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

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This study explores the impact of water users' associations (WUAs) on farmers' productivity in Punjab province of Pakistan. We find that the presence of WUAs provide a productivity gain of ten and eight percent for farmers at the tail end of watercourses and those that rely solely on groundwater. The productivity impact of WUAs on farmers that rely more on groundwater suggests that improving the management of surface water through functioning watercourse level institutions can be a viable option in reducing over-utilization of groundwater resources and the pressure it creates on the already strained energy situation in the country. However, we find no evidence of WUAs improving productivity for those at the head and middle of watercourses, indicating that the performance of WUAs is likely to face challenges from these groups.

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I. Introduction

When poor cost recovery and bureaucratic inefficiencies lead to poor operation and maintenance of irrigated agriculture, with the resulting economic, environmental, and social problems, one of the major policy recommendations to improve the productivity of irrigated agriculture has been to transfer irrigation management from government bureaucracy to users, in a bid to relieve governments the financial burden of funding recurrent expenditure for operation and maintenance, as well as improve cost recovery, accountability, and farmers' sense of ownership (Dinar, Balakrishnan, and Wambia, 2004; Ul Hassan, 2011; Ul Hassan, Hamid, and Khan, 2003). In fact, global experience shows that either a serious breakdown in services, an environmental disaster affecting large numbers of people, a fiscal crisis making the status quo untenable, or a combination of some of these, usually drive irrigation management transfer (IMT) (Ul Hassan, 2013; Vermillion and Sagardoy, 1999). Vermillion and Sagardoy (1999) describe the list of 44 countries that have adopted IMT policies in the last three decades of the 20th century, in addition to countries that have undertaken IMT earlier than that (such as United States, Japan, Spain, Israel and Argentina) and countries that have had sustainable farmer-managed irrigation systems for hundreds of years (such as Indonesia, Thailand, China, and Peru). However, the implementation and impact of IMT on irrigation management significantly varies across countries and contexts. Ul Hassan (2011), for instance, describes the impact of IMT negligible in Central Asia, medium in India and Sri Lanka, weak to medium in Pakistan, and high in Turkey.

Despite having the world's largest contiguous irrigation network with 80 percent of agricultural land being irrigated, irrigated agriculture in Pakistan is challenged by water scarcity, salinity, waterlogging, and high conveyance losses particularly at the watercourse level. Out of the 139 million acre-feet of annual water flow available in the rivers of the Indus basin, Pakistan diverts 75 percent of the water to the canal irrigation system. However, a fourth of this water, amounting to 26 million acre-feet of water is lost due to conveyance losses in the canal system (Bandaragoda and ur Rehman, 1995). Furthermore, out of the 78 million acre-feet of water that reaches the head of watercourses, 45 percent is lost due to conveyance losses in watercourses. In addition, the water sector in Pakistan suffers from over exploitation of fresh groundwater, low efficiency in water delivery and use, poorly funded operation and maintenance, and poor cost recovery for irrigation and drainage (Dinar, Balakrishnan, and Wambia, 2004). The problems are rooted in several underlying factors which characterize Pakistan's agricultural sector, including public sector inefficiencies, structure of the agrarian society, land tenure system, irrigation system design, and political economy resulting from the interplay of all these factors (Dinar, Balakrishnan, and Wambia, 2004).

These challenges in the country's irrigated agriculture gave impetus for the government of Pakistan to start IMT in 1997, when the country decentralized its centralized provincial irrigation departments into autonomous organizations. Though slightly different across provinces and canal circles in its form and level of implementation, overall, the IMT focuses at the level above the watercourse and has three layers of governance structures. Under these reforms, (i) provincial irrigation departments would become financially autonomous authorities, with responsibility from barrages to canal head work, (ii) Area Water Boards would be established around all canal commands to take over and manage the irrigation and drainage system from canal head work to distributaries and minors, and (iii) farmer organizations to be be organized to take over the operation and maintenance of minors, distributaries, and lower level drainage infrastructures (Dinar, Balakrishnan, and Wambia, 2004; Ul Hassan, Hamid, and Khan, 2003). Water users' associations (WUAs) at the watercourse level, come into the IMT picture in Pakistan only as they have to nominate one member to the general assembly of farmer organizations at the minor/distributary level. Other than that, the IMT process is mute on the formation, mandate, and management of WUAs at the watercourse level, leaving them to operate under the provincial ordinances of the early 1980's that govern them.

