Transaction Costs in Irrigation Management in Kathmandu Valley, Nepal

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1 Introduction

Agriculture remains an important livelihood option in developing countries like Nepal, where it not only contributes about 32% of the GDP but also provides employment for more than two thirds of the population (NPC 2007). Agricultural incomes crucially depend on productivity-enhancing infrastructure, irrigation being one of them. About 1.8 million hectares of land in Nepal is irrigable. However, currently, only 1.2 million ha of this area is under irrigation although the facility is not available even for this land throughout the year. The total irrigated area, as a percentage of the total cultivable area in Nepal, is only 28% (NPC 2007). In Nepal, both the state and the farmers play a role in creating and maintaining irrigation infrastructure (Regmi 2007). In areas where irrigation is by surface water through gravity flow, it needs either community or state involvement for both proper maintenance and for efficient water distribution.

The small-scale canal irrigation systems of the Kathmandu Valley typically represent common pool resource features of non-excludability and rivalry (see an early discussion of these issues by Coman (1911) in the American context).[1] It is

[1]In other contexts the excludability problem can be resolved (see, Araral 2009).

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difficult to exclude any farmer in the command area from utilizing irrigation water, but its use upstream will indubitably reduce its availability to those living downstream of the canal. Thus, water allocation and provisioning are two potential problems associated with the management of irrigation systems (Ostrom 1990). The operation and maintenance of an irrigation system require coordination among many farmers. Unfortunately, resource management is riddled with conflicts and free-rider problems which often result in poor maintenance (Tang 1992). Numerous solutions for creating a strong institutional mechanism have been suggested to solve such problems which include re-alignment of property rights, state action, as well as collective action at the community level (Baland and Platteau 1996).

Transaction costs are in the nature of investment in institutions for collective action in order to improve the productivity of irrigation systems through better coordination. In this paper, like much of this literature, the term “institutions” represent “rules of the game” (for a nuanced discussion, see North (1991)). Production is not just a technical relation between inputs and output but is located in a system of governance (Williamson 1998). Productivity differences between firms, and nations, could well be attributed significantly to differences in institutions (Acemoglu et al. 2014; North 1990). Received theory associates “efficiency” with lower transaction costs (Ostrom 2005). As Tadelis and Williamson (2013) point out, the central problem of economic organisation is adaptation to reduce transaction costs.

In agrarian systems, transaction costs have been found to have an inverse relationship with productivity (Stifel and Minten 2008). However, there is no uniformity in the empirical literature on what items are considered to be transaction cost. For example, Stifel and Minten (2008) measure transaction cost as the gap between farm gate prices and market prices which includes transportation costs. Toufique (2012) has included the cost of searching and monitoring agricultural labor as transaction costs. These inclusions lead to difficulty in separating out production costs from transaction costs.

Our study systematically estimates the quantum of transaction costs and analyzes the impact of transaction costs on agricultural productivity in Nepal’s Farmer Managed Irrigation System (FMIS), which to the best of our knowledge has not been attempted by any prior study.

1.1 Transaction Costs: A Brief Discussion

Transaction costs are said to arise when an individual or a group of individuals exchange ownership rights over economic assets and enforce their exclusive rights. It includes the costs of (a) information search; (b) bargaining and negotiation; (c) ensuring the fulfillment of contract; (d) compensation valuation; and (e) legal expenses to gather evidence, present a case, challenge opponents, award and collect damages (Field and Olewiler 1995; Holloway et al. 2000). Some authors have also included the cost of isolation (or transportation from producer to market) as a transaction cost (Stifel and Minten 2008).

The total cost of bringing a commodity (or service) to the market comprises both transformation costs, which include the cost of inputs of land, labor, and capital involved in transforming the physical attributes of a good, and transaction costs, which include the cost of defining, protecting, and enforcing the property rights to goods (North 1990). Institutions, which are the key to achieving economic efficiency, must therefore minimise transaction costs by generating both trust as well as social norms for mutual benefit (North 1990; Ostrom 1994; Fukuyama 1995; Uphoff and Wijayaratna 2000).

