty, is often difficult to draw in practice.”

3.4 Rent-seeking

Water theft creates groups of winners (head outlets) and losers (tail outlets), each of which lobbies the “powers-that-be” for its desired outcome. The head coalition $C_H = \{n|n \in [0, \hat{n}]\}$ and the tail coalition $C_T = \{n|n \in (\hat{n}, N]\}$ each try to sway the authority to, respectively, continue the corruption or to end the corruption and restore the de jure water allocation. As in Tullock (1980), we assume that the probability P of C_H winning this rent-seeking contest depends on the effort level, e_j , of both coalitions $j = H, T$ as follows:¹⁴

$$P = \frac{\iota_H e_H}{\iota_H e_H + \iota_T e_T}, \quad (6)$$

where the ι_j represent the *marginal influence* of coalition j . When $\iota_H \neq \iota_T$, there is a power asymmetry along the channel; this is the sense in which intercommunity inequality matters for outcomes.¹⁵

Assuming a unitary marginal cost of effort,¹⁶ expected net surplus for C_H is

$$\begin{aligned} \pi_H &= P\hat{n}(\hat{s} - b) + (1 - P)\hat{n}s_0 - e_H \\ &= \hat{n}s_0 + P\Delta_H - e_H, \end{aligned} \quad (7)$$

where $\Delta_H = \hat{n}(\hat{s} - s_0 - b)$, and for C_T is

$$\begin{aligned} \pi_T &= (1 - P)(N - \hat{n})s_0 - e_T \\ &= (N - \hat{n})s_0 - P\Delta_T - e_T \end{aligned} \quad (8)$$

¹⁴The linearity of each player’s effort in the probability function is a standard simplification in the literature on games of rent-seeking (see Nitzan 1994).

¹⁵Insofar as some of the rent-seeking effort translates into utility for the authority, there is an incentive for whoever is in charge to *hold* a lobbying contest with non-trivial win probabilities for each side.

¹⁶This assumption, applied to lobbying effort by both head and tail coalitions, is innocuous. High (low) marginal influence ι_j is equivalent to low (high) marginal cost of effort.

where $\Delta_T = (N - \hat{n})s_0$.

We assume that each coalition chooses its rent-seeking effort taking that of the other coalition as given. Assuming an interior solution,¹⁷ $e_T = \Omega e_H$, where $\Omega = \Delta_T/\Delta_H$ is the ratio of win-loss differentials. Thus, in the Nash equilibrium, $P = \tilde{P}$, where

$$\tilde{P}(b) = \frac{\iota_H \Delta_H(b)}{\iota_H \Delta_H(b) + \iota_T \Delta_T}. \quad (9)$$

The equilibrium probability of maintaining corruption depends on each coalition's net gains from winning the lobbying contest weighted by their marginal influence. We may write equation (9) more compactly as

$$\tilde{P}(b) = \frac{\theta}{\theta + \Omega(b)}. \quad (10)$$

where $\theta = \iota_H/\iota_T$ is a parameter representing the *relative* influence of the head coalition vis-à-vis the tail coalition.

3.5 Optimal control of water theft

Bureaucracy: Bureaucracy is characterized by hierarchy; the official on the ground, directly engaged in corruption, is an agent of a higher level office. We assume that the local official is, in effect, paid an efficiency wage and thus has career concerns (see Jacoby and Mansuri 2017 and the citations therein). As long as he stays in his current position he receives bribe income $\hat{n}b$; otherwise, he receives his outside option, which we normalize to zero. Whether the local official is retained depends on the pressure exerted on the irrigation department by the contending interests along the channel. If C_H wins the lobbying contest, as described formally in the previous subsection, the corrupt official will be retained, whereas if C_T wins, the official will be ‘detected’ and reassigned (or fired). For simplicity, we suppose that once the corrupt official leaves, he is replaced, at least temporarily, by a non-corrupt

¹⁷For sufficiently low ι_T , $e_T = e_H = 0$ is optimal and political influence plays no role in water allocation.

regime under direct irrigation department oversight.¹⁸

The local official chooses his bribe b for the channel to maximize expected income

$$V_B(b) = \tilde{P}(b)\hat{n}b. \quad (11)$$

Thus, the official faces a trade-off between greater bribe income, on the one hand, and a higher *equilibrium* probability of retaining his position, on the other. In particular, the higher the bribe, the less net surplus is available to head outlets and, hence, the less effort their coalition exerts to retain the official.

Farmer Organizations: While FO officials are assumed to be just as corrupt as the local irrigation department officials, their objective function differs in a key respect. Under bureaucratic control, lobbying is directed upward, to the office with the authority to fire or transfer the corrupt official. In a decentralized structure, farmers lobby the FO and at least part of this lobbying *directly* benefits FO officials. Decentralization thus breaks the separation between corruption and rent-seeking that prevails in the bureaucratic hierarchy.

Suppose that the FO receives utility $u(b) = U(e_T(b) + e_H(b))$ from the total rent-seeking effort expended. We may think of u as the perks of power or the value of political support to remain in power or to be reelected, or all three. The FO chooses b to maximize

$$V_F(b) = \tilde{P}(b)\hat{n}b + u(b). \quad (12)$$

V_F combines the local irrigation official's objective V_B with that of the higher-level department office, which we previously could (and did) ignore. Importantly, since $u' < 0$ (higher bribes, by curtailing total rent-seeking effort, make the FO worse off), the FO official has *lower* marginal corruption incentives than the irrigation official and, hence, charges a lower

¹⁸Again, it would be in the interest of the irrigation department to provide for such a (credible) regime precisely to extract rents through the lobbying contest (see fn. 15).

bribe (see lemma 1, Appendix A).

3.6 Implications of decentralization

Our outcome variable, tail shortage, is the *expected* difference in water available at the first and last outlet of a channel. In terms of the model, $TS_r = \tilde{P}(b_r)(\hat{w} - 0) + [1 - \tilde{P}(b_r)](w_0 - w_0) = \tilde{P}(b_r)\hat{w}$, where $r = B, F$ denote bureaucracy and FO, respectively. The model yields three results (see Appendix A for proofs):

Proposition 1. $TS_F > TS_B$

This result says that water theft increases after decentralization, or $\Delta TS = TS_F - TS_B > 0$. Intuitively, the bribe amount falls under FO authority because, as noted, the marginal incentives for bribery are reduced. Water theft, however, is *decreasing* in the bribe amount, because higher bribes reduce head outlets' surplus and, hence, their support for the status quo (so \tilde{P} must fall).

Next, we have that decentralization increases water theft by more on channels along which head outlets are relatively powerful; i.e., along those with high θ :

Proposition 2. $\frac{\partial \Delta TS}{\partial \theta} > 0$.

Essentially, theft responds more to political influence when bribes are low (i.e., under FOs).¹⁹

Lastly, we have a symmetry result following directly from the definition $\theta = \iota_H / \iota_T$:

Proposition 3. $\frac{\partial \Delta T}{\partial \log \iota_H} = -\frac{\partial \Delta T}{\partial \log \iota_T}$.

A one percent increase in head influence has an equivalent effect on the change in tail shortage as a one percent decrease in tail influence.

In the remainder of the paper, we take these implications of decentralization to the data.

¹⁹Jacoby and Mansuri (2017) prove that $\partial TS(b_B) / \partial \theta > 0$ so that water theft is increasing in θ under both irrigation department and FO authority.

4 Main Impact of Irrigation Reform

4.1 Pipeline strategy

Our baseline regression model for tail shortage, exploiting the pipeline variation, is

$$Y_{it} = \alpha_1 \tau_{it}^1 + \alpha_2 \tau_{it}^2 + \beta \log CV_{it} + \mu_i + \delta_t + \gamma_c t + \varepsilon_{it} \quad (13)$$

where the τ_{it}^j are indicators for whether channel i is in the midst of its first ($j = 1$) or second ($j = 2$) FO tenure during *kharif* season of year t . As noted, we control for the seasonal CV of weekly head discharge as well as for channel fixed effects, μ_i , which sweep out permanent channel characteristics, including those correlated with the likelihood of receiving an FO earlier rather than later. We also include year dummies δ_t and Circle-specific time-trends, as represented by the penultimate term in equation (13). Difference-in-differences (or fixed effects) estimation of treatment effects is typically predicated on the parallel trends assumption, which is to say that, absent intervention, average outcomes would have evolved similarly for both treatment and control groups. Here, with the exception of LCC East, which has no pre-reform observations (see Table 1), we are able to estimate separate time trends, γ_c , for each FO Circle. Thus, we directly control for differential pre-intervention time trends across the unit of policy choice (recall that Area Water Boards for the formation of FOs were established at the Circle level).