The IMT process in Pakistan faced challenges primarily from two groups that would benefit from the status quo - irrigation department officials who were extracting rents from farmers by making water artificially scarce and its supply unpredictable, and the influential land owners who would want to have as much water as they could get (Dinar, Balakrishnan, and Wambia, 2004; Ul Hassan, 2013). These groups mischaracterized the reforms as privatization of the irrigation and drainage system, designed and imposed by IMF and the World Bank as a condition of providing financial support to Pakistan, which evoked emotional support from the media (Dinar, Balakrishnan, and Wambia, 2004). Small farmers and tenants also feared that water rates would go up and influential farmers would exploit them (Ul Hassan, 2013). This has resulted in a half-hearted implementation where, in Punjab, the first handover of irrigation management to a minor/distributary level farmers organization was delayed until 2005 (Ul Hassan, 2013), the provincial irrigation and drainage authority reduced the number of operation and maintenance responsibilities of the farmer organizations to only "reporting offenders" (Ul Hassan, 2011), and the irrigation network continues to be governed by primarily British era legislation except on the canals where Area Water Boards exist (Ul Hassan, 2009).

In this study, we focus on watercourse level institutions, where water losses and inefficiencies are the highest in the country's irrigation network with the corresponding high return to improved water management and governance. In particular, the study explores whether or not the presence of a watercourse level water users' association (WUA) improves farmers' productivity and the returns to land in Punjab province of Pakistan. These WUAs came into existence close to two decades prior to the latest wave of IMT in 1997, and this study analyzes their impact on productivity in the context of the recent IMT as each WUA has to nominate a member to the distributary/minor level farmer organization, wherever they exist.

Despite the challenges that the IMT process has faced in Pakistan, a number of case studies report that farmer managed distributaries and minors are performing better than the pre-reform period. In Lower Chenab Canal East canal command area, Baig et al. (2009) and Raza, Ashfaq, and Baig (2009) reported yield and recovery of irrigation charges has improved with an overall improvement in operation and maintenance of the system after the transfer of the management to farmers' organizations. Zaman et al. (1998) also reported that WUAs in Hakra 4-R distributary were successful in mobilizing labor and monetary resources for maintenance work as well as in conflict resolution among farmers on the watercourses. Our paper contributes to the ongoing discussion on the topic by providing a province-level picture using a methodological approach applicable at a wider scale rather than irrigation system level case studies.

Evidence in the literature from other parts of the world suggests that WUAs 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), and conflict resolution (Waheed, 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).

The rest of the paper is organized as follows. Section two provides the background on the regulatory environment in Pakistan for water users' participation in surface irrigation while section three describes the data and variables used in the estimation. Section four describes the methodology, followed by results and discussion in section five, and conclusions in section six.

II. The Surface Water Regulatory Environment and Formation of WUAs in Pakistan

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 Khyber Pakhtunkhwa provinces, 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 is empowered to enforce watercourse maintenance (Byrnes, 1992). Consequently, in 1981, three Pakistani provinces (Punjab, Baluchistan, and North Western Frontier Provinces) each promulgated its own WUA Ordinance while the Sindh WUA Ordinance was promulgated in 1982 (Byrnes, 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 Khyber Pakhtunkhwa provinces, 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 users' associations, because it gives little authority to the association for dispute resolution or for penalizing users who are conducting unlawful activities on the watercourses.

Watercourse level users' associations (also known as khal panchayats in Punjab) consist of five executive committee members. Under the Watercourse Users Ordinances (1981, 1982), 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. 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 percent requirement which was established in the previous ordinance.

As discussed above, the World Bank assisted on-farm water management (OFWM) project and its project office in the department of agriculture were instrumental in the formation of WUAs and the ordinances that govern them. Thus, it is important to explore the performance of WUAs under the light of what OFWM does on the farms or watercourses and its operational linkages with WUAs. The main activities done on watercourses by OFWM are watercourse lining and land leveling (Jehangir and Horinkova, 2002). However, OFWM assisted watercourse improvements could not begin until farmers on a watercourse organize themselves into a registered WUA (Byrnes, 1992). The OFWM project office claims that it has organized about 48,000 WUAs in the last 30 years in Punjab, a huge number compared to the 58,500 watercourses in the province (OFWM, 2015). Though a number of these watercourses have become defunct after establishment (Jehangir and Horinkova, 2002), it indicates that the productivity impact of existing WUAs is in part due to the initial long term investment made in improving the watercourses by OFWM, as well as the WUAs' ability to organize its members to maintain and upkeep the watercourse over time.

