The impact of water users' associations on the productivity of irrigated agriculture in Pakistani Punjab

Dawit Kelemework Mekonnen

International Food Policy Research Institute
2033 K St. NW, Washington D.C, 20006 USA
Email: d.mekonnen@cgiar.org

Hira Channa

Pakistan Strategy Support Program
Islamabad, Pakistan
Email: hirachanna@gmail.com

Claudia Ringler

International Food Policy Research Institute
2033 K St. NW, Washington D.C, 20006 USA
Email: c.ringler@cgiar.org

☆Selected Paper prepared for presentation at the Agricultural & Applied Economics Associations 2014 AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014.

The impact of water users' associations on the productivity of irrigated agriculture in Pakistani Punjab *

Abstract

The government of Pakistan has been involved in the transfer of irrigation management to farmers' organizations at different levels of irrigation networks. Khal Panchayats or water users' associations are mandated to mediate water distribution conflicts, maintain watercourses, report on tampering of outlets and shortage of water supply in the outlet to minor or distributary-level farmer organizations, collect water charges, and provide timely information about rotational running of channels to the farmers. As such, irrigators on watercourses with Khal Panchayats can potentially perform better than those without such institutions. This study explores whether or not the presence of Khal Panchayats on a watercourse and farmer organizations on the canal improves farmers' productivity and the returns to land as was envisioned during the Irrigation Management Transfer. The study utilizes the Pakistan Rural Household Panel Survey (Round 1.5) that has detailed plot level information with highly disaggregated data on irrigation type, methods, and institutions. We used the Hausman-Taylor model to regress the value of output per acre on agricultural inputs, soil and water conservation practices, plot characteristics, household demographics, and the presence of institutions such as Khal Panchayats and farmer organizations. We find that households whose plots are located on watercourses with Khal Panchayats are likely to earn 27 percent more value per acre as compared to farmers on watercourses without such institutions. The effect of the presence of Khal Panchayats is more pronounced in Kharif (the main rainy season) than in the Rabi season. Khal Panchayats lead to improved water management mainly through reducing water theft and conflicts around water, as well as improving maintenance of the watercourse and timing of water arrival. This suggests that while the Irrigation Management Transfer (IMT) progress has been slow in Punjab province, largely due to resistance to change by the vested interests embedded in the Punjab Irrigation Department, even the limited implementation of the IMT has already yielded substantial benefits. The presence of farmers' organization (FO) on the minor or distributary as well as the interaction of the presence of a KP and an FO, are statistically insignificant, though they have the the expected positive signs.

Keywords: : Farmers' organizations, Khal Panchayats, irrigation management transfer, productivity, Pakistan, water users' association

*****Preliminary draft. Please do not cite.**

I. Introduction

The Indus Basin in Pakistan has one of the largest and most complex irrigation networks in the world. The network irrigates almost 34.5 million acres and consists of 44 canal systems. The length of the canals is over 56000 km while the length of the nearly 107,000 watercourses is above 1.6 million kilometers. Water is diverted to the main canals through a series of barrages and 12 inter-link river canals. These canals in turn deliver water to branch canals, distributaries, minors and eventually watercourses.

The initial pieces of legislation governing the irrigation network in the Indus Basin were passed during the colonial era by the British. According to the Canal and Drainage Act (1873) governing the irrigation network in Punjab and KPK (Khyber Pakhtunkhwa province) and the Sindh Irrigation Act (1879), the construction and major repairs of watercourses are the responsibility of the provincial authorities, while overall maintenance of the watercourses is unregulated by these acts and are in effect the responsibility of the users (Muhammad, 1998).

For more than a century, farmers and irrigation officials have relied on traditional form of farmers' organizations called "khal committees" to mobilize labor during maintenance of watercourses. However, there has been increasing awareness, particularly after the on-farm watercourse maintenance (OFWM) pilot project (1976-80) that these informal "water users associations" did not prove effective in motivating farmers to continue providing the labor needed to maintain the watercourses after improvement (Byrnes, 1992). Studies of the OFWM pilot project experience led to the conclusion that the farmers on a watercourse would only begin to take responsibility for maintaining their watercourse after improvement if they were organized into a formal, legally-recognized Water Users' Association (WUA) that was empowered to enforce watercourse maintenance (Byrnes, 1992). Consequently, in 1981, three Pakistani provinces (Punjab, NWFP[1], and Baluchistan) each promulgated its own WUA Ordinance while the Sindh WUA Ordinance was promulgated in 1982 (Byrnes,

1. North Western Frontier Province (NWFP) is the current KPK province.

1992; Muhammad, 1998). More than 50 percent of water users can come together and apply to the Field Officer of the OFWM for registration of their association (Muhammad, 1998).