4.2 Pipeline results

Results for the pipeline approach using all channel-years (Table 2, column 1) indicate that the first FO tenure significantly *increased* tail shortage. The average treatment effect estimate of 0.063 translates into 68% of the average pre-reform tail shortage across all FO channels and years (0.092). Thus, the irrigation reform worsened discharge at the tail relative to

Table 2: Baseline Treatment Effect Estimates – Pipeline Strategy

	(1)	(2)	(3)	(4)
1st FO tenure (α_1)	0.0628*** (0.00743)	0.0532*** (0.00766)	0.0620*** (0.00750)	0.0636*** (0.00753)
2nd FO tenure (α_2)	0.00614 (0.0114)	0.00728 (0.0191)	0.00483 (0.0114)	-
F -test $\gamma_c = 0$	17.7***	21.5***	19.4***	17.9***
p -value $\alpha_1 = \alpha_2$	0.000	0.034	0.000	-
R^2 (within)	0.101	0.105	0.104	0.107
No. of observations	8,826	6,799	8,634	7,989
Number of channels	1,003	775	1,003	1,003
Number of FOs	396	312	396	396

Notes: Robust standard errors in parentheses (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.1$), clustered on FO. Dependent variable in all specifications is tail shortage $Y = DPR^H - DPR^T$. All specifications include controls for $\log(\text{CV})$ of weekly discharge, channel fixed effects, year dummies, and Circle-specific time trends. Guide to specifications: (1) All channel-years; (2) Drops LCC East; (3) Drops cases of FO tenure extended by court-stay; (4) Drops all channel-years in second FO tenure.

the head by around two-thirds of the original gap, presumably by exacerbating water theft. Recall that we are controlling for the other major determinant of tail shortage, namely the variability of discharge into the channel as measured by weekly discharge CV at the head.

The Circle-specific time trends are strongly significant (net of year dummies), as indicated in Table 2. However, we are not able to allow for a separate time trend for LCC East, as this FO Circle has no pre-treatment observations. To make sure that LCC East is not driving our results as a consequence, we drop all observations from this FO from the estimation in column 2. Comparison to column 1 reveals that lack of pre-trends for LCC East is not a serious lacuna.

The pipeline results imply no discernible effect of the second FO tenure. Although the standard error on the second tenure coefficient is about 50% larger than that on the first tenure coefficient, lack of precision is clearly not the whole story since we can still strongly reject the equality restriction $\alpha_1 = \alpha_2$. As noted, however, FOs had their second tenures

in only two of the five FO circles (see in Table 1); in fact, 84% of these observations are from LCC East, which, recall, was intended to be a showcase for the irrigation reform. Additionally, as also noted, a large proportion of second tenures in LCC East were extended by court stays. To check robustness against the concern that FO tenures were endogenously extended by legal action, we drop all such channel-year observations (whether in the first or second FO tenures) in column 3. The results are virtually unchanged. Finally, in the last column of Table 1, we present the estimate for the first FO tenure treatment effect when all second tenure observations are dropped. Again, there is essentially no difference between this specification and that in column 1.

4.3 Spatial matching strategy

Before setting out the regression model for use with spatially matched controls, we discuss our GIS buffer strategy. A buffer is a locus of GIS coordinates equidistant from each coordinate of an FO channel. Spatial matching consists in finding the set of channels from non-FO Circles that lie entirely within a buffer of given radius. Figure 4 illustrates a 40 kilometer buffer for a channel in Bahawalnagar Circle along with one particular control channel, of which there are typically many.²⁰

The choice of radius for the GIS buffer presents a tradeoff. The smaller the radius, the more similar treatment and control channels are likely to be along unobserved dimensions (given spatial correlation in these unobservables). However, a smaller radius also implies a smaller likelihood of finding *any* channels lying both within the buffer and within an adjacent non-FO Circle. A radius of 40 km, in particular, leads to a sample consisting of 302 FOs covering 747 channels, with 915 non-FO channels as controls (but each of these typically appearing in many buffers). Thus, the choice of 40 km radius implies a loss of 94 of our

²⁰There are no GIS shape files for Circle borders, so we cannot match on the basis of distance to these administrative boundaries.

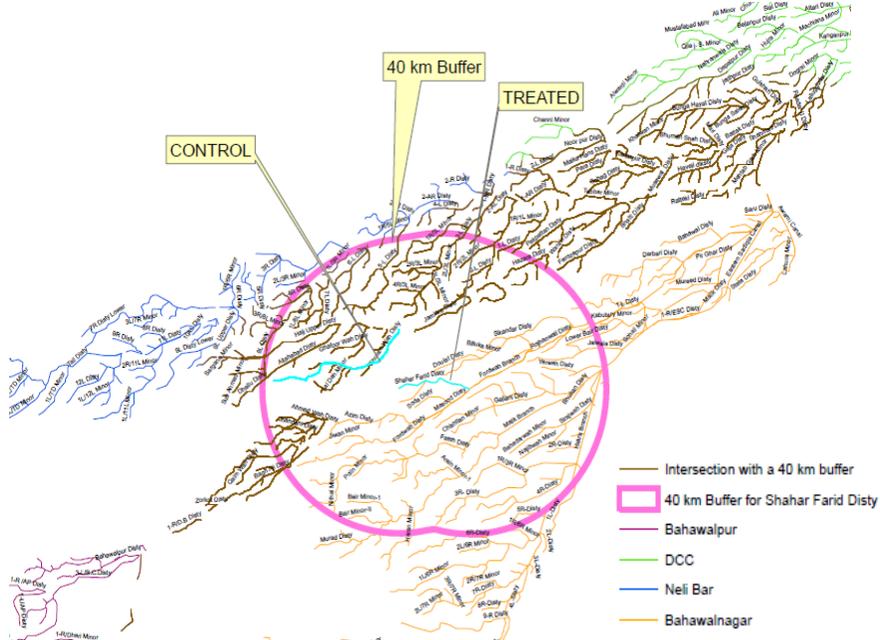


Figure 4: EXAMPLE OF 40 KM BUFFER FOR SPATIAL MATCHING

original 396 FOs in the sense that we do not have spatially matched controls for them. By contrast, moving to a 60 km buffer radius matches 348 FOs covering 883 channels (with 1233 non-FO control channels). But shrinking the buffer radius down to 20 km nets only 130 FOs covering a mere 351 channels; since we believe that this is too few to constitute a useful sample, we do not pursue the 20 km buffer strategy.

Indexing buffers by subscript b , our regression model becomes

$$Y_{ibt} = \alpha_1 \tau_{it}^1 + \alpha_2 \tau_{it}^2 + \beta \log CV_{it} + \mu_i + \gamma_c t + \phi_{bt} + \varepsilon_{ibt} \quad (14)$$

where ϕ_{bt} is a buffer-year fixed effect.²¹ To understand the source of identifying variation in equation (14), let us simplify the model so that we have just two time periods, before and after reform. First-differencing over time for each channel in this case is equivalent to

²¹Due to the high dimensionality of both the channel and buffer-year fixed effects, we must estimate equation (14) using an iterative technique (Guimaraes and Portugal, 2010).

channel fixed effects and yields

$$\Delta Y_{ibt} = \alpha_1 \Delta \tau_{it}^1 + \alpha_2 \Delta \tau_{it}^2 + \beta \Delta \log CV_{it} + \gamma_c + \tilde{\phi}_b + \Delta \varepsilon_{ib}, \quad (15)$$

where $\tilde{\phi}_b$ is a buffer fixed effect. Thus, the average treatment effect of an FO tenure is identified off of *within buffer* variation in channel-level discharge differences (pre/post) between FO and non-FO channels that lie in adjacent FO and non-FO Circles, respectively. In contrast to the pipeline approach, *the spatial matching estimator uses none of the variation in the timing of reform across FO Circles*; this is for the simple reason that, by construction, a given buffer only contains channels from one FO Circle. Note that, because they are based on different samples, regression models (14) and (13) are not nested and, hence, cannot be readily tested against one another.