In selecting watercourses to be improved, the OFWM gives preference to those watercourses with high potential for increased land and irrigation water productivity, i.e, those watercourse located in saline groundwater areas, those located within fresh groundwater areas but without tubewells, and those cultivated by low income farmers. The higher percentage of hard lining permitted for saline groundwater zones was to address the problem of irretrievable losses of deep percolated water, whereas percolation losses in fresh groundwater zones become available for subsequent pumpage from groundwater storage (Byrnes, 1992). As a result, one can expect that even those farmers that completely rely on groundwater can benefit from watercourse improvements and the associated upkeep and maintenance provided by a well-functioning WUA. The selection criteria also implies that there is an inherent selection bias in the watercourses selected for water course improvement and a necessary precaution must be made in the analysis of the impact of WUAs on agricultural productivity.

III. 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 Pakhtunkhwa 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 942 farm households in total, with 521 households in Punjab, 305 households in Sindh, and 116 households in Khyber Pakhtunkhwa provinces.

In the Round 1.5 Pakistan Rural Household Panel Survey, Khal Panchayats are reported among 25 percent of the households in Punjab, less than two percent in Sindh, and are almost non-existent in Khyber Pakhtunkhwa. Given the emphasis of this study on the role of Khal Panchayats, we have restricted our analysis to those households in Punjab. Given the large number of crops grown by the households, we have focused on seven important crops in terms of their share of harvested land. These crops are rice, cotton, sugarcane, sorghum, and millet in the Kharif (rainy) season, and wheat and berseem in the Rabi (dry) season. These crops account for more than 90 percent of the harvested land in the respective seasons. Out of the 521 sampled households in Punjab, 458 of them produce at least one of rice, cotton, sugarcane, sorghum, millet, wheat, or berseem. The final sample size for the Punjab sub-sample has 458 households in the Rabi season and 393 households in the Kharif season, for a total of 851 observations in the two seasons. We lost more observations in the Kharif season due to the more diversified nature of crop mixes in the Kharif season than in Rabi.

Soil erosion, waterlogging, and salinity have been reported as prevalent by only two, six, and three percent of the respondents (Table 1). Unlike other provinces such as Sindh, where waterlogging and salinity has been reported to be a severe problem (Mekonnen et al., 2015), the soil health in Punjab appears to be relatively good. Flooding is the main type of irrigating the plots with other types of irrigation such as use of furrows or bed and furrows accounting for only less than 10 percent (Table 1). About 40 percent of the households in Rabi and 20 percent in Kharif did not sell any of the selected crops.

Table 1 about here

Whenever they exist, the three main roles of Khal Panchayats are maintenance of watercourses, influencing timing of water release, and collection of abiana[1] (Table 2). Khal Panchayats are also involved in dispute settlement and maintenance of the canal.

Table 2 about here

Among households with a KP on their watercourse, two third of them responded that the KP has improved water management. These households reported that 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 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 3 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. If the household did not sell the crop, the average price in the village is used to compute the value of output produced. The value of output per acre in the Kharif season is about 43 percent higher than that in the Rabi season,

[1] Water charges or fees per acre.

which is not surprising since the mix of Kharif crops is dominated by cash crops such as cotton and sugarcane. The Kharif crops are heavier consumers of water and pesticide, and are also more labor intensive (Table 3). 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 49 years and about 55 percent of them have attended school.

Table 3 about here

IV. 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 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 (such as farmers' work ethic, ability, and social networks) are likely to affect and hence 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. However, in the process of eliminating the individual effects through first-differencing or mean-differencing, the fixed effects estimator 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, our main variable of interest, is 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, which we use in this study, is presented as follows.

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

where y_{it} is the value of output per acre; X_{1it} is a vector of K_1 variables that are time-varying and uncorrelated with μ_i ; Z_{1it} is a vector of L_1 variables that are time invariant and uncorrelated with μ_i ; X_{2it} is a vector of K_2 variables that are time-varying and correlated with μ_i ; Z_{2it} is a vector of 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 $i = 1, \ldots, n,$ where n is the number of individuals in the sample and, for each time period $t = 1, \ldots, T_i$.