According to these Ordinances, WUAs are empowered, to improve, rehabilitate, operate, and maintain watercourses; establish water delivery schedules and supervise water allocation and distribution; ensure all members get their share of water in a timely manner; removing obstructions on courses; employing labor for maintenance activities; and ensuring that all members contribute. All of these authorities, however, can be curtailed by the provincial authorities (Byrnes, 1992; Muhammad, 1998). In Sindh and KPK, half of the watercourse associations can come together to form a distributary association and half of the distributary associations can come together to form a canal association.

Muhammad (1998) argues that the WUA Ordinances makes for weak user associations, because it gives little authority to the association for dispute resolution or for penalizing users who are conducting unlawful activities on the watercourses.

In 1997, irrigation and drainage authorities were formed for all the provinces. The irrigation and drainage authorities are meant to be autonomous bodies eventually taking over from the irrigation departments. The responsibility of the irrigation and drainage authority is to supply water from the barrages to the canals. Area Water Boards need be formed at each canal and Farmer Organizations have to be formed for every distributary. The responsibility of the provincial irrigation and drainage authority is to collect dues from the Area Water Boards which in turn are responsible for collection from the Farmer Organizations on the distributaries. This legislation does not mention user' associations at the watercourse level. Because of this, the formation of watercourse level users' associations continued to be governed by the Water Users' Association Ordinance in Punjab, Sindh, and KPK.

Watercourse level users' associations (also known as khal panchayats in Punjab) consist of 5 executive committee members. Under the Watercourse Users Ordinance, all of the farmers on that watercourse represent the general body of the association from which the executive committee of the khal panchayat is elected. The executive committee of the farmer organization is elected from the chairpersons of the watercourse user associations. The Area Water Boards consist of farmer members and non-farmer members. The farmer members are elected from the executive committees of the farmer organizations and the non-farmer members are generally engineers appointed by the Irrigation and Drainage Authority.

In Sindh, the Sindh Irrigation and Drainage Authority Rules and the Water Users Ordinance have been repealed by the Sindh Water Management Ordinance 2002 (SIDA, 2002). This ordinance retains the irrigation and drainage authority and establishes similar roles and responsibility for water users' associations at all tiers. A significant change is that two-thirds of water users on a watercourse need to apply for registration for an association, instead of only the 51% requirement which was established in the previous ordinance.

Despite the above legislations, the transfer of water management to WUAs has not taken place as envisaged and much of the irrigation network continues to be governed by primarily British era legislation, except on the canals where Area Water Boards exist, mainly due to opposition from powerful political stakeholders and a prevailing belief that water users cannot be trusted to manage their water (Ul Hassan, 2009).

In addition, there are not enough scientific studies that rigorously analyze the existing WUAs to shed light on whether such transfer of irrigation management in Pakistan has resulted in the expected benefits of improved watercourse maintenance, reduced water conflicts, reduced water theft, improved water rotation and timely delivery, and the resulting benefits of increased agricultural productivity. Evidence in the literature from other parts of the world suggests that WUA have led to yield improvements (Liu et al., 2002; Samad and Vermillion, 1999), efficient utilization of water and increased production in a dry year (Uphoff and Wijayaratna, 2000), mobilizing labor and monetary resources for maintenance work (Zaman et al., 1998), and conflict resolution (Waheed, 1998; Zaman et al., 1998). There is also evidence that these benefits are space and context specific as the success of WUAs depends on factors such as democratic election of WUA leaders (Liu et al., 2002), existing social networks such as caste or biradari ties (Waheed, 1998), whether the watercourses are improved or traditional (Alam et al., 2012), the presence of sub-groups within the WUA (Zhang et al., 2013), and how active the farmer organization is (Gedara et al., 2012).

This study explores whether or not the presence of formal Khal Panchayats on a watercourse and farmer organizations on the canal lead to improved water management which in turn would translate into improved returns to land in Punjab province of Pakistan.