Finally, even though the general time-pattern of tail shortage is absorbed in the buffer-year fixed effects included in equation (14), Circle-specific trends γ_c are still identified because FOs from the same Circle appear in many different buffers. Indeed, it is important to control for Circle-specific trends since it is conceivable that tail shortages in FO Circles and in adjacent non-FO Circles were not on parallel trajectories prior to decentralization.²²

4.4 Spatial matching results

²²Our analysis of pre-trends in the three late-reforming FOs (Bahawalnagar, LBDC, and Derajat; see Table 1) is summarized in Appendix Figure B.2. While parallel trends between these FOs and all non-FO channels from 2006-2010 can be formally rejected, this is no longer the case when 2006 data are dropped. Below, therefore, we check our estimates for robustness to the removal of 2006 observations.

Table 3: Baseline Treatment Effect Estimates – Spatial Matching

	40 km buffer				60 km buffer			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1st FO tenure (α_1)	0.0480*** (0.00881)	0.0478*** (0.00882)	-	0.0520*** (0.00866)	0.0441*** (0.00864)	0.0439*** (0.00864)	-	0.0462*** (0.00849)
2nd FO tenure (α_2)	0.0505*** (0.0169)	0.0504*** (0.0169)	-	-	0.0369*** (0.0141)	0.0367*** (0.0140)	-	-
FO tenure ($\alpha_1 = \alpha_2$)	-	-	0.0485*** (0.00806)	-	-	-	0.0425*** (0.00743)	-
F -test $\gamma_c = 0$	6.8***	6.8***	7.1***	6.2***	7.2***	7.2***	7.8***	7.0***
p -value $\alpha_1 = \alpha_2$	0.894	0.888	-	-	0.658	0.663	-	-
R^2 (within)	0.601	0.601	0.601	0.601	0.570	0.570	0.570	0.571
Observations	223,109	222,970	223,109	222,508	674,296	674,121	674,296	673,517
Number of clusters	751	751	751	751	916	916	916	916
Number of FOs	302	302	302	302	348	348	348	348

Notes: Robust standard errors in parentheses (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.1$), clustered on FO/distributary (distributary for non-FO channels). Dependent variable in all specifications is tail shortage $Y = DPR^H - DPR^T$. All specifications include controls for log(CV) of weekly discharge, channel fixed effects, buffer-year fixed effects, and Circle-specific time trends. Guide to specifications: (1,5) All channel-years; (2,6) Drops cases of FO tenure extended by court-stay; (3,7) Constrains $\alpha_1 = \alpha_2$; (4,8) Drops all channel-years in second FO tenure.

The spatial matching strategy yields estimates of the first FO tenure treatment effect that are similar in magnitude to those from the pipeline strategy, regardless of whether we adopt a 40 km (Table 3, column 1) or a 60 km (column 5) buffer radius. Relative to the pre-reform scenario in FO Circles, the first tenure effects imply a 52% (40 km buffer) and 48% (60 km buffer) increase in tail shortage. In contrast to the pipeline case, however, the second FO tenure effects here are statistically significant and of similar magnitude to the first tenure effects, so that we cannot reject the equality restriction $\alpha_1 = \alpha_2$. Moreover, none of these results depends on the inclusion of the potentially suspect observations involving court stays (cols. 2 and 6). The rest of Table 3 reports specifications that restrict first and second FO tenure effects to be equal (columns 3 and 7) and specifications that drop channel-years in second FO tenures altogether (columns 4 and 8). All of these various treatment effects are within a range of 10% of each other, i.e., well within a single standard error.²³

4.5 Discussion

Two distinct panel data strategies have yielded broadly consistent findings: Irrigation reform in Punjab increased tail shortage initially (i.e., in the first FO tenure) by at least 50% relative to the pre-reform baseline. Since, as we have argued, the efficient allocation of canal water involves *zero* tail shortage, decentralization had a social cost. In other words, the takeover by FOs could not both accentuate head-tail inequality in canal water *and* (through side-payments) lead to a Pareto improvement of welfare. While we cannot compute the social cost directly, outlet-level data on land values from Punjab (see Jacoby and Mansuri 2017) allow us to infer that the wealth redistribution was substantial; in particular, the reform

²³Equality of Circle-specific time-trends can also be rejected in all specifications. Note, as well, that dropping observations from 2006, thereby rendering parallel the pre-trends in FO and non-FO circles (see fn. 22), does not appreciably affect our results (the estimate of α_1 in specification (5) falls to 0.041 (0.009) and that of α_2 falls to 0.030 (0.014)).

increased the value of head-end land by about 9% *relative* to the value of tail-end land.²⁴

Evidence on the second FO tenure, which is far less frequent in the data than the first tenure, is not as clear-cut. Results depend importantly upon the estimation strategy, which is to say upon the comparison group. When the comparison group consists of channels in other FO circles in the same years that were not in their second FO tenures (pipeline strategy), we find no effect of second FO tenure. But, when the comparison group is non-FO channels lying in the same 40 or 60 km buffer, we find a positive effect on tail shortage; in particular, we cannot reject the null that first and second tenure effects are identical. Since there is no theoretical reason to suggest that these effects *should* differ, we will rely on the spatial matching strategy in the analysis to follow.

5 Role of Political Influence

Under what conditions will decentralization produce more equitable allocations? Our theoretical model formalizes the political process at the canal level as a rent-seeking contest between rival coalitions of irrigators. Asymmetry of political influence (θ) thus affects the outcome of irrigation reform. The empirical challenge is to measure the *relative* influence of outlets at the head versus those at the tail. In Pakistan, the natural proxy for political power is land ownership.²⁵ Despite active tenancy markets, land sales markets are thin in Pakistan, with the vast bulk of ownership transferred through inheritance. As a consequence, the local distribution of land ownership can be seen as both stable and as largely independent of the

²⁴The data come from a survey of around 4000 outlets along 470 non-FO channels in Punjab. Within the same channel, land at the head is valued at a 11.1% premium over land at the tail. Moreover, the *DPR* on these same channels (averaged over 2012-14) is higher by 0.055 at the head than at the tail. Assuming, plausibly, that the entire head-tail land value differential is attributable to variation in canal water availability, a treatment effect of 0.044 is tantamount to a $11.1 \times 0.044/0.055 = 8.9\%$ increase in relative land values.

²⁵In Jacoby and Mansuri (2017), we use both landownership and political/bureaucratic/hereditary office-holding as proxies for political power. However, because the latter variables are only available for 470 non-FO channels in Punjab, they are excluded from the present analysis.

distribution of farmer productivity or soil fertility (factors which are, at any rate, purged from our regression specifications using channel fixed effects).

5.1 Land ownership data and *mouza* matching

We use data from four Agricultural Censuses (1980, 1990, 2000, and 2010) to characterize the distribution of landownership along Punjab’s irrigation channels. Since Pakistan carries out a “sample census,” about 13% of villages (*mouzas*) are covered in any given round (and 9% of households), yielding roughly 3500 villages per round with considerable overlap across rounds. Thus, between 1980-2010, nearly 7700 unique villages appear in the Agricultural Census. Given the relative stability of the land ownership distribution over time, we treat the most recent observations on all of these villages equally for the purposes of constructing our aggregates.²⁶ Irrigated villages from the census are matched to their corresponding canal *outlets* using village-outlet lists supplied by the Punjab irrigation department. Following irrigation department designation, head villages are defined as those that match to outlets on the upper 40% by length of a given channel; tail villages as those that match to outlets on the lower 20%.