1.2 Transaction Costs and Resource Management

Traditionally four key factors in natural resource management have been thought to have influenced transaction costs: uncertainty, asset specificity, frequency of decision-making, and care or effort intensity (Williamson 1985). Recently, adaptation costs for farmers facing climate change are also being considered (Araral 2013). Uncertainty about a resource, which could be due to natural factors (such as natural disasters, timing of monsoons) or man-made factors (such as security of property rights), can result in high levels of transaction costs. Similarly, the frequency of decision-making could raise transaction costs since transaction requires time, ranging from daily to seasonal, and resource commitment from involved agents (Birner and Wittmer 2004; Williamson 1991). Asset specificity describes the condition where an asset is essential in a particular transaction and its absence would adversely affect productivity. The asset could take any form—physical or otherwise and as Tadelis and Williamson (2013) emphasize the identity of transactors makes a difference to efficiency. In the case of effort- and care-intensive transactions, the former describes production activity while the latter describes protection activity (Fenoaltea 1984). If the existing institutional structure changes, the transaction cost structure may also change. Co-management has the potential to increase the ex-ante transaction costs although it may also result in a reduction in ex-post transaction costs (Kuperan et al. 1998).

Transaction costs exist at several resource management stages: description of the resource use context, regulatory design, and implementation of agreed rules (Hanna 1995). Previous studies have shown that transaction costs can vary across regions and sectors. In Kenya, transaction costs of landowners arising from collaborative wildlife management were relatively low (Mburu et al. 2003) but in the Philippines, monitoring alone accounted for more than 50% of the total costs of co-management in the fisheries (Kuperan et al. 1998). The transaction costs accounted for 37% of the total costs in another study from the Philippines of a community-based coastal management program where the share of the transaction cost was as high as 74% of the total cost in the implementation phase (Sumalde and Pedroso 2001).

In Nepal, Adhikari and Lovett (2006) found transaction costs to be a major component of resource management costs in the community forestry sector ranging between 9 and 14% of the total cost. Another study based on two irrigation systems located within the Kathmandu Valley distinguished between the conveyance and congestion costs for canal maintenance. When the conveyance cost of water was high, all farmers paid the maintenance fee regularly, but when upstream farmers showed reluctance to cooperate with downstream farmers, congestion costs became important and farmers paid more for waiting, watching, and negotiating (Osanami and Joshi 2005). These studies do not however systematically either estimate or analyze the nature of the transaction costs or their impacts on productivity in the irrigations systems of Nepal even though irrigation in Nepal has been widely studied.

1.3 Farmer Managed Irrigation Systems: A Short Review

In the 1960s and 70s, the Government of Nepal committed significant expenditure (approximately Nepali Rs. 17 billion according to various NPC documents) toward the development of irrigation canals with support from various external agencies. However, despite sophisticated engineering infrastructure and highly trained staff, the performance of these government-managed irrigation systems was not satisfactory (APROSC 1978; Singh 2010), leading both to low productivity and severe deprivation of tail-enders (WECS 1982). This received further attention with the commencement of its basic needs fulfillment program in the 1980s.

Recognizing its inability to develop and manage large numbers of irrigation infrastructure by itself, the Government started providing assistance to FMIS in different parts of the country in the 1980s with support from donor-driven programs (such as Irrigation Line of Credit (ILC), and Irrigation Sector Program (ISP)). However, while this helped to increase the irrigated area, it also placed many of the FMIS under the Irrigation Department for a short period of time (Pradhan 2002).

The need to devolve responsibility for irrigation systems management to local user organizations gained momentum in Nepal only after 1990. The Government of Nepal not only transferred irrigation systems to farmers but also provided strong institutional support to farmers for the management of irrigation water under the new policy (NPC 2007). However, various pieces of legislation, like the Water Resource Act of 1992, Water Resource Regulation of 1993, and Irrigation Regulation of 1999, vested the ownership of water with the state. These laws made it mandatory to register canals with the state even if they had been traditionally managed by farmers. Evidence suggests that the registration of irrigation systems has not fared well. Even in the Kathmandu Valley, which houses the capital of the country, registration of irrigation institutions had not reached the 50% mark despite the legal requirement to do so (Dulal and Pradhan 2002).

Since irrigation development has been a community-level concern given the nature of the terrain in the hill tracts, it is important to understand how transaction costs influence agricultural productivity. With this objective in mind, we examine the relation between transaction costs and productivity (measured as the total value of output per hectare).

2 Methods

Administratively, Nepal is divided into 75 districts which are further divided into Village Development Committees (VDCs) and Municipalities for purposes of governance. There are 3914 VDCs and 58 Municipalities including one metropolitan and four sub-metropolitan cities. The VDCs and municipalities are further subdivided into smaller units called the wards. There are 9 wards in each VDC while the number of wards in a municipality ranges from 10 to 35. Nepal has approximately 16,000 FMISs which irrigate approximately 714,000 hectare (i.e., 67% of the total irrigable area) of the country (Lam 1998; Pradhan 2002; Shivakoti 2007). The average farm size per household is 0.8 hectare (CBS 2001).