II. Data and Descriptive Statistics

The data used in this study is a subset of the Pakistan Rural Household Panel Survey (Round 1.5) that is collected from Punjab, Sindh, and Khyber Pakhtun Khwa (KPK) provinces of Pakistan by the International Food Policy Research Institute in early 2013. The survey gathered detailed plot-level information on agricultural production with a particular focus on the contribution of irrigation to Pakistan's agriculture sector to identify entry points for managing the country's canal, ground, and surface water resources in a more efficient, equitable, and sustainable way, which will be crucial to meeting agricultural production challenges. The survey covers 980 farm households in total, with 543 households in Punjab, 317 households in Sindh, and 120 households in KPK.

In the Round 1.5 Pakistan Rural Household Panel Survey, Khal Panchayats are reported among 35 percent of the households in Punjab, less than 2 percent in Sindh, and are almost non-existent in KPK. Given the emphasis of this study on the role of Khal Panchayats, we have restricted the estimation to those households in Punjab. In addition, we excluded plots that exclusively use ground water as the presence of surface water institutions such as KPs, FOs, or locations on the watercourse are not applicable for such plots. Given the large number of crops grown by the households, we have focused on four important crops in terms of their share of harvested land. These four crops are rice, cotton, and sugarcane in the Kharif season and wheat in the Rabi season. The remaining excluded crops are mainly fodder crops such as sorghum, millet, and barseem. The final sample size in the estimation has 207 households.

Among the sampled farmers in Punjab that produce either rice, wheat, cotton, or sugarcane using surface water, about 39 percent reported that there is a Khal Panchayat (KP) on the watercourse that serves their plots (Table I). In addition, about 21 percent of the sampled households reported that there is a farmer organization (FO) that reports to the Provincial Irrigation and Drainage Authority on the distributary that feeds the watercourse.

TABLE I: Descriptive Statistics on Khal Panchayats, Farmer Organizations, and Soil Health

	Rabi 2011-12		Kharif 2011	
	Percent	St. Dev.	Percent	St. Dev.
Khal panchayat (KP) exist on the watercourse	38.65	(48.81)	38.65	(48.81)
Farmer Organization (FO) exist on the canal	20.77	(40.67)	20.77	(40.67)
Crop Residue left on the crop	74.40	(43.75)	67.63	(46.90)
Flood irrigation used	89.86	(30.27)	68.60	(46.52)
Plot Exposed to Erosion	11.11	(31.50)	11.11	(31.50)
Plots experience waterlogging	6.28	(24.32)	6.28	(24.32)
Plots experience salinity	3.87	(19.32)	3.87	(19.32)
Some plots are left fallow periodically	1.93	(13.80)	4.35	(20.44)
Household practices zero or minimum tillage	0.97	(9.81)	0	(0)
Crop Rotation used on the plots	5.31	(22.49)	7.25	(25.99)
Observations	207		207	

Note: Standard deviations are in brackets

Whenever they exist, the three main roles of Khal Panchayats are maintenance of watercourses, influencing timing of water release, and collection of abiana[2] (Table II). Khal Panchayats are also involved in dispute settlement and maintenance of the canal.

Among households with a KP on their watercourse, two third of them responded that the KP has improved water management. As shown in Table III, KPs lead to improved water management mainly through reducing water theft and conflicts around water as well as through improved maintenance and timing of water arrival. However, a third of the households with KPs along their watercourses, responded that the presence of a KP has

2. Water charges or fees per acre.

TABLE II: Roles of KPs identified by survey respondents in areas with KPs

	Percentages
Collection of Abiana	70
Maintenance of canal	20
Maintenance of watercourse	70
Dispute settlement	40
Influencing the timing of water release	70
Observations	80

Respondents can give up to three roles of KPs, hence the percentages do not add up to 100.
Source: Authors' computations from PRHPS Round 1.5.

not lead to improved water management. KPs that fail to improve water management are characterized by farmers as a KP that does nothing at all, fails to serve equally, fails to improve the timing of water, or it is located in a watercourse with too little water to begin with.

TABLE III: Mechanisms through which KPs lead to improved water Management identified by survey respondents

	Percentage of respondents
Water arrives on time	50
More information on when water arrives	10
Improved maintenance	50
Enhanced financial situation	10
Less conflicts around water	80
Less water theft	80
More information on crops and technologies	10
Observations	53

Respondents can give up to three ways in which management has improved with KP.
The percentage is among those who reported that KPs improved water management on the watercourse.

The disapproval rate in terms of being unable to improve water management is worse for Farmer Organizations (FOs) as compared to the 33 percent disapproval rate for KPs. More than half of the farmers who confirmed the presence of an FO on their canal, responded that the FO has not led to improved water management on the canal. Some of the reasons provided for such failure include, in order of importance, being an FO that does nothing at all, political pressure, unable to serve equally, having little water in the canal, and conflict within the organization.