We compute land ownership statistics by position on the channel. For instance, mean landholdings at the head is a household (population weighted) average based on unit record data from all irrigated census villages that match to head outlets; likewise, for mean landholdings at the tail.²⁷ To the extent that large landowners are the dominant source of political influence, we compute the 90th percentiles of land ownership, in addition to the means, at each channel position. Since the Agricultural Census does not provide household landownership broken down by irrigated and rain-fed areas, even though it is the former that is most germane to the lobbying effort along a channel, we deflate household landownership

²⁶To the extent that land ownership data from the 1980s and 1990s are dated, they introduce measurement error biasing against finding (differential) treatment effects.

²⁷We drop any channel-position with fewer than 20 household level observations.

by the ratio of cultivated area under irrigation to total cultivated area in the *mouza*.

Note that the Agricultural Census samples all types of households within each *mouza*, whether cultivating or not and whether they own land or not. Arguably, the population of cultivators and/or landowners is most relevant for the political-economy of irrigation. Since non-cultivating households without land should have little, if any, influence with the FO, or with the irrigation department for that matter, this population might reasonably be excluded in calculating channel position-level land statistics. On the other hand, including these non-farm households could have an important scaling function. For example, a community of a hundred households each owning a hundred acres is likely to have more influence than a community consisting of just a single hundred-acre farm surrounded by 99 non-farm households; yet, mean landholdings *across farm households* is identical in these two communities, whereas mean landholdings *across all households* is indeed higher in the presumptively more powerful one. Of course, if the second community, instead, consisted of a hundred hundred-acre farms and a hundred non-farm households, the mean across all households would imply that the second is less powerful than the first when it is, in fact, equally powerful. In this case, using the means across farm households would (correctly) imply communities with identical lobbying influence. In short, for our purposes, there is no unambiguously valid choice of population over which to compute land ownership statistics. Prudence, therefore, dictates using both approaches.

Because the four rounds of sample census data are not everywhere dense in villages, we are not able to match *both* head and tail *mouzas* for every channel. Our analysis of power asymmetry is, thus, based on fewer FOs than were present in the baseline samples. For the 60 km spatial matching sample, the number of FOs covered falls from 349 to 247, when land statistics are taken over only farm households, and to 252, when land statistics are taken over all census households.²⁸ There is also a modest (positive) correlation between land

²⁸Of the 247 FOs represented in the former case, 15% are in Bahawalnagar Circle, 29% are in Derajat,

ownership statistics at head and tail of the same channel (see Appendix Figure B.3), which is why these variables must be included together in the regressions.

5.2 Heterogeneity results

With these considerations, we now specify a mapping from the land distribution at position j of the channel to relative political influence of the form $\iota_j(L) \propto \exp(L)$. Thus, if we choose to represent the distribution of landholdings by the mean, \bar{L} , we would have $\log \theta_i = \bar{L}_{iH} - \bar{L}_{iT}$, where \bar{L}_{ij} , $j = H, T$, is mean landownership on position j of channel i . Taking the spatial matching case, the augmented specification (dropping second FO tenure effects) is

$$Y_{ibt} = \alpha_1 \tau_{ibt}^1 + \delta_H \tau_{ibt}^1 \bar{L}_{iH} + \delta_T \tau_{ibt}^1 \bar{L}_{iT} + \beta \log CV_{it} + \mu_i + \gamma_c t + \phi_{bt} + \varepsilon_{ibt}. \quad (16)$$

Under the symmetry restriction $\delta_H = -\delta_T$ (see Proposition 3), this regression is equivalent to interacting the treatment dummy with $\log \theta_i$. Symmetry, however, implies that head outlets obtain just as much additional influence over allocations at the margin from (say) one acre higher mean landownership at the head as from one acre *lower* mean landownership at the tail. Although this restriction emerges from our simple model of rent-seeking and the assumption that $\iota_H(\cdot) = \iota_T(\cdot)$, we would rather test $\delta_H = -\delta_T$ than impose it a priori.

17% are in LBDC, 21% are in LCC East, and 17% are in LCC West. The corresponding breakdown across all 396 FOs in Punjab is 17%, 30%, 13%, 21%, and 18%. In line with this similarity in composition, main treatment effects are very close to those in Table 3 when estimated on the smaller samples of channels with land data (results available upon request).

Table 4: Influence Asymmetry and FO Performance

	Census Farm Households				All Census Households			
	Mean		90 th percentile		Mean		90 th percentile	
$\tau^1 (\alpha_1)$	0.0502** (0.0212)	0.0547*** (0.0109)	0.0547*** (0.0197)	0.0551*** (0.0109)	0.0647*** (0.0183)	0.0578*** (0.0107)	0.0662*** (0.0204)	0.0574*** (0.0108)
$\tau^1 \times \bar{L}_H (\delta_H)$	0.00558** (0.00230)	-	0.00181 (0.00117)	-	0.00834** (0.00357)	-	0.00343** (0.00157)	-
$\tau^1 \times \bar{L}_T (\delta_T)$	-0.00466 (0.00319)	-	-0.00178 (0.00111)	-	-0.0107** (0.00473)	-	-0.00460** (0.00208)	-
$\tau^1 \times (\bar{L}_H - \bar{L}_T)$	-	0.00518*** (0.00194)	-	0.00179** (0.000842)	-	0.00933*** (0.00308)	-	0.00388*** (0.00130)
p -value $\delta_H = -\delta_T$	0.810	-	0.984	-	0.657	-	0.636	-
R^2	0.571	0.571	0.571	0.571	0.570	0.570	0.570	0.570
No. of Obs.	586,417	586,417	586,417	586,417	602,425	602,425	602,425	602,425
No. of clusters	892	892	892	892	909	909	909	909
No. of FOs	247	247	247	247	252	252	252	252

Notes: Robust standard errors in parentheses (***) $p < 0.01$, (**) $p < 0.05$, (*) $p < 0.1$, clustered on FO/distributary. All specifications use spatial matching with 60 km buffer. Dependent variable is tail shortage $Y = DPR^H - DPR^T$. Channel-years in 2nd FO tenure dropped. All specifications include controls for $\log(CV)$ of weekly discharge, channel fixed effects, Circle-specific time trends, and buffer-year fixed effects. \bar{L}_j denotes mean or 90th percentile of land ownership distribution at position j of channel computed over census farm households (cols 2-5) or all census households (cols 6-9); τ^1 is indicator for first FO tenure.

Table 4 reports the results of the heterogeneity analysis based on spatial matching with a 60 km buffer. We cannot formally reject the symmetry hypothesis whether we use the mean or the 90th percentile of landholdings at each channel position, or whether we use statistics based on farm households or based on all census households. The similarity of the estimates across the alternative reference populations for the computation of landownership statistics is comforting, given the aforementioned arbitrariness of this choice.²⁹

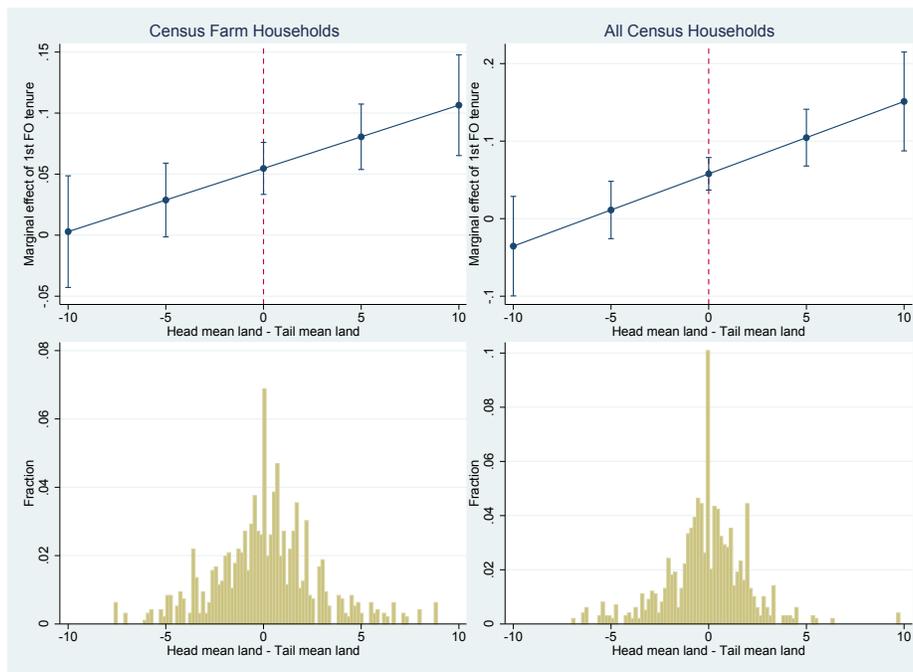


Figure 5: MARGINAL EFFECT OF 1ST FO TENURE BY $\log \theta$

Figure 5 summarizes the key finding of the heterogeneity analysis based on the restricted estimates (cols 2 and 6 of Table 4). In channels with relatively greater average landownership at the head than at the tail, the post-reform allocation of canal water worsened (disfavored the tail) to a significantly *greater* extent. In other words, decentralization not only appears to have aggravated rent-seeking, but to have aggravated it by more in channels along which