We chose three districts (Kathmandu, Lalitpur, and Bhaktapur) located in the Kathmandu Valley, which is reputed for its agricultural production.[2] The valley is home to about 1.7 million people 60% of whom reside in the urban centers while the remaining 40% reside in the countryside (CBS 2001). The total cultivable area in the three districts is approximately 12,800, 11,069, and 7097 hectare, respectively. The major cereal crops cultivated in the valley are paddy, wheat, maize, and millet while the major cash crops are potato, oilseed, and vegetable. Irrigation water is necessary for wheat, winter potato, and early paddy (planted before the onset of the monsoons in May). In the case of the paddy plant, the normal rainfall is sufficient once planted. The summer potato crop which is cultivated just after the harvesting of paddy does not need much water since the land is wet during this period. Only the winter crop is crucially dependent on irrigation, and potato and wheat are the typical winter crops although some farmers may get a second crop of paddy in this season. In some parts of Kathmandu, however, farmers plant paddy in May, in order to cultivate two crops of potato after the paddy harvest.

2.1 Data Collection Strategy

As a first step, we listed and categorized the 415 irrigation systems within the three districts according to the number of VDCs they cover. This classification yielded 51 large (comprising 3 VDCs and above), 122 medium (comprising 2 VDCs), and 242 small (comprising just 1 VDC) irrigation systems. We selected twenty systems from each category randomly. We collected both system-level data and household-level data. Selection of canals and households was done using the stratified random sampling technique.

We divided the farmers in the large systems into three groups as head-, middle-, and tail-enders while grouping farmers in the medium-sized systems into two as head- and tail-enders. On the other hand, we considered all farmers in the small

[2]At the time of the survey, Nepal was under political turmoil and it was difficult to undertake data collection in other parts of Nepal.

Table 1 Classification and selection strategy of FMIS irrigation systems

Systems	Systems covering village	Total systems within Kathmandu Valley	No. of systems selected randomly	Households selected randomly and surveyed	No. of households finally used in analysis
Small	1	242	20	60 (3 from each system)	55
Medium	2	122	20	120 (3 from head and 3 from tail of each system)	100
Large	3 and above	51	20	180 (3 from head, 3 from middle and 3 from tail-end users)	145
Total		415	60	360	300

Source Fieldwork by authors

system as head-end users. Since our sample included twenty canals from each category of irrigation systems, the number of households surveyed was 180, 120, and 60 for the large, medium, and small systems, respectively (see Table 1). We collected the data during the winter of 2007.

The survey instruments included two separate questionnaires that were administered at the system and household levels. The system-level questionnaire recorded the characteristics of the Water User Associations (WUA) and the canal system while the household-level questionnaire included questions about the respondent's and household's demographic and socioeconomic characteristics and their agricultural practices. It also recorded the time spent on different components of transaction during the two seasons, winter and summer, of the previous year, which was the year 2006. While the survey collected socioeconomic and institutional data, its main focus was on capturing transaction costs information.

2.2 Monetary Estimation of Transaction Costs

Transaction costs estimation involved both a direct monetary measurement as well as an imputed measurement. The direct measure included payments to hired labor while the imputed measure involved the opportunity cost of time that individuals expended on organizational work. Households in the Kathmandu Valley can opt for non-farm employment throughout the year. Thus, we use the normal daily wage labor rate in Kathmandu as the opportunity cost of time, which was arrived at by averaging the wage rates for the peak and slack seasons.

In the case of community-based resource management of irrigation water, farmers incur costs in the form of negotiation, in monitoring activities related to the institutional design, in maintenance of the organization, and enforcement of rights over the water. We therefore classify the transaction costs into two broad categories,

Table 2 Individual household annual transaction cost for different activities (N = 300) (in NRs)

Sl. No.	Item (Major components)	Mean	Std. Dev.	Min	Max
1	Formation	3.1	4.8	0	24.9
2	Communication	1.3	1.8	0	10.1
3	**Ex-ante (sum 1 + 2)**	6.6	8.6	0	33.9
4	Meeting	21	41.4	0	212.5
5	WWN	265.2	250.4	0	1400
6	**Ex-post (sum 4 + 5)**	291.7	258.8	0	1515.9
7	**Total (sum 3 + 6) (Household + System)**	298.3	259.3	**0**	**1518.3**

Source Fieldwork by authors

ex-ante and ex-post costs,[3] which we in turn divide into five broad activities: (i) meeting, (ii) formation costs, (iii) waiting, watching, and negotiating (WWN), (iv) conflict resolution, and (v) communication (see Table 2).