Soil erosion, waterlogging, and salinity have been reported as prevalent by only eleven, six, and four percent of the respondents (Table I). Unlike other provinces such as Sindh, where waterlogging and salinity has been reported to be a severe problem (Mekonnen et al., 2013), the soil health in Punjab appears to be relatively good. Flooding is the main type of irrigating the plots with other type of irrigation such as use of furrows or bed and furrows accounting for only less than 10 percent (Table I).

Table IV provides a brief summary of the continuous variables used in the model. The crop value has been evaluated at the price which the farmer received. The value of the crop output and each of the inputs are higher in the Kharif season as compared to the Rabi season. There is also greater variation in the Kharif season primarily because the Kharif season consists of multiple crops i.e rice, cotton, and sugarcane, while the Rabi season consists only of wheat. The Kharif crops are heavier consumers of water and pesticide, and are also more labor and machine intensive. The higher mean and variation in seed use in the Kharif season is primarily due to sugarcane in which seedlings are used for the sowing process. Fertilizer use constitutes primarily of nitrogen application with some phosphorous use and this is only slightly different for both seasons implying that fertilizer use in this area is not modified significantly to suit crop requirements. The average age of household heads is 50 years and about 58 percent of them have attended school.

The definitions of variables included in the estimation are provided in Table V.

III. Methodology

The Hausman and Taylor instrumental variables estimation of the random effects model is used in this study as it provides two main advantages over the basic fixed effects and random effects models. The random effects model is based on the assumption that the unobserved

TABLE IV: Descriptive Summaries on Agricultual Output, Input Uses, and Household Demographics

	Rabi 2011-12	Kharif 2011
Value of output (Rs/acre)	30074.9	47195.5
	(8457.8)	(28413.5)
Fertilizer used (kg/acre)	137.8	135.7
	(66.56)	(72.59)
Machinery Hours (Hours/Acre)	3.563	4.335
	(2.352)	(2.908)
Family Labor Hours (Hours/Acre)	75.24	154.0
	(63.82)	(135.7)
Hired Labor Hours(Hours/Acre)	35.73	104.6
	(43.37)	(128.2)
Number of pesticide sprays (Sprays/Acre)	0.562	2.117
	(0.817)	(2.622)
Total Seed used (kg/acre)	55.99	491.6
	(18.12)	(1016.9)
Volume of groundwater used (Inches)	19.21	33.53
	(23.41)	(48.82)
Volume of surface water used (Inches)	20.36	42.99
	(22.65)	(48.21)
Age of the household head	50.05	50.05
	(13.66)	(13.66)
Household head attended school	0.575	0.575
	(0.496)	(0.496)

Standard deviations are in parenthesis

TABLE V: Definition of Variables Used in the Estimation

Variable Name	Variable Definition
Dependent Variable	
Value of output (Rs/acre)	Price per unit of the crop × production quantity
Input Variables	
Fertilizer used (kg/acre)	Total kg's of UREA and DAP consumed
Machinery Hours per acre	Number of hours for which tractors and bullocks were used
Family Labor Hours per acre	Number of hours for which family labor was used
Hired Labor Hours per acre	Number of hours for which hired labor was used
Pesticide sprays per acre	Total number of sprayings per acre
Total Seed used (kg/acre)	Total seed or seedlings used
Volume of groundwater (Inches)	Average depth × number of irrigations × area irrigated
Volume of surface water (Inches)	Average depth × number of irrigations × area irrigated
Age of the household head	Age in years of household head
Indicator Variables (Yes=1, No=0)	
Household head attended school?	Dummy for school attendance
Khal panchayat (KP)	Variable indicating whether household belongs to KP
Farmer Organization (FO)	Variable indicating whether household belongs to FO
Crop Residue	Whether crop residue had been left on the plot previously
Flood irrigation	Flood irrigation used on plot
Plot Exposed to Erosion?	If the plot was exposed to erosion
Waterlogging?	Presence of waterlogging on plot reported by respondent
Salinity?	Presence of salinity on plot reported by respondent
Was the plot very fertile?	Quality of soil as reported by respondent
Plots periodically left fallow	Whether plot had been left fallow in previous seasons
Zero or minimum tillage	Zero or Minimum Tillage practiced
Crop rotation	Use of Crop Rotation on the plots

All values are initially calculated at the plot level and then aggregated to the household level.
Each of the values were standardized by the cultivated land size in acres.
Indicator variables were also averaged across plots.

individual specific effects are uncorrelated with the included explanatory variables (Greene, 2008) and will produce inconsistent estimators of all parameters if such correlation exists (Wooldridge, 2002). This is a concern for the model used in this study since the unobserved individual effects is likely to be correlated with the level and type of agricultural input use decisions and practices of soil and water conservation measures.