²⁹Appendix Table B.2 reports specifications with channel-year observations in second FO tenures *included* (constraining first and second tenure effects to be equal), with similar results.

political power asymmetry reinforces locational asymmetry (Proposition 2). Tail-end irrigators on channels along which large landowners most predominate at the *head* saw a doubling of their relative shortage. By contrast, tail-end irrigators on channels along which large landowners most predominate at the *tail* suffered essentially no erosion in water allocation following the irrigation management transfer.

5.3 Robustness to channel-level inequality

A large literature on collective action in commons management highlights the importance of heterogeneity among users (e.g., Ostrom 1990; Baland and Platteau 1997), although the effect of inequality on outcomes is often theoretically ambiguous (Bardhan and Dayton-Johnson 2002). In the context of surface irrigation systems, Bardhan (2000) and Dayton-Johnson (2000) find that the landholdings Gini coefficient is negatively associated with cooperation in water allocation and channel maintenance. Our concern here is that, if FOs along channels with, say, greater wealth inequality produce less cooperative outcomes, and if overall *channel-level* land inequality is correlated with head-tail differences in landholdings, then our heterogeneity results in Table 5 may be spurious.

To deal with this concern, we construct channel-level measures of land inequality—Gini coefficient, share of land owned by top 5%, and proportion of landless—using the Agricultural Census and both reference populations (see subsection 5.1).³⁰ In particular, these measures incorporate households from all census villages that match to outlets on the head, tail, *and* middle 40% of a given channel. In Table 5, we add these variables one-by-one to specifications (2) and (6) of Table 4. In each case, the coefficient of interest, that on $\tau^1 \times (\bar{L}_H - \bar{L}_T)$, is virtually unaffected.³¹

³⁰For the calculation of the Gini coefficient, landholdings of landless households are set to 10^{-8} .

³¹Greater channel level inequality does sometimes appear to be detrimental to FO performance, but only when considering all census households. The literature mentioned above focuses on heterogeneity strictly among *users* of the commons, which here would be farm households.

Table 5: Influence Asymmetry–Robustness to Channel-level Inequality

	Census Farm Households			All Census Households		
	Gini	Top 5% share	Landless prop.	Gini	Top 5% share	Landless prop.
τ^1	0.0571 (0.0581)	0.0159 (0.0342)	0.0515*** (0.0156)	-0.0898 (0.0687)	0.00624 (0.0364)	-0.0128 (0.0274)
$\tau^1 \times (\bar{L}_H - \bar{L}_T)$	0.00519*** (0.00191)	0.00499*** (0.00192)	0.00519*** (0.00194)	0.00932*** (0.00305)	0.00917*** (0.00301)	0.00939*** (0.00302)
$\tau^1 \times inequality$	-0.00396 (0.0911)	0.0719 (0.0596)	0.0206 (0.0659)	0.189** (0.0868)	0.0810 (0.0546)	0.146*** (0.0511)
R^2	0.571	0.571	0.571	0.570	0.570	0.570
No. of Obs.	586,417	586,417	586,417	602,425	602,425	602,425
No. of clusters	892	892	892	909	909	909
No. of FOs	247	247	247	252	252	252

Notes: Robust standard errors in parentheses (***) $p < 0.01$, (**) $p < 0.05$, (*) $p < 0.1$), clustered on FO/distributary. All specifications use spatial matching with 60 km buffer. Dependent variable is tail shortage $Y = DPR^H - DPR^T$. Channel-years in 2nd FO tenure dropped. All specifications include controls for $\log(CV)$ of weekly discharge, channel fixed effects, Circle-specific time trends, and buffer-year fixed effects. \bar{L}_j denotes mean land ownership at position j of channel computed over census farm households (cols 2-4) or all census households (cols 5-7); τ^1 is indicator for first FO tenure.

6 Conclusion

How a shift in resource control from centralized bureaucracy to local government affects allocations of publicly provided goods has been an empirical terra incognita. It is worth reiterating why this is so: natural experiments in decentralization are extremely rare, rarer still in contexts where rent-seeking (or, rather, the consequences thereof) can be objectively measured. The devolution of irrigation management in Pakistan’s Indus basin combined with an extensive water discharge database provides just such a felicitous circumstance.

We have compared changes in water discharge along channels whose management was taken over by locally elected farmer organizations (FOs) to changes that occurred in channels that remained centrally managed. Water theft increased by more in the former case, leading to a large redistribution of wealth. That decentralization also increased water theft by more along channels with a greater preponderance of large landowners at the head suggests that investment in de facto political power (borrowing the terminology of Acemoglu and Robinson 2008) can *more* than offset changes in de jure political power brought about by institutional

reform. Here, as our theoretical model indicates, decentralization shifts the lobbying arena from the upper-tier of the bureaucratic hierarchy to the communal governance structure and thereby enhances rent-seeking.

While our evidence is not favorable to the decentralization effort in the Indus basin inasmuch as it did not deliver on its promise of a more equitable (and efficient) distribution of canal water, it would be premature to throw out the reform baby with the bathwater. Successful decentralization would likely involve directly addressing power asymmetries along the irrigation system, such as by giving tail-enders *exclusive* control over FOs.³² In terms of the model, this policy would make it more likely that the efficient allocation is implemented. Tail-enders would have every incentive to enforce the *warabandi* system, while head-end influence within the FO would be minimized. More generally, as Mansuri and Rao (2013) argue, state support, both in setting and in enforcing the rules of the game, is a key ingredient for effective local governance.

³²Merely establishing reservations whereby each FO must have a certain number of members or officers representing tail outlets may not be enough. In our data, a reasonable proportion of FO presidents (20%) and of the four-member FO management committee (18% on average) own land at the tail. In these cases, tail-enders' interests are nominally represented in the FO. However, analysis similar to that in Table 4 (available from the authors upon request) reveals no significant difference in decentralization outcomes between FOs with and without tail representation. To be sure, caution must be exercised in interpreting these results as we do not understand why some FOs have officers with tail-holdings and others do not. Nevertheless, taken on their own terms, these findings do not support a *partial* reservation for tail-enders.

References

- [1] Acemoglu, D., & Robinson, J. (2008). Persistence of Power, Elites, and Institutions. *American Economic Review*, 98(1), 267-293.
- [2] Alatas, V., Banerjee, A., Hanna, R., Olken, B. A., Purnamasari, R., & Wai-Poi, M. (2013). Does elite capture matter? Local elites and targeted welfare programs in Indonesia (No. w18798). National Bureau of Economic Research.
- [3] Anderson, S., Francois, P., & Kotwal, A. (2015). Clientelism in Indian villages. *American Economic Review*, 105(6), 1780-1816.
- [4] Baland, J. M., & Platteau, J. P. (1997). Wealth inequality and efficiency in the commons Part I: the unregulated case. *Oxford Economic Papers*, 49(4), 451-482.
- [5] Baland, J. M., & Robinson, J. A. (2008). Land and power: Theory and evidence from Chile. *American Economic Review*, 98(5), 1737-1765.
- [6] Bardhan, P. (2000). Irrigation and cooperation: An empirical analysis of 48 irrigation communities in South India. *Economic Development and cultural change*, 48(4), 847-865.
- [7] Bardhan, P., & Dayton-Johnson, J. (2002). Unequal irrigators: heterogeneity and commons management in large-scale multivariate research. *The drama of the commons*, 87-112.
- [8] Bardhan, P., & Mookherjee, D. (2006a). Decentralisation and accountability in infrastructure delivery in developing countries. *Economic Journal*, 116(508), 101-127.
- [9] Bardhan, P., & Mookherjee, D. (2006b). Decentralization, corruption and government accountability. *International handbook on the economics of corruption*, 6, 161-188.