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

$$y_{it} - \overline{y_\iota} = (X_{1it} - \overline{X_{1\iota}})\beta_1 + (X_{2it} - \overline{X_{2\iota}})\beta_2 + (\epsilon_{it} - \overline{\epsilon_\iota}) \qquad (2)$$

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 land. As discussed above, we consider plots with rice, cotton, sugarcane, sorghum, and millet in the Kharif season, and wheat and berseem in the Rabi season. Given this seasonal crop type dichotomy and the potential difference of the crops to respond differently to agricultural inputs, we have included crop dummy variables that exhaust all the combinations of crop mixes in the sample. We have grouped some of the crop mixes with very few observations, for instance, growing all the five crops in Kharif or growing just one of the fodder crops in Kharif, into one miscellaneous-crop group.

The time invariant endogenous variables (Z_{2it}) in the estimating model include the presence of Khal Panchayats on the watercourse (KPs), the interaction of the existence of KPs with locations on the watercourse, the presence of farmers' organizations on the minor or distributary, the use of groundwater, whether the farms experience waterlogging and salinity problems, and an education variable that shows whether the household head ever attended school. Khal Panchayats have either been formulated under the on-farm water management (OFWM) project or by Area Water Boards in areas where the irrigation network is managed by these institutions. While the formulation and registration of the Khal Panchayats requires the approval of 51 percent of the farmers on that watercourse, the initiation of these bodies requires the involvement of external government or non-governmental agencies. As such, the de jure existence of the KPs can be considered to be exogenous to an individual farmers' choice. However, the de facto function or performance of the KP in improving irrigation water management is likely to be endogenous and hence is treated as one in our model. Moreover, the establishment of WUAs is highly linked with the watercourse improvement project (OFWM), which chooses the watercourses for such interventions based on their potential for improved land and water productivity and the cooperativeness of the farmers on the watercourse. As a result, the watercourses with and without WUAs can be quite different and treating these institutions as exogenous can give biased results. So, we treat them as part of the set of endogenous variables (Z_{2it}).

The time invariant exogenous variables (Z_{1it}) that enter into our estimating model include the age of the household head (since the data refers to two consecutive seasons) and district dummy variables that will capture a host of location specific factors that affect agricultural productivity, such as average rainfall, temperature, and other district level unobserved effects.

The time varying endogenous variables of the model (X_{2it}) include fertilizer use per acre, volume of total ground and surface water per acre, machine hours (hours of use of tractors, threshers, and land laser-levelers) per acre, labor days per acre, number of pesticide sprays in the season per acre, and the interaction of all these inputs and their squared terms. The season dummy variable is also allowed to interact with KPs and minor/distributary level farmer organizations to see whether these institutions have differential impacts during the Kharif and Rabi seasons. The crop dummies that are included to control for crop specific effects 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. Other time varying endogenous variables in the model include average length of one irrigation turn, tenancy status of the land, and whether the farmer uses flooding to apply the irrigation water as opposed to using furrows or bed and furrows.

The time varying exogenous variables (X_{1it}) include satisfaction with the timing of canal water for each season, average slope, soil types, and fertility of the plots used in the season, distance to the location where output was sold, whether the plots of the household are located at the head, middle, or tail end of the watercourse, and the season dummy variable.

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 one if such substitution occurs and zero otherwise.

V. Results and Discussion

The econometric results from OLS and a random effects estimator (under the assumption that any unobserved effect that affects productivity is uncorrelated with the included variables in the estimation) are presented in the first four columns of Table 4. In general, the OLS and random effects estimators give comparable results on many variables, with markedly different set of results on others, to our preferred method of Hausman-Talyor random effects estimator. Due to the appropriateness of the Hausman-Taylor approach to our model, as presented in the methodology section, we will focus the discussion of the results on the last two columns of Table 4.

The results show that the impact of Khal Panchayats (KPs) on farm productivity varies by the location of the household on the watercourse. KPs lead to a productivity increase of about 10.5 percent more value of output per acre for those households at the tail of the watercourse, and about 8.3 percent more value of output per acre for those who are not using canal water, though the later effect is only marginally significant (with a p-value of 0.106). Thus, farmers who would be residual claimants of water distribution in the absence of an establishment that streamlines the use of irrigation water use along the watercourse, i.e, those with plots at the tail end of the watercourse as well as those who were unable to use from the canal, are set to gain productivity improvements from a well performing KP.