On the other hand, fixed effects estimator produces consistent estimators without assuming away the potential correlation between the included explanatory variables and the unobserved heterogeneity but in the process of eliminating the individual effects through first differencing or mean differencing, it also removes any time invariant explanatory variables. Thus, in fixed effects estimation, the effect of time invariant explanatory variables will simply be absorbed into the fixed effects (Greene, 2008), making the effects of the two sets of variables indistinguishable. This is a concern when the main interest of variable is time invariant in the panel. As such, the presence of Khal Panchayts and farmer organizations, our main variables of interest, are invariant in the two seasons we have data for the sample.

The Hausman and Taylor (1981) estimator, unlike the random effects estimator, allows some of the included explanatory variables to be endogenous, and, unlike the fixed effects estimator, it allows for the identification of time invariant included explanatory variables from unobserved individual effects. The Hausman-Taylor estimator is presented as follows.

$$y_{it} = X_{1it}\beta_1 + X_{2it}\beta_2 + Z_{1it}\delta_1 + Z_{2it}\delta_2 + \mu_i + \epsilon_{it} \tag{1}$$

where

X_{1it} is K_1 variables that are time-varying and uncorrelated with μ_i ;

Z_{1it} is L_1 variables that are time invariant and uncorrelated with μ_i ;

X_{2it} is K_2 variables that are time-varying and correlated with μ_i ;

Z_{2it} is L_2 variables that are time invariant and correlated with μ_i ;

μ_i is the unobserved, panel-level random effect that is assumed to have zero mean and finite variance σ_μ^2 and to be independently and identically distributed (i.i.d) over the panels ;

ϵ_{it} is the idiosyncratic error that is assumed to have zero mean and finite variance σ_ϵ^2 and to be i.i.d. over all the observations in the data;

β_1; β_2; δ_1; and δ_2 are the corresponding $K_1 \times 1$, $K_2 \times 1$, $Z_1 \times 1$, and $Z_2 \times 1$, coefficient vectors to be estimated; and

$i = 1, \cdots, n$, where n is the number of individuals in the sample and, for each time period i, $t = 1, \cdots, T_i$.

Given the endogeneity of X_{2it} and Z_{2it}, Hausman and Taylor proposed instrumental variable estimator that uses only the information within the model. Taking deviations from the mean results in

$$y_{it} - \overline{y_i} = (X_{1it} - \overline{X_{1i}})\beta_1 + (X_{2it} - \overline{X_{2i}})\beta_2 + (\epsilon_{it} - \overline{\epsilon_i}) \tag{2}$$

to consistently estimate β_1 and β_2 by least squares, which are the usual fixed effects estimators. Hausman and Taylor show that the group mean deviations can be used as $(K_1 + K_2)$ instrumental variables for estimation of β_1, β_2, δ_1, and δ_2. Because Z_1 is uncorrelated with the disturbances, it serve as a set of L_1 instrumental variables. That leaves a need for additional L_2 instrumental variables. Hausman and Taylor show that the group means for X_1 can serve as these remaining instruments and the model will be identified as long as K_1 is greater than or equal to L_2.

In our estimating model, we use a translog specification as a flexible functional form with the levels, interactions, and squared terms of the explanatory variables. The translog specification is a second order polynomial approximation of an arbitrary production function. To reduce the collinearity problem associated with such specifications, all the variables have been standardized by their respective means before taking their logarithmic transformation.

The dependent variable y_{it} is the value of production per acre of wheat, rice, cotton, and sugarcane. Wheat is the major Rabi crop while rice, cotton, and sugarcane dominate in the Kharif season. Given this seasonal crop type dichotomy and the potential difference of the crops to respond differently to agricultural inputs, we have included the interaction terms of season as well as crop types to all agricultural inputs as additional explanatory variables.