- [10] Bardhan, P., & Mookherjee, D. (2006). Pro-poor targeting and accountability of local governments in West Bengal. *Journal of development Economics*, 79(2), 303-327.
- [11] Bandaragoda, D. J., & ur Rehman, S. (1995). Warabandi in Pakistan's canal irrigation systems: Widening gap between theory and practice. No. 7. IWMI.
- [12] Basurto, P., Dupas, P., & Robinson, J. (2015). Decentralization and efficiency of subsidy targeting: Evidence from chiefs in rural Malawi. Unpublished, Stanford University.
- [13] Beath, A., Christia, F., & Enikolopov, R. (2017). Direct democracy and resource allocation: Experimental evidence from Afghanistan. *Journal of Development Economics*, 124, 199-213.
- [14] Bromley, D. W., Taylor, D. C., & Parker, D. E. (1980). Water reform and economic development: institutional aspects of water management in the developing countries. *Economic Development and Cultural Change*, 365-387.
- [15] Chakravorty, U., & Roumasset, J. (1991). Efficient spatial allocation of irrigation water. *American Journal of Agricultural Economics*, 73(1), 165-173.
- [16] Chambers, R. (1988). *Managing canal irrigation: Practical analysis from south Asia*. New Delhi: Oxford.
- [17] Dayton-Johnson, J. (2000). Determinants of collective action on the local commons: a model with evidence from Mexico. *Journal of Development Economics*, 62(1), 181-208.
- [18] Fan, C. S., Lin, C., & Treisman, D. (2009). Political decentralization and corruption: Evidence from around the world. *Journal of Public Economics*, 93(1), 14-34.
- [19] Guimaraes, P. and P. Portugal (2010). A Simple Feasible Alternative Procedure to Estimate Models with High-Dimensional Fixed Effects, *Stata Journal*, 10(4), 628-649.

- [20] Holmes, T. J. (1998). The effect of state policies on the location of manufacturing: Evidence from state borders. *Journal of Political Economy*, 106(4), 667-705.
- [21] Hoffman, V., P. Jakiela, M. Kremer, and R. Sheely (2017). There is no place like home: Theory and evidence on decentralization and politician preferences. Unpublished.
- [22] Jacoby, H. & Mansuri, G. (2017). Misgoverning the Commons: Corruption and Rent-seeking in Pakistan's Indus Basin. World Bank, Washington DC.
- [23] Mansuri, G., and Rao, V. (2013). *Localizing development: Does participation work?*. World Bank Publications.
- [24] Mookherjee, D. (2015). Political decentralization. *Annual Review of Economics* 7, no. 1 (2015): 231-249.
- [25] Meinzen-Dick, R. (2007). Beyond panaceas in water institutions. Proceedings of the National Academy of Sciences, 104(39), 15200-15205.
- [26] Moore, M. (1989). The fruits and fallacies of neoliberalism: the case of irrigation policy. *World Development*, 17(11), 1733-1750.
- [27] Nitzan, S. (1994). Modelling rent-seeking contests. *European Journal of Political Economy* 10, no. 1: 41-60.
- [28] Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. New York: Cambridge University Press.
- [29] Ostrom, E. & Gardner, R. (1993). Coping with asymmetries in the commons: self-governing irrigation systems can work. *Journal of Economic Perspectives*, 7(4), 93-112.
- [30] Rijsberman, F. R. (2008). Water for food: corruption in irrigation systems. *Global Corruption Report 2008*, P. 67-84.

- [31] Rinaudo, J. D., Strosser, P., & Thoyer, S. (2000). Distributing water or rents? Examples from a public irrigation system in Pakistan. *Canadian Journal of Development Studies/Revue canadienne d'études du développement*, 21(1):113-139.
- [32] Rinaudo, J. D. (2002). Corruption and allocation of water: the case of public irrigation in Pakistan. *Water Policy*, 4(5), 405-422.
- [33] Sampath, R. K. (1992). Issues in irrigation pricing in developing countries. *World Development*, 20(7), 967-977.
- [34] Tullock, G. (1980). Efficient rent-seeking. In Buchanan, J.; Tollison, R.; & Tullock, G., *Toward a theory of the rent-seeking society*, pp. 97-112.
- [35] Van Waijjen, E. G., Hart, W. W. H., Kuper, M. & Brouwer, R. (1997). "Using a hydro-dynamic flow model to plan maintenance activities and improve irrigation water distribution: application to the Fordwah distributary in Punjab, Pakistan." *Irrigation and Drainage Systems* 11, no. 4: 367-386.
- [36] Vermillion, D. L. (1997). Impacts of irrigation management transfer: A review of the evidence. Sri Lanka: International Irrigation Management Institute.
- [37] Wade, R. (1982). The system of administrative and political corruption: Canal irrigation in south India, *J. of Development Studies*, 18(3): 287-328.
- [38] World Bank (2004) *World Development Report 2004: Making Services Work for Poor People*. Washington, DC: World Bank.

Appendix

A Proofs

The following results hold at $\theta = 1$, which is to say at the mean of relative influence:

Lemma 1. $b_F < b_B$.

Proof. The FOC for the bureaucratic official is $V'_B(b_B) = 0$ (the SOC $V''_B < 0$ is always satisfied) and the FOC for the FO official is $V'_B(b_F) + u'(b_F) = 0$. Since equilibrium efforts are $e_j = \tilde{P}(1 - \tilde{P})\Delta_j$, we have $e_H + e_T = \tilde{P}(1 - \tilde{P})(\Delta_H + \Delta_T) = \Delta_H\Delta_T/(\Delta_H + \Delta_T)$ at $\theta = 1$. Thus,

$$u'(b_B) = \frac{U'(\cdot)\Delta_T^2\Delta'_H}{(\Delta_H + \Delta_T)^2} < 0$$

since $\Delta'_H(b) = -\hat{n}$. It follows that $V'_B(b_F) > V'_B(b_B)$, which, by $V''_B < 0$, $\Rightarrow b_F < b_B$. \square

Proof of Proposition 1: We have $TS(b_r) = TS_r = \tilde{P}(b_r)\hat{w}$, and Taylor expansion

$$TS(b_F) \approx TS(b_B) + TS'(b_B)(b_F - b_B).$$

Since $\tilde{P}'(b_r) < 0 \Rightarrow TS'(b_B) < 0$, lemma 1 $\Rightarrow TS_F > TS_B$. \blacksquare

Proof of Proposition 2: We have Taylor expansion

$$TS_\theta(b_F) \approx TS_\theta(b_B) + TS_{\theta b}(b_B)(b_F - b_B).$$

where subscripts denote partial derivatives and $TS_{\theta b}(b_B) = \tilde{P}_{\theta b}(b_B)\hat{w}$. Next,

$$\tilde{P}_{\theta b} = \left[\frac{\tilde{P}}{b} + \tilde{P}_b \right] \frac{b_\theta}{b} - \frac{\tilde{P}_\theta}{\tilde{P}}.$$

Evaluated at b_B , the expression in square brackets is proportional to $V'_B(b_B)$ and thus vanishes. Since $\tilde{P}_\theta > 0$, $TS_{\theta b}(b_B) < 0$, which, with lemma 1, proves the result. \blacksquare