Operation and maintenance of canals cost money and some of the resources are generated internally by WUA members and these form part of the production costs. The delivery of water to the farm could however involve additional expenses (like supervision) in the nature of transaction costs which are over and above the maintenance costs. Efficient institutions are synonymous with lower transaction costs (ex-post), as a lower transaction cost implies more labor time being available for directly productive purposes. Institutional efficiency therefore is expected to have a direct and positive impact on agricultural productivity.

The *formation cost* is a one-time fixed cost which we calculated on the basis of the time and resources devoted by farmers at the time of WUA formation. Water allocation among other things is decided at WUA meetings. The time taken at such *meetings* constitutes a part of transaction cost.

Once there is an informal agreement, a larger group is invited which takes the shape of a general body which formalizes the formation of the WUA and selects the members of the Ad Hoc Executive Committee. They normally accept the format commonly used by other WUAs with minor alterations. Sometimes, a representative of Nepal Irrigation Water Users Association motivates the formation of a WUA and also participates in the initial general meeting. The next step is to register the association and it starts with an application to the Water Resource Committee. The cost of registration is very small (about NRs 50) but there are other associated costs which are larger like travel and time costs, typing and printing costs. After registration, the WUA gets a certificate of registration, and subsequently, a general body meeting of all the user farmers is convened. This meeting elects an executive

[3]The separation of ex-post and ex-ante costs is also sighted as a difference between the Property Rights Theory (PRT) and the Transaction Costs Economics theories. While PRT has stressed on reduction of ex-ante costs the latter have emphasised on reduction of ex-post costs (see Tadelis and Williamson 2013).

committee of up to 11 members. The committee must have at least 33% women and two should be from among the minority or deprived group of people.

Even after such allocation has been decided and agreed upon, given the weakness of such institutions in ensuring the contractual decisions, individual farmers end up *waiting* at the canal head and along the irrigation channel for their turn so that they receive their winter allocation. They also have to *watch* so that no one interferes with the supply to their fields and to ensure that their allocation is not taken by someone else. Sometimes, they also have to spend time *negotiating* since contracts in the WUA between participating farmers may be incomplete or need re-enforcing routinely. We also recorded the instances when a negotiation resolved a dispute. Our survey recorded the time spent on each of these activities by households and is labeled waiting, watching, and negotiating (WWN).

As far as water distribution is concerned, the upstream farmers usually have the right of prior appropriation. However, in some cases we found that downstream farmers were also able to negotiate water allocations. In Siddhipur Raj Kulo, for example, (located in the northeast of Lalitpur municipality) an institutional arrangement has evolved where the lower riparian farmers get the water before the upper riparian. One reason for this arrangement could be well-established social networks—almost all the farmers here are of the same caste (a social category, *Newar*). The chairman of the WUA is a widely respected civil servant who also worked within the royal palace and so all the farmers accepted his decisions.

On the other hand, in Sankhu (located in the northeast of Kathmandu District and one of the oldest towns of the Kathmandu Valley) where there is considerable social heterogeneity (different castes), there were reports of conflict. The people of Salambutar (lower riparian) were mostly Bahun Kshetry and the upper riparian were Newari, and there was lack of cooperation among them. There were reports of water diversion to the downstream farms at night for the plantation of paddy. This led to efforts by upper riparian to spend more time on supervision (WWN).

When participating farmers are unable to resolve an issue bilaterally regarding water distribution, then we term it as a situation of *conflict*. In this study, a conflict specifically meant dispute regarding water diversion in the last two cropping seasons which was not resolved mutually but required a mediator. Information was sought from the respondent if any member of the household was involved either as a conflicting party or mediator in any such dispute. If yes, we recorded the time and money spent in resolving the conflict and is a component of transaction costs.

While WWN and "conflict resolution" are ex-post transaction costs, "communication" and "formation" are ex-ante transaction costs. Meeting costs, depending on the nature of the meeting, could be either ex-ante or ex-post.