The time invariant exogenous variables (Z_{1it}) that enter into our estimating model include the presence of Khal Panchayats on the watercourse (KPs), the presence of minor or distributary level farmers' organizations (FOs), and the interaction of the presence of KPs and FOs. Khal Panchayats have either been formulated under the National Project for Improvement of Watercourses (NPIW) or by Area Water Boards (AWBs) in areas where the irrigation network is managed by the AWBs. Farmer Organizations are only present in areas governed by Area Water Boards. While the formulation and registration of the Khal Panchayats requires the approval of 51% of the farmers on that watercourse and Farmer Organizations are formed from the members of the Khal Panchayats, the initiation of these bodies requires the involvement of external government or non-governmental agencies. This is the main reason why it is assumed that the presence of Khal Panchayats and Farmer Organizations is exogenous to the household itself.

The time varying exogenous variables (X_{1it}) include volume of canal water per acre, location of the plots on the watercourse (head, middle, tail), season dummy, the problem of waterlogging or salinity, and the interaction of these variables with the season dummy variable. The season dummy variable is allowed to interact with KPs, FOs, and the interaction of the KPs and FOs.

The time varying endogenous variables of the model (X_{2it}) include fertilizer use per acre, machine hours (hours of use of threshers, land laser-levelers, and bullock traction) per acre, hours of tractor use per acre, hired labor days per acre, family labor days per acre, number of pesticide sprays in the season per acre, amount of seed used per acre, and the interaction of all these inputs and their squared terms. X_{2it} also include the interaction of the season variable with all the production inputs since differences in season may also affect the returns to the specific inputs in addition to the intercept term. The volume of ground water per acre and whether the farmer uses flooding to apply the irrigation water as opposed to using furrows or bed and furrows are included in the potentially endogenous time varying set of variables. When the input variables such as fertilizer and hours of machinery use have zero values, making log transformation difficult, we followed Battese (1997) in replacing a value of one in place of the zeros before the log transformation and add a dummy variable in the estimation that gets a value of 1 if such substitution occurs and zero otherwise.

In the Kharif season, the sample is skewed towards cotton, which has high value of output per acre and yet uses less of some inputs such as tractor hours and seed as compared to rice and sugarcane. Likewise, some of the inputs are relevant to only some of the crops. For instance threshers are mainly used for wheat and the seed (or seedling) amount for sugarcane is higher than the seed amount of other crops. To capture such crop level differences, we have included crop dummy variables as well as the interaction of these crop dummies with the individual inputs. The crop dummies and their interactions with inputs are allowed to be potentially endogenous since crop choices are under the control of the farmer and hence are likely to be correlated with the unobserved individual heterogeneity.

The time invariant endogenous variable (Z_{2it}) in the estimating model is an education variable that shows whether a household head ever attended school.

IV. Results and Discussion

The econometric results show that farmers operating on a watercourse where a Khal Panchayat exists are more productive than those on a watercourse without such an institution. As shown in Table VI, the value of agricultural outputs per acre for farmers with a Khal Panchayat (KP) is 27 percent higher than those without a Khal Panchayat. The presence of farmers' organization (FO) on the minor or distributary as well as the interaction of the presence of a KP and an FO, are statistically insignificant, though they have the the expected positive signs.

The effect of the presence of Khal Panchayats is more pronounced in the Kharif (the main rainy) season than in the Rabi season. A closer look of our sample in Punjab provides at least three potential explanations of why KPs and FOs can be more important in the Kharif season. First, the value of output in Khariff is higher than that of Rabi by almost 59 percent, implying that the returns to KP and FOs (that comes from timely watercourse maintenance or warabandi or reduced conflict) is higher in the Khariff season. Second, the main crops in the Khariff season are water intensive crops such as rice, cotton, and sugarcane, while the main Rabi crop is wheat, with the implication that the returns to orderly water distribution (both in volume, timing, incidence of conflicts, and maintenance) will be higher in Khariff. Third, because we have excluded plots that solely use ground water, both the amount of canal water and ground water are higher in Khariff than in Rabi in our final sample. As a result, the relative importance of irrigation water sources is in favor of surface water in both the Kharif and Rabi seasons, making the return to participation in KPs and FOs higher in the Kharif season.

As may be expected, surface water is more important in determining value of output per acre in the Kharif season while ground water is more important in that regard in the Rabi season.

Table VI shows evidence that households with plots at the tail end of the watercourse are negatively affected as they turn out to have lower level of output per acre.

Though it has the expected negative sign, the waterlogging and salinity variable is not estimated with precision mainly because of lack of variability in the data set since only less than six and four percent of the observations in the estimating model reported to have salinity and waterlogging problems on their plots.