B Additional Figures and Tables

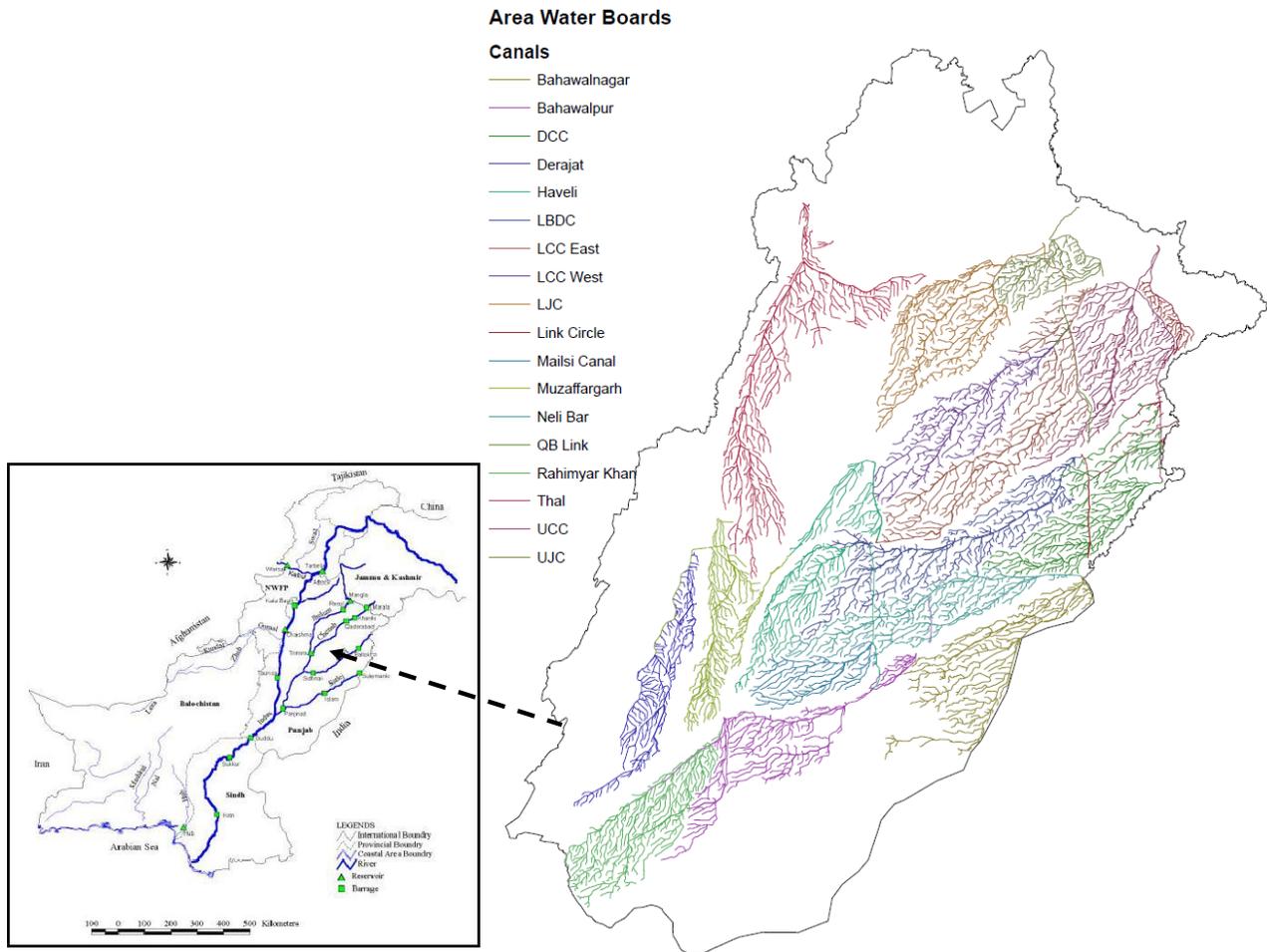


Figure B.1: INDUS BASIN IRRIGATION SYSTEM IN PUNJAB

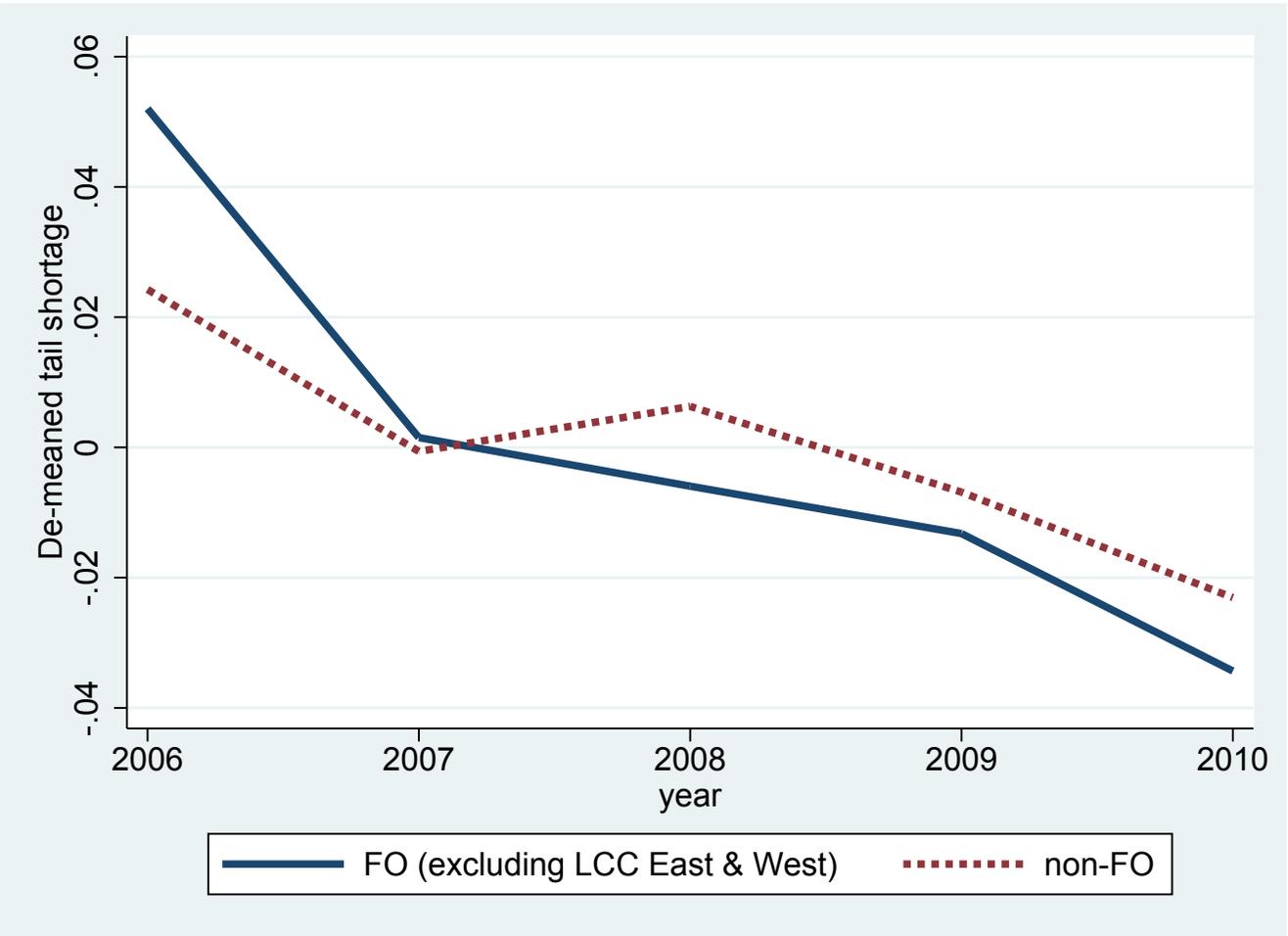


Figure B.2: TAIL SHORTAGE PRE-TRENDS IN FO AND NON-FO CIRCLES

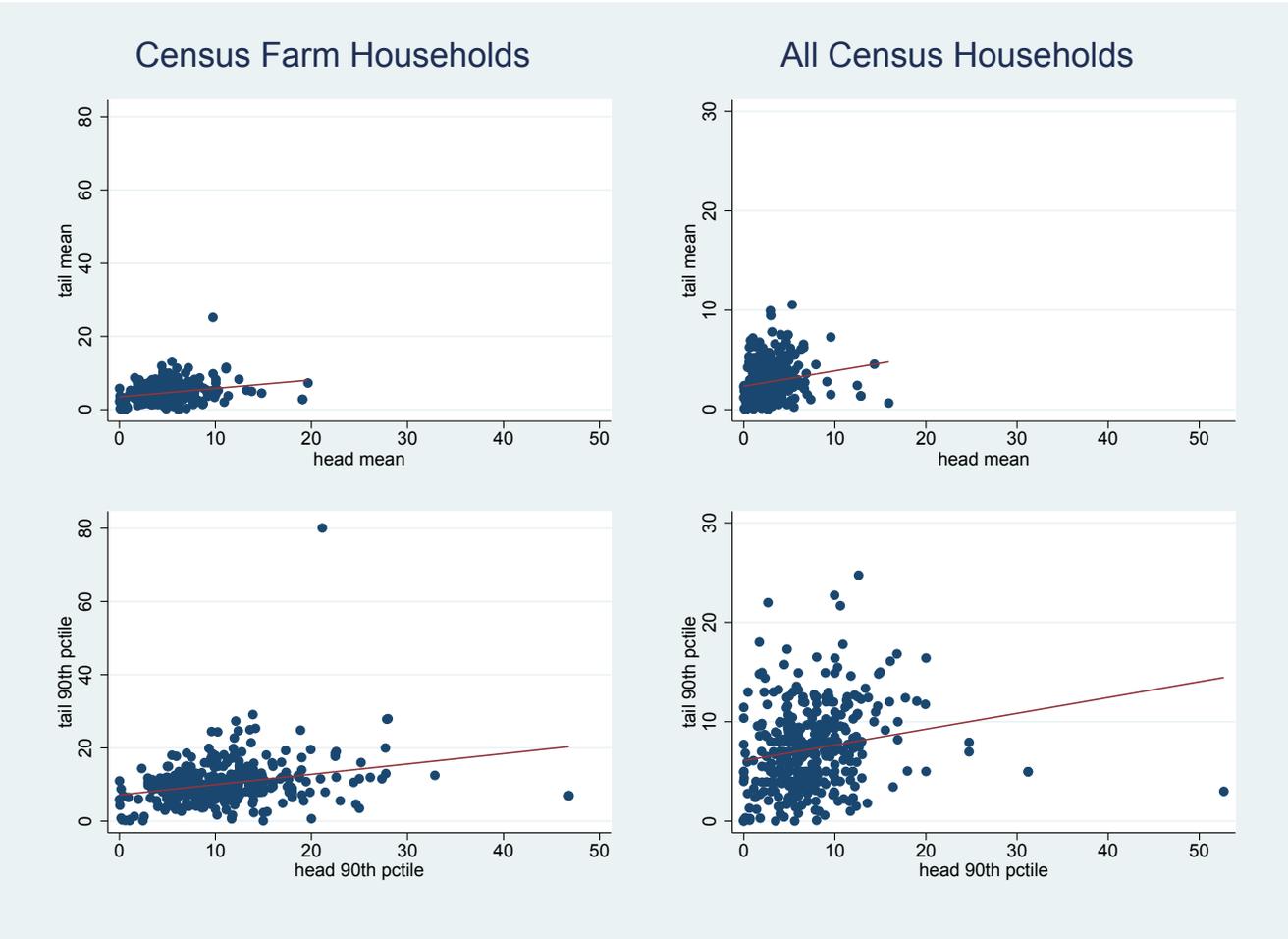


Figure B.3: LAND OWNERSHIP STATISTICS (IN ACRES) AT CHANNEL HEAD AND TAIL

Table B.1: Descriptive Statistics for Sample Channels

Canal type	FO Circles						Non-FO Circles							
	<i>N</i>	Number of outlets			Position on parent			<i>N</i>	Number of outlets			Position on parent		
	(%)	Head	Middle	Tail	Head	Middle	Tail	(%)	Head	Middle	Tail	Head	Middle	Tail
Distributary	453 (45.0)	9.9 (11.1)	7.0 (8.3)	9.8 (9.8)	0.31 (0.46)	0.40 (0.49)	0.29 (0.45)	788 (42.5)	10.5 (10.7)	8.0 (8.2)	10.5 (9.5)	0.28 (0.45)	0.38 (0.49)	0.34 (0.47)
Minor	488 (48.5)	3.0 (4.3)	2.8 (3.5)	4.7 (3.5)	0.44 (0.50)	0.37 (0.48)	0.19 (0.39)	921 (49.7)	4.3 (5.1)	3.7 (3.7)	5.6 (4.3)	0.41 (0.49)	0.42 (0.49)	0.17 (0.37)
Sub-minor	66 (6.8)	1.8 (2.4)	1.8 (2.2)	3.7 (2.5)	0.53 (0.50)	0.38 (0.49)	0.09 (0.30)	144 (8.0)	2.8 (3.6)	2.6 (2.7)	4.1 (2.6)	0.45 (0.50)	0.40 (0.49)	0.15 (0.35)
Total	1007 (100)	6.0 (8.9)	4.7 (6.6)	7.0 (7.7)	0.39 (0.49)	0.38 (0.49)	0.23 (0.42)	1853 (100)	6.8 (8.5)	5.4 (6.4)	7.6 (7.4)	0.36 (0.48)	0.40 (0.49)	0.24 (0.43)

Notes: Figures are means or proportions (standard deviations in parentheses) unless otherwise noted. FO Circles consist of the five Area Water Boards that formed FOs under the irrigation reform; non-FO Circles consist of the 12 Area Water Boards that did not form FOs. Head, middle, and tail are defined as, respectively, the first 40%, second 40%, and last 20% of a channel by length. Parent refers to the canal from which a channel off-takes.