The formation cost is a one-time fixed cost which we calculated on the basis of the time and resources devoted by farmers during WUA formation. We therefore used the lowest bank interest rate in Nepal for lending during the period of the study (9%) to estimate the annual transaction costs of formation. To arrive at the annual formation cost, we took the annual interest on the original sum spent irrespective of which year the initial payment was made. Suppose a WUA was formed in 2004 and the formation cost was Rs. 1000 at that time, the annual formation cost was considered to be Rs. 90 for that WUA in our study.

We estimated the total annual transaction time by adding the expenses incurred by households at the system level as well as at the household level. In our study, the system-level transaction costs are communication cost, conflict resolution cost, general meeting time cost, preliminary meeting cost, and formation cost. The household-level costs are meeting costs and waiting, watching, and negotiating costs. In order to make these compatible and allow an analysis at the level of household, we divided the system-level total annual transaction time by the total number of households within the system and added it to the household-level transaction time. The general meeting time at the system level was included in the household's transaction cost estimate through the system-level costs in order to avoid the problem of double counting. We valued the imputed time cost by converting every 7 hours into one working day. We found that the system-level expenses attributable to the households are about 9% of the total transaction costs.

3 Results

Survey results show that the major part of the transaction costs are under the category of waiting, watching, and negotiating (about 81%) and ex-post transaction costs are about 90% of the total transaction costs per hectare (see Table 2).

The average ex-post transaction costs per hectare in smaller systems was the lowest and not unexpectedly, large systems had the highest ex-post transaction cost per hectare (see Table 3). Agriculture was the dominant occupation for at least one member of every household interviewed. The average family size was 6 while about half the household heads were illiterate. Most irrigation systems in the area were the work of the ancestors of the present users. Only 4 had been constructed using direct bilateral assistance during the present users' lifetime. Rivers and streams were the sources of water for most of the canals. The average irrigated area varied between 0.14 hectare (for small systems) and 0.20 hectare (for large systems) per household. The average length of the canal varied between 1.8 km in the case of small and medium canals to 2.8 km in the case of large systems (see Table 3).

All the 300 farmers in our sample were cultivating paddy which is the main summer crop. In winter, 269 farmers were undertaking cultivation of which 209 cultivated wheat and only 74 cultivated potato. Evidently, potato is the most remunerative crop. Potato cultivators reported the highest average value (gross returns) per hectare about NR 147,052 and wheat was much lower at NR 26,911. All farmers cultivated paddy in summer and the average return per hectare from paddy was reported to be NR 119,082 (see Table 4).

The winter crop is crucially dependent on irrigation as rain-fed agriculture in this season is not viable. Therefore, the reliability of irrigation will play a crucial role in crop choice and therefore farm profitability. The net scarcity of water after crop

Table 3 Summary table by type of canal system

		Large	Medium	Small	Total
Transaction cost (in NRs.)	Mean	2,249.90	2,536.60	1,306.70	2,172.50
	Confidence interval	[1,951.3; 2,548.4]	[2,041.4; 3,031.9]	[1,069.0; 1,544.3]	[1,949.0; 2,396.1]
Type of organisation (Registered = 1, Not registered = 0)	Mean	0.5	0.3	0.3	0.4
	Confidence interval	[0.4; 0.5]	[0.2; 0.4]	[0.2; 0.5]	[0.3; 0.4]
Canal quality (Good = 1, Poor = 0)	Mean	0.5	0.4	0.1	0.4
	Confidence interval	[0.4; 0.6]	[0.3; 0.5]	[−0.0; 0.1]	[0.3; 0.4]
Irrigation reliability (Reliable = 1, Not reliable = 0)	Mean	0.6	0.7	0.6	0.6
	Confidence interval	[0.5; 0.7]	[0.6; 0.8]	[0.5; 0.8]	[0.6; 0.7]
Total value of output/hectare (in NRs.)	Mean	179,916.4	164,243.2	147,125.9	168,680.4
	Confidence interval	[164,513.9; 195,318.9]	[146,766.2; 181,720.2]	[122,346.2; 171,905.6]	[158,192.4; 179,168.4]
Winter output/hectare (in NRs.)	Mean	58,636.70	56,983.30	49,234.60	56,284.40
	Confidence interval	[44,118.7; 73,154.6]	[42,910.3; 71,056.3]	[33,388.3; 65,080.9]	[47,378.0; 65,190.9]
Length (in kms)	Mean	2.8	1.8	1.9	2.3
	Confidence interval	[2.4; 3.2]	[1.5; 2.0]	[1.7; 2.1]	[2.1; 2.5]
Canal quality by type of system	Poor	24.33	20.67	17.33	62.33
(each cell represents % of all	Good	24	12.67	1	37.67
systems)	All	48.33	33.33	18.33	100
Type of organisation	Not registered	42.86	37.36	19.78	100
	Registered organization	56.78	27.12	16.1	100
Reliability of irrigation	Reliable	52.53	29.29	18.18	100
	Not reliable	46.39	33.73	19.88	100