Production in the province appears to be inhibited by shortage of labor. Increasing both hired and family labor are likely to increase value of output per acre (Table VI). The return on family labor is higher on seeding and pesticide application and has higher return during the Rabi season. In addition, there appears to be a relationship of substitutability between family labor and hired labor.

Increasing pesticide applications also lead to increased returns and the gains from pesticide applications are higher during the Rabi season where wheat is the main crop produced.

V. Conclusion

Parts of Pakistan have witnessed a slow and gradual transfer of the management of irrigation networks from the government bureaucracy to users' associations. In Punjab province, for instance, farmers on a watercourse form a watercourse level water users' association (Khal Panchayats) with the mandate to coordinate irrigation water withdrawals by making sure water arrives on time on the rotational turn of the farmer through reducing water theft and improving the maintenance of the watercourse. The chairpersons of the Khal Panchayats in turn make a distributary or canal level farmers' organization (FO) to streamline water usage and distribution from the canal to the watercourses. For a country like Pakistan, with nearly 107,000 watercourses stretching for more than 1.6 million kilometers and irrigating about 35 million acres of land, the success or failure of such irrigation management transfers from the government to users has far-reaching implications on the country's agricultural production, its poverty reduction efforts, and its wider economy at large. Despite the importance of irrigation management transfer in one of the world's largest irrigation networks, there are not enough rigorous studies in the literature that shed light on whether such transfer of irrigation management in Pakistan has resulted in the expected benefits of improved watercourse maintenance, reduced water conflicts, reduced water theft, improved water rotation and timely delivery, and the resulting benefits of increased agricultural productivity. This study explores whether or not the presence of Khal Panchayats on a watercourse and farmer organizations on the canal have impact on returns to land as measured in the value of output per acre.

The study utilizes Pakistan Rural Household Panel Survey that has detailed plot level information with high resolution on irrigation types, methods, and institutions. Using a two season panel data from Punjab province of Pakistan, we estimated a Hausman-Taylor estimation of the value of output per acre on agricultural inputs, soil and water conservation practices, plot characteristics, household demographics, and the presence of institutions such as Khal Panchayats and farmer organizations.

TABLE VI: Regression Results from Hausman-Taylor Random Effects Model

	Coefficient	p-value
Khal panchayat (KP) exist on the watercourse	0.268**	(0.011)
Farmer Organization (FO) exist on the canal	0.020	(0.928)
Presence of both KP and FO	0.019	(0.945)
Season, Kharif=1, Rabi=0	1.858*	(0.060)
Season*presence of KP	0.446***	(0.000)
Season*presence of FO	0.110	(0.563)
Season*Membership in KP and FO	-0.248	(0.252)
Total surface water used (Inches)	0.052	(0.326)
Location of plot along watercourse	-0.147**	(0.030)
Flood irrigation used	0.109	(0.262)
Total groundwater used (Inches)	0.039	(0.492)
Season*Canal irrigation water	0.109**	(0.020)
Season*Ground irrigation water	-0.004	(0.944)
Season*Canal plot location	-0.051	(0.319)
Log of fertilizer used (kg/acre)	0.216	(0.445)
Log of machinery hours used per acre	-0.246	(0.359)
Log of hired labor days used per acre	0.162**	(0.024)
Log of family labor days per acre	0.198**	(0.047)
Log of number of sprays used per acre	0.290***	(0.002)
Log of seeds used(kg/acre)	-0.144	(0.702)
Log of hours of use of threshers	-0.133	(0.792)
Fertilizer*Capital	-0.118	(0.185)
Fertilizer*Labor	-0.007	(0.831)
Fertilizer*Pesticide	0.072	(0.137)
Squared term for log of Fertilizer	0.044	(0.402)
Squared term for log of machinery hours	0.335**	(0.029)
Squared term for log hired labor days	-0.011	(0.741)
Squared term for log of no. of sprays	0.026	(0.720)
Squared term for seed used	-0.113	(0.531)
Squared term for thresher hours	-0.465*	(0.084)
Season*Thresher hours	-0.910	(0.323)
Thresher hours*pesticide spray	-0.313***	(0.004)
Family labor*Hired labor	-0.070*	(0.057)
Family labor*No. of sprays	0.170***	(0.001)
Family labor*Seed	0.048***	(0.008)
Season*No. of sprays	-0.372***	(0.001)
Season*Family labor	-0.203**	(0.033)
Waterlogging or salinity present on any plot	-0.064	(0.689)
Constant	10.826***	(0.000)
Observations	207	

Some statistically insignificant coefficients have been suppressed for brevity.