However, caution must be made in the attribution of these effects only to WUAs. This is because the WUAs, as discussed above, are not always established as a pure institutional innovation in water management but sometimes as a pre-condition for infrastructural improvements such as canal linings. On the other hand, even those structures would not last long if the users are not organized to clean and maintain it over time as witnessed during the OFWM pilot project (1976-1980) where improved watercourses deteriorated due to lack of maintenance, as well as during the Punjab accelerated watercourse cleaning campaign in 1980, where about 10,000 watercourses were cleaned but the benefits were estimated to last no more than two years because adequate provisions had not been made for maintenance (Byrnes, 1992). Thus, in Pakistan's context, the productivity improvements we see from water users' associations at the tertiary level possibly includes the effect of investments that usually follow the formation of the associations, making it difficult to distinguish these two effects from our data. Nevertheless, the results show the need for investment (both on infrastructure and organization of well-performing farmers' institutions) in Pakistan's tertiary level network. In addition, the fact that watercourse lining focuses on saline groundwater zones with the problem of irretrievable losses of deep percolation, and less on fresh groundwater zones where the water can subsequently be pumped by groundwater users, partly explains why even those farmers that solely rely on groundwater can benefit from such investments and institutions.

On the other hand, the effect of WUAs on the productivity of farmers located at the head and middle of the watercourse is not statistically significantly different from zero. This lack of observed productivity improvements from KPs at the head and middle of watercourses implies potential challenges on the performance of KPs from head and middle end users. In addition, despite the emphasis of the recent wave of IMT in Pakistan on the part of the irrigation network above the watercourse level, we did not find productivity enhancing effects of minor and distributary level farmers organizations, possibly because their roles have been reduced to only "reporting offenders" from a list of operation and maintenance responsibilities (Ul Hassan, 2011).

Table 4 shows that timely supply of canal water is one of the major determinants of farm productivity. Households who said they are satisfied with the timing of supply of canal water earn three percent more output per acre as compared to those who are not satisfied with the timing of supply of canal water. Households with higher average length of one irrigation turn are also found to be more productive.

The econometric results show that the value of output per acre in Punjab is responsive to the availability and use of additional volume of irrigation water and pesticide applications. We find no evidence for productivity-enhancing effects of increased use of fertilizer and machinery hours. Table 3 suggests a possible explanation of why this may be expected. Fertilizer applications and machinery hours per acre are higher in the Rabi season where productivity as measured by value of output per acre is 43 percent lower compared to the Kharif season. This mismatch in the amount of use of these inputs and productivity is reflected in the econometric estimation to give unexpected signs on the coefficients of the two inputs as well as their interactions with other inputs.

In the Rabi season, farmers who produce only the fodder crop berseem are less productive as compared to the base group of farmers who produce only wheat in the season. However, farmers who produce both wheat and berseem are more efficient than those who produce only wheat or only berseem. For Kharif crops, the base group of farmers who produce only rice are more productive than farmers who produce only the fodder crop sorghum but are less productive than those who produce cotton and a fodder crop or sugarcane and a fodder crop.

Robustness Checks

The Hausman-Taylor regression results presented in Table 4 and discussed so far, make two assumptions on the way we treat those households that responded that they do not know about the presence of KPs on their watercourse and on missing values on the KP variable. Out of the 485 households in Punjab in the sample that produce at least one of the seven crops included for this study, 51 of them said they do not know about the existence of KPs, while 96 of them did not respond to the question. All the 96 missing values on the presence of KPs are from farmers who solely use groundwater with no access to a canal water. So, we either had to drop these observations from the analysis (which we were reluctant to do because we hypothesized that the presence of KPs may have indirect impact even on sole groundwater users because of how these institutions were established) or to include them in the analysis and interpret these missing values to mean that KPs do not exist (with the argument that since they are sole groundwater users, KPs do not have direct influence on their irrigation water use). The results in Table 4 are from the later assumption that interprets the missing values of the KP variable on sole groundwater users to mean that KPs do not exist. However, this decision can be contestable. Thus, in the first two columns of Table A.1, we provide results from a robustness check in which we dropped from the estimation, sole groundwater users who did not respond to the question on the presence of KPs. The results do not hinge on this decision. In fact, the impact of KPs on tail end users has increased by about one percentage point.