Source Fieldwork by authors

Table 4 Value of Output per hectare and farmer's perception of reliability of irrigation water (for different crops)

Variable	Obs	Mean	Std. Dev.	Min	Max
Value of output per hectare (in NRs)					
Summer (Paddy)	300	119,082.5	46,917.3	19,200	230,400
Wheat	209	26,911.1	16,967.5	720	79,200
Potato	74	147,052.3	102,337.8	25,500	533,333.3
Winter Crops (Wheat + Potato)	269	56,284.4	74,039.6	720	533,333.3
Farmer's perception of reliability of Irrigation water					
Summer (Paddy)	300	0.7	0.4	0	1
Wheat	206	0.55	0.5	0	1
Potato	74	0.88	0.3	0	1
Winter Crops (Wheat + Potato)	269	0.63	0.5	0	1

Source Fieldwork by authors

choice has been adjusted to water availability will determine the likelihood of conflicts over water allocation, and, therefore, the size of transaction costs needed to resolve such conflicts. The perceived reliability of irrigation was 88% for potato growers, whereas it was only 55% for wheat growers in the previous agricultural year.

We examined the quality of canals because it crucially determines quantity of water flow in an irrigation system. When the flow is adequate, the transaction costs will be lower since conflicts are less likely to arise. We divided the infrastructure quality of canals, using parameters such as the use of concrete in the canal, the quality of lining of the canal, leakage in the canal, into two categories: good and poor (see Table 3). Canals were categorized as "good" infrastructure if it had more than 25% lining, and headworks with or without concrete. The rest were classified as "poor." On the basis of this classification, we determined most of the canals to be in "poor" condition either due to leakages arising from improper lining or due to lack of a proper dam structure at the intake point of the canal which made it difficult to consolidate water from the source.

We determined that approximately 62% of the households were using canals with "poor" infrastructure. Interestingly, most of the canals in good condition belonged to the large systems—probably because the water travels a longer distance in these canals and therefore requires better quality canals. Almost, all the small canals were in the category of "poor".

During our surveys, we learned that half the surveyed irrigation systems had undergone rehabilitation during the last 3 decades. Approximately 2/3 of the systems had received partial support from the government for this purpose. Only in the case of 10% of the systems were the user farmers themselves responsible for repairs. The users had received partial support from non-government donors to repair the remaining systems.

Some of the irrigation systems, formed after 1990, had formal registration. In most cases, the motivating factor in organizing and registering the institution had been the possibility of receiving external assistance to repair the canal. The large systems' category had the highest number of households with membership in registered WUAs compared to the medium and small systems (see Table 3).

A majority of the systems (60%) had not registered their WUA (see Table 5). According to our survey data, approximately 87% of the unregistered WUAs did not receive any support. In contrast, only 12.6% of the registered WUAs failed to receive any support and about 85% of them did receive support from the government. WUAs registered with government agencies had a higher likelihood of receiving financial assistance for maintenance purposes (the correlation between support and registered WUAs was 0.7, which was significant at 1%) (see Table 6).

Those who received external support also had high probability of having good infrastructure (correlation coefficient = 0.29, significant at 5%, see Table 6). Downstream and ex-post transaction costs are also positively correlated and significant even though the association is weak (0.18). One possible explanation for this is that those who are located downstream are likely to spend more time and effort to ensure that irrigation water reaches their fields. Thus, systems with registered WUAs had good infrastructure and more reliable irrigation. Where the ex-post transaction cost was low (i.e., where farmers exerted themselves less in ensuring the flow of water), or where the farmers were located downstream, they had less reliable irrigation. We also note that there is a negative relationship but insignificant association between ex-post transaction costs and total value of output per hectare (−0.08).