Table B.2: Influence Asymmetry and FO Performance – Alternative Estimates

	Census Farm Households				All Census Households			
	Mean		90 th percentile		Mean		90 th percentile	
τ ($\alpha_1 = \alpha_2$)	0.0453** (0.0189)	0.0505*** (0.00973)	0.0487*** (0.0173)	0.0507*** (0.00972)	0.0569*** (0.0165)	0.0528*** (0.00953)	0.0584*** (0.0183)	0.0526*** (0.00957)
$\tau \times \bar{L}_H$ (δ_H)	0.00494** (0.00208)		0.00167 (0.00105)		0.00728** (0.00294)		0.00289** (0.00124)	
$\tau \times \bar{L}_T$ (δ_T)	-0.00385 (0.00298)		-0.00148 (0.00102)		-0.00874** (0.00437)		-0.00368* (0.00193)	
$\tau \times (\bar{L}_H - \bar{L}_T)$		0.00446** (0.00183)		0.00157** (0.000783)		0.00788*** (0.00264)		0.00319*** (0.00108)
p -value $\delta_H = -\delta_T$	0.752	-	0.888	-	0.767	-	0.722	-
R^2	0.571	0.571	0.571	0.571	0.570	0.570	0.570	0.570
No. of Obs.	586,679	586,679	586,679	586,679	602,703	602,703	602,703	602,703
No. of clusters	892	892	892	892	909	909	909	909
No. of FOs	247	247	247	247	252	252	252	252

Notes: Robust standard errors in parentheses (***) $p < 0.01$, (**) $p < 0.05$, (*) $p < 0.1$, clustered on FO/distributary. All specifications use spatial matching with 60 km buffer. Channel-years in 2nd tenure included with 1st and 2nd tenure effects constrained to be equal (τ is indicator for FO tenure, either 1st or 2nd). Dependent variable is tail shortage $Y = DPR^H - DPR^T$. All specifications include controls for $\log(CV)$ of weekly discharge, channel fixed effects, Circle-specific time trends, and buffer-year fixed effects. \bar{L}_j denotes mean or 90th percentile of land ownership distribution at position j of channel computed over census farm households (cols 2-5) or all census households (cols 6-9).