The second assumption we make is on the way we treat the "do not know" responses on KPs. If farmers do not know about the existence of a KP on their watercourse, either a KP does not exist or it was established but not functioning at all. Thus, in the results presented in Table 4, we interpret these "do not know" responses to mean that a KP (or at least a functioning one) does not exist on the watercourse, otherwise the farmers would have known about it when they are called for maintenance, asked to pay the irrigation charges, or in other KP related activities. When we drop these observations, the results still show that tail end users are set to benefit from KPs, although the impact has reduced by about one percentage point. However, when we drop both missing values on KPs from sole groundwater users, as well as the "do not know responses" simultaneously, the impact of KPs on tail end users is no more statistically significant as shown in columns 3 and 4 in Table A.1. This lack of statistical significance is possibly because of the significant slicing of the data, and the resulting loss of variation.

As discussed in section III, KPs are reported among 25 percent of the sampled households in Punjab, in less than two percent of the sample in Sindh, and are almost non-existent in KPK. That is the reason why the analysis of this study of KPs focuses on Punjab. If we include all the three provinces, as shown in columns 5 and 6 of Table A.1, the impact of KPs on tail end users is no more statistically significant at 10 percent level of significance. This is, perhaps, not surprising because we are deliberately including data that has no information on the presence of KPs, thereby diluting the impact of KPs where they are actually in operation.

VI. 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. 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. So far, most of the literature on the impact of farmers' participation in the management of the irrigation network in Pakistan focus on specific case studies. This particular study is expected to contribute to this discussion by providing a province wide evidence on whether the presence of Khal Panchayats on a watercourse has impacts 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 estimate 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.

We find that the impact of Khal Panchayats (KPs) on farm productivity varies by the location of the household on the watercourse. We find no evidence of KPs improving productivity for those at the head and middle of watercourses. However, KPs lead to a productivity increase of about ten percent for those households located at the tail end of the watercourse, and an eight percent productivity increase for those who solely rely on groundwater.

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 their differential impact along the watercourse in favor of tail end users and those marginalized from the use of surface water informs the susceptibility of these institutions to potential challenges from head end water users. This is particularly worrisome when head end water users are powerful and politically connected to be able to thwart the performance of khal panchayats, and calls for a cautious design and transfer of irrigation water management to watercourse level farmers' organizations. On the other hand, the productivity enhancing impact of WUAs on heavy groundwater users (those farms located at the tail of the watercourse or that solely rely on groundwater) suggests that improving the management of surface water through functioning watercourse level institutions can be a viable option in reducing excessive reliance on groundwater resources, the pressure it creates on the already strained energy situation in the country, and the environmental problems associated with increasing reliance on groundwater such as groundwater overdraft and salinization.

Table 4 about here

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TABLE 1: Descriptive Statistics on Khal Panchayats and Soil Health in Punjab (Yes Percent given)

	Rabi 2011-12		Kharif 2011	
	Percent	Standard Deviation	Percent	Standard Deviation
Khal panchayat (KP) exists on the watercourse	0.242	(0.429)	0.262	(0.440)
Plots experience waterlogging	0.0546	(0.227)	0.0534	(0.225)
Plots experience salinity	0.0328	(0.178)	0.0331	(0.179)
Flood irrigation used	0.906	(0.292)	0.725	(0.447)
Plot Exposed to Erosion	0.175	(0.380)	0.153	(0.360)
Household did not sell any of the selected crops	0.400	(0.490)	0.201	(0.401)
Observations	458		393	

Source: Authors' computation

Table 2: Roles of KPs identified by survey respondents in areas with KPs

	Percentages
Collection of Abiana	67
Maintenance of canal	24
Maintenance of watercourse	71
Dispute settlement	38
Influence timing of water release	67
Observations	104

Respondents can give up to three important roles of KPs, hence the percentages do not add up to 100.

Source: Authors' computations from PRHPS Round 1.5.