Overall, about 79% of the non-registered WUAs reported poor infrastructure quality while 70% of the registered WUAs reported good infrastructure quality (see Table 5). Our data suggest that large systems performed better in terms of infrastructure quality which declines as the size of the system decreases. Also, the proportion of WUAs which received government or external support is lowest among the smaller systems and highest among the large systems. It is possible that the

Table 5 Summary table by type of organisation and irrigation reliability

	Type of organisation			Irrigation reliability		
	Not registered	Registered	Total	Not reliable irrigation	Reliable irrigation	Total
Canal quality						
Poor	79.14	20.86	100	42.77	57.23	100
Good	30.09	69.91	100	29.25	70.75	100
Support from government						
No support	87.37	12.63	100	39.88	60.12	100
Received Support	14.55	85.45	100	33.33	66.67	100
Total	60.67	39.33	100	37.36	62.64	100

Source Fieldwork by authors

Table 6 Correlation matrix of select variables ($N = 300$)

	Support	Downstream	Total value per hectare	Type of organisation	Ex-ante TC per hectare	Ex-post TC per hectare	Canal quality
Support	1						
Downstream	0.0618	1					
Total value of output per hectare	0.0824	0.0262	1				
Type of organisation	0.7184***	0.0624	0.1600***	1			
Ex-ante TC per hectare	0.4241***	−0.0237	0.1147**	0.3541***	1		
Ex-post TC per hectare	0.1037*	0.1809***	−0.018	0.0333	0.2118***	1	
Canal quality	0.4506***	0.1653***	0.2279***	0.4866***	0.2233***	0.0189	1

Significance level ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source Authors

larger strength in membership of the large systems enables them to lobby for external support much more than smaller groups.

The difference in the ex-post transaction costs between those who received support (higher costs) and those who did not (lower costs), irrespective of the type of system, was significant (see Table 7). There was no significant difference reported in total output per hectare but the downstream farmers incurred a significantly higher transaction costs than upstream ones (see Table 7). This is an expected outcome since problems of ensuring water supply to tail-enders in irrigation systems are well recorded in the literature (Ostrom 1990; Shivakoti 2007).

There was no significant difference reported in total output per hectare by upstream and downstream farmers which was not unexpected as farmers in order to achieve similar output spend time ensuring water flows and their WWN costs are higher as seen earlier (see Table 7).

We also examined the output and ex-post transaction cost differences between those who received support and those who did not in our sample (see Table 7). It turns out that farmers who belonged to a WUA which received support had higher ex-post transaction costs and also higher output per hectare.

Farmers during the interview were asked whether they received reliable irrigation water. On average, farmers who had reliable irrigation had a significantly higher productivity (see Table 7). The reliability of a system as expected would depend on the existence of good infrastructure: well-maintained canals in good working condition. Seventy-one percent of the farmers who had good infrastructure reported reliable irrigation and those with poor infrastructure reported only 57% reliability (see Table 5). So, the key to reliability is the presence of good irrigation infrastructure.

It is common for farmers in this area to have informal meetings before any organization is given shape. It is recognized in prior studies that if there is any prior social link or cooperative link, forming new groups becomes easier, less costly, and time-consuming (Putnam 1993). For groups that have never worked together before, consensus building could take considerable time and effort (Seabright 2000).

Although we did not collect data on other components of production costs during our survey, for purposes of comparison, we used the estimates of the Government of Nepal on the total annual human labor requirements for the cultivation of paddy, wheat, and potato, which was 181, 141, and 235 days, respectively. This dataset had a separate line item for cost of marketing which was used for calculation of profit by the agricultural department. We, however, only used the production cost data and not the marketing data.

Table 7 Summary table of two-sample *t*-tests (with unequal variances)