We find that households whose plots are located on watercourses with Khal Panchayats are likely to earn 27 percent more value per acre as compared to farmers on watercourses without such institutions. The effect of the presence of Khal Panchayats is more pronounced in Kharif (the main rainy season) than in the Rabi season. Khal Panchayats lead to improved water management mainly through reducing water theft and conflicts around water, as well as improving maintenance of the watercourse and timing of water arrival. The result on canal level farmer organizations is not statistically significant.

The econometric results indicate a degree of success of Khal Panchayats in improving the returns on irrigation land in the Punjab province of Pakistan. That is, on average, the presence of Khal Panchayats is improving irrigation water management but the result does not suggest that all Khal Panchayats are successful. According to farmers' own evaluation of Khal Panchayats, a third of the farmers reported that the Khal Panchayat on their watercourse is ineffective to improve water management either because it is inactive or it fails to serve equally. Future research will focus on teasing out the determinants of success of Khal Panchayats and how the dynamics of their formation and management affects their potential to improve agricultural water management.

References

Alam, A., H. Kobayashi, I. Matsumura, and M. Esham. 2012. "Factors Influencing Farmers Participation in Participatory Irrigation Management: A Comparative Study of two Irrigation Systems in Northern Areas of Pakistan." *Mediterranean Journal of Social Sciences*, pp. 275.

Battese, G.E. 1997. "A Note on the Estimation of Cobb-Douglas Production Functions When Some Explanatory Variables Have Zero Values." *Journal of Agricultural Economics* 48:250–252.

Byrnes, K.J. 1992. "Water Users Associations in World Bank-Assisted Irrigation Projects in Pakistan." World Bank Technical Paper No. 173, The World Bank.

Gedara, K.M., C. Wilson, S. Pascoe, and T. Robinson. 2012. "Factors Affecting Technical Efficiency of Rice Farmers in Village Reservoir Irrigation Systems of Sri Lanka." *Journal of Agricultural Economics* 63:627–638.

Greene, W.H. 2008. *Econometric Analysis*. Pearson Education, Inc.

Hausman, J.A., and W.E. Taylor. 1981. “Panel Data and Unobservable Individual Effects.” *Econometrica* 49:1377 – 1398.

Liu, J., R. Meinzen-Dick, K. Qian, L. Zhang, and L. Jiang. 2002. “The impact of irrigation management transfer on household production in central China.” *China Economic Quarterly* 17:465–480.

Mekonnen, D., C. Ringler, I. Muhammad, A. KC, J. Gill, X. Ma, H. Shafiq, D. Sengupta, E. Bryan, and D. Spielman. 2013. “Pakistan Rural Household Panel Survey Report (Round 1.5).” Working paper, International Food Policy Research Institute.

Muhammad, D. 1998. “Legal framework for irrigation management in Punjab and Sindh Provinces, Pakistan.” Working paper, International Water Mangement Institute.

Samad, M., and D.L. Vermillion. 1999. “Assessment of participatory management of irrigation schemes in Sri Lanka: Partial reforms, partial benefits.” Working paper, International Water Management Institute.

SIDA. 2002. *Sindh Wate Management Ordinance 2002*. : Sindh Government.

Ul Hassan, M. 2009. “The conception, design and implementation of IMT in Pakistans Punjab: A public policy reflection.” *South Asian Water Studies* 1:132–142.

Uphoff, N., and C. Wijayaratna. 2000. “Demonstrated benefits from social capital: the productivity of farmer organizations in Gal Oya, Sri Lanka.” *World Development* 28:1875–1890.

Waheed, C. 1998. “Water Users’ Assosciations in Pakistan:Institutional, organizational and participatory aspects.” PhD dissertation, Georg-August-Universitt Gttingen.

Wooldridge, J.M. 2002. *Econometric Analysis of Cross Section and Panel Data*. The MIT Press, Cambridge, MA.

Zaman, W.u., N. Sultan, B. Asghar, and M.A. Kamran. 1998. “Formalization of Water Users Associations by farmer leaders of Hakra 4-R Distributary.” Working paper, International Water Mangement Institute.

Zhang, L., N. Heerink, L. Dries, and X. Shi. 2013. “Water users associations and irrigation water productivity in northern China.” *Ecological Economics* 95:128–136.