Table 3: Descriptive Summaries on Agricultural Output, Input Uses, and Household Demographics

	Rabi 2011-12	Kharif 2011
	Mean	Mean
Value of output (Rs/acre)	142132.7	202937.3
	(124312.5)	(239781.5)
Fertilizer used (kg/acre)	477.7	426.9
	(491.6)	(504.0)
Machinery Hours (Hours/Acre)	18.20	12.53
	(17.29)	(13.49)
Labor Hours (Hours/Acre)	661.3	871.9
	(548.2)	(769.1)
Volume of Water Used (Inches)	197.1	311.4
	(274.6)	(386.2)
Number of pesticide sprays (Sprays/Acre)	1.541	3.845
	(1.495)	(3.425)
Age of the household head	48.86	49.18
	(13.35)	(13.72)
Household head attended school	0.557	0.542
	(0.497)	(0.499)
Observations	458	393

Standard deviations are in parenthesis

Table 4: Regression results using the Punjab sub-sample

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS		Random Effects		Hausman-Taylor	
Dependent Variable: Log of value of output per acre						
	Coef.	se	Coef.	se	Coef.	se
Log of fertilizer (kg/acre)	0.10*	(0.06)	0.19***	(0.07)	0.03	(0.08)
Log of machinery hours per acre	-0.01	(0.04)	0.01	(0.04)	-0.07	(0.05)
Log of number of sprays per acre	0.02***	(0.01)	0.02***	(0.01)	0.02***	(0.01)
Log of labor days used(Days/acre)	0.47***	(0.16)	0.51***	(0.17)	0.38	(0.24)
Log of total water used (Inches)	0.17**	(0.07)	0.04	(0.09)	0.38***	(0.09)
Squared of log of machinery hours	0.03**	(0.01)	0.01	(0.02)	0.08***	(0.02)
Water* Capital used	-0.02	(0.02)	-0.01	(0.02)	-0.06***	(0.02)
Machinery hours*No. of sprays	0.00	(0.00)	0.00	(0.00)	-0.00**	(0.00)
Labor* Pesticide used	-0.02***	(0.00)	-0.02***	(0.01)	-0.02***	(0.01)
Squared term for log of no. of sprays	-0.00	(0.00)	-0.00	(0.00)	-0.00***	(0.00)
Square of water used	-0.08**	(0.04)	-0.02	(0.05)	-0.13**	(0.06)
Season, Kharif=1, Rabi=0	0.02	(0.02)	0.05**	(0.03)	-0.00	(0.02)
Timely supply of canal water	-0.00	(0.01)	0.00	(0.01)	0.03**	(0.01)
Average length of one irrigation turn	0.01**	(0.00)	0.00	(0.00)	0.02***	(0.01)
Distance of plot from homestead	-0.00	(0.00)	-0.00	(0.00)	-0.02*	(0.01)
Middle of the watercourse	-0.01	(0.01)	0.00	(0.01)	-0.01	(0.02)
Tail of the watercourse	-0.01	(0.01)	-0.00	(0.01)	-0.02	(0.03)
Uses only groundwater	0.02	(0.02)	0.00	(0.02)	0.06*	(0.03)
Uses groundwater	-0.00	(0.01)	-0.00	(0.01)	-0.20	(0.51)
KP exist on the watercourse	0.02	(0.02)	0.05*	(0.03)	-0.28	(1.31)
KP*Season	0.01	(0.01)	-0.05	(0.05)	0.01	(0.01)
KP*Middle of the watercourse	0.00	(0.02)	-0.01	(0.02)	0.08	(0.06)
KP*Tail of the watercourse	-0.01	(0.02)	-0.02	(0.02)	0.10*	(0.06)
KP*Uses only groundwater	-0.02	(0.02)	-0.03	(0.02)	0.08	(0.05)
Farmer Organization (FO) on the canal	-0.00	(0.01)	-0.02	(0.02)	0.33	(1.65)

Presence of FO*Season	-0.02*	(0.01)	0.01	(0.05)	-0.01	(0.01)
Plots experience waterlogging	0.00	(0.01)	0.01	(0.01)	-0.30	(1.93)
Plots experience salinity	-0.00	(0.01)	0.00	(0.01)	-0.11	(1.55)
Producing wheat and berseem in Rabi	0.03***	(0.01)	0.03***	(0.01)	0.02	(0.01)
Producing only berseem in Rabi	0.04***	(0.01)	0.10***	(0.02)	-0.05***	(0.02)
Producing sorghum only in Kharif	-0.02	(0.02)	-0.02	(0.02)	-0.06***	(0.02)
Producing cotton and millet in Kharif	0.05***	(0.01)	0.03	(0.02)	0.04**	(0.02)
Producing sugar and sorghum in Kharif	0.06***	(0.02)	0.04	(0.03)	0.04**	(0.02)
Constant	0.55***	(0.11)	0.53***	(0.12)	-0.21	(1.00)
Observations	851		851		851	
R-squared	0.416		0.555			
Number of households			467		467	