	Ex-post transaction costs per hectare (in NRs) by irrigation reliability (N = 265)			Ex-post transaction costs per hectare (in NRs) by location (N = 300)			Ex-post transaction costs (in NRs) by support (N = 300)		
	Not reliable	*Reliable*	*Combined*	*Upstream*	*Downstream*	*Combined*	*No support*	*Support*	*Combined*
Observation	99	166	265	154	146	300	190	110	300
Mean	2583.48	1907.84	2160.25	1819.42	2544.99	2172.53	2014.35	2445.75	2172.53
Standard error	198.82	155.76	124.04	151.83	171.60	115.95	129.79	221.47	115.95
Standard deviation	1978.28	2006.76	2019.14	1884.12	2073.51	2008.36	1789.07	2322.81	2008.36
Lower confidence limit	2188.92	1600.31	1916.03	1519.48	2205.82	1944.34	1758.33	2006.80	1944.34
Upper confidence limit	2978.04	2215.37	2404.47	2119.37	2884.16	2400.72	2270.38	2884.70	2400.72
T-value of diff = mean(0) − mean(1)		2.68			−3.17			−1.68	
Pr(|T| > |t|)		0.0081			0.0017			0.0946	
	Total value of output per hectare (in NRs) by irrigation reliability (N = 265)			Total value of output per hectare (in NRs) by location (N = 300)			Total value of output per hectare (in NRs) by support (N = 300)		
	Not reliable	*Reliable*	*Combined*	*Upstream*	*Downstream*	*Combined*	*No support*	*Support*	*Combined*
Mean	151,621.6	187,936.5	174,369.8	166,312.3	171,178.3	168,680.4	162,873.2	178,711.2	168,680.4
Standard error	8460.42	7539.60	5775.04	7581.15	7592.93	5359.41	6922.25	8361.53	5359.41
Standard deviation	84,180.11	97,140.99	94,010.84	94,079.63	91,745.71	92,827.72	95,416.67	87,696.45	92,827.72
Lower confidence limit	134,832.1	173,050	162,998.8	151,335.1	156,171.2	158,133.5	149,218.4	162,138.9	158,133.5
Upper confidence limit	168,411	202,823	185,740.8	181,289.6	186,185.4	179,227.4	176,528	195,283.5	179,227.4
T-value of diff = mean(0) − mean(1)		−3.21			−0.45			−1.46	
Pr(|T| > |t|)		0.0015			0.65			0.15	

Source Authors

4 Discussion and Conclusion

The share of transaction time as a percentage of the total human labor required for the production of crops on average was 5% when all households were considered—it was 4.5% for upstream and 6.5% for downstream households. Moreover, the transaction time for winter crops was four times that for summer crops. This is mainly because the summer crop has the benefit of the monsoon rains and is thus less dependent on canal water. Farmers rely on canal water to irrigate the winter crop and thus have to devote more time for WWN. Transaction cost per hectare, however, is only about 1.7% of the total value of output per hectare. Our understanding from field surveys is that if the farmers did not spend this time (primarily WWN) the resulting loss in productivity could be very large. Therefore, this is a cost-minimizing strategy for farmers.

We are not able to gauge whether our estimates of transaction costs are high or low because there are no other studies to date on transaction costs in Nepal's FMIS. Our findings are, however, consistent with those of Mburu et al. (2003) although our estimates are lower than those of Adhikari and Lovett (2006) as we have discussed earlier.

Our study confirms some of the received knowledge on institutions and FMIS but also provides new insights. We find that for smaller systems, formalization is associated with higher productivity. While transaction costs and productivity are weakly inversely related for households in large irrigation systems, and in small systems, transaction costs and productivity are positively correlated in unregistered WUAs (see Fig. 1) which nuances on Stifel and Minten's (2008) findings of an inverse relation. Farmers incur transaction costs at two stages: during registration of a WUA, which is an ex-ante cost, and after formation, which includes time for meetings, dispute resolution, and WWN, which are ex-post costs. WWN is the bulk and constitutes 81% of the total transaction cost. Transaction time was about 5% of the total human labor required for agricultural production. However, as a proportion of total value of output, transaction costs are only about 1.7%. Even though the transaction cost as a proportion of total output is small, transaction activities are clearly important to the farmers because they enable efficient water allocation. The absence of the transaction activity could cause a large drop in productivity due to dysfunctional water sharing arrangements resulting in unavailability of water (Alchian and Demsetz 1973). Our survey revealed that farmers with reliable irrigation reported higher productivity as anticipated. It is therefore rational for farmers to invest in ensuring reliable irrigation. This may also be driving the association between formalization and productivity in smaller WUAs as registered associations have greater access to external funds for maintenance of canals.

Our study confirms that farmers who are more in need of reliable irrigation undertake greater transaction activity. We find transaction costs are higher for households cultivating downstream in a canal system than those for households cultivating upstream. This is in conformity with much of the literature on FMIS (e.g., Ostrom 1990). Similarly, seasonal differences arise in transaction activity too. Transaction costs are four times higher for winter crops (when there is little rain) than for summer crops when the area receives monsoon rains.

While this study is able to compute the transaction costs incurred by farmers in FMIS, the expenses incurred by government agencies were not included and future studies could consider them for a more holistic evaluation of the WUA and FMIS. Further, the cost of cultivation information could be used to examine the efficiency of WUA at the farmer level and its causal impact on farm-level profits. Importantly, given the impacts on agriculture due to climate change that are increasingly evident, future studies could look at farmer adaptation costs in Nepal in the context of Transaction costs analysis.

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