Standard errors in parentheses

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

Appendix

Table A.1: Robustness Check: Dropping missing values on KPs (1& 2), dropping both missing values and "don't know" responses on KPs (3&4), using sample from Punjab, Sindh, and KPK without dropping missing values and "don't know" responses (5 & 6)

	(1)	(2)	(3)	(4)	(5)	(6)
	Missing values on KPs dropped		Missing values & "don't know" dropped		Punjab, Sindh, & KPK	
Dependent Variable: Log of value of output per acre		Estimator: Hausman-Taylor				
	Coef.	se	Coef.	se	Coef.	se
Log of fertilizer (kg/acre)	-0.01	(0.09)	-0.33	(0.22)	-0.10	(0.08)
Log of machinery hours per acre	-0.04	(0.06)	-0.17	(0.11)	0.02	(0.05)
Log of number of sprays per acre	0.02**	(0.01)	0.02	(0.01)	0.01	(0.01)
Log of labor days used(Days/acre)	0.35	(0.26)	-0.31	(0.47)	-0.04	(0.20)
Log of total water used (Inches)	0.31***	(0.11)	0.29*	(0.18)	0.23***	(0.08)
Square of water used	-0.19***	(0.07)	-0.11	(0.11)	-0.04	(0.05)
Average length of one irrigation turn	0.02***	(0.01)	0.02*	(0.01)	0.02***	(0.01)
Water* Capital used	-0.08***	(0.03)	-0.05	(0.04)	-0.03*	(0.02)
Machinery hours*No. of sprays	-0.00***	(0.00)	-0.00	(0.00)	-0.00***	(0.00)
Labor* Pesticide used	-0.02***	(0.01)	-0.01	(0.01)	-0.01**	(0.00)
Season, Kharif=1, Rabi=0	-0.01	(0.02)	-0.01	(0.03)	0.03***	(0.01)
Timely supply of canal water	0.03**	(0.01)	0.03	(0.02)	0.03**	(0.01)
Distance of plot from homestead	-0.02*	(0.01)	-0.03	(0.02)	-0.02**	(0.01)
Middle of the watercourse	-0.00	(0.03)	0.01	(0.04)	0.02	(0.02)
Tail of the watercourse	-0.01	(0.03)	0.01	(0.04)	0.02	(0.02)
Uses only groundwater	0.09**	(0.03)	0.09*	(0.05)	0.10***	(0.03)
Uses groundwater	-0.02	(0.55)	0.40	(1.15)	0.14	(0.35)
KP exist on the watercourse	0.31	(1.00)	3.50	(4.55)	0.29	(1.10)
KP*Middle of the watercourse	0.08	(0.06)	0.05	(0.09)	0.04	(0.05)
KP*Tail of the watercourse	0.11*	(0.06)	0.07	(0.09)	0.08	(0.05)
KP*Uses only groundwater	0.09	(0.06)	0.06	(0.09)	0.04	(0.05)
KP*Season	0.02*	(0.01)	0.01	(0.02)	0.01	(0.01)
Farmer Organization (FO) on the canal	-0.42	(1.24)	-3.76	(4.87)	-0.33	(0.95)
Presence of FO*Season	-0.01	(0.01)	-0.01	(0.02)	-0.01	(0.01)
Plots experience waterlogging	0.43	(1.47)	2.83	(3.90)	0.47	(1.21)
Plots experience salinity	-0.51	(1.19)	0.45	(2.39)	0.06	(1.10)
Household did not sell crops	0.02***	(0.01)	0.03***	(0.01)	0.02***	(0.01)
Producing wheat and berseem in Rabi	0.01	(0.01)	-0.01	(0.03)	-0.01	(0.01)
Producing only berseem in Rabi	-0.07***	(0.02)	-0.09***	(0.03)	-0.08***	(0.01)

Producing sorghum only in Kharif	-0.08***	(0.02)	-0.10***	(0.04)	-0.14***	(0.01)
Producing cotton and millet in Kharif	0.04*	(0.02)	0.06	(0.04)	-0.02*	(0.01)
Producing sugar and sorghum in Kharif	0.04*	(0.02)	0.02	(0.04)	-0.02*	(0.01)
Constant	-0.05	(1.04)	-0.78	(2.54)	-0.60	(2.29)
Observations	696		601		1,017	
Number of households	374		325		601	

Standard errors in parentheses

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