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Skirting the Rules: Collective Management and Informal Exchange of Formal Water Rights in Pakistan

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I. Introduction

Irrigation has been a fundamental source of growth in Pakistan's agriculture. The security, flexibility, and enhanced water supply provided by irrigation has directly spurred adoption of high yielding varieties, multiple cropping, and input intensification. However, surface irrigation in much of Pakistan has been crippled by worsening problems of inefficient, inequitable, and unreliable delivery, poor maintenance, and insufficient cost recovery, with potentially severe ill-consequence for the livelihoods of millions of peasant farmers.

These problems can be traced in part to the political economy of public irrigation that in its present form provides inadequate incentives for government agencies to maintain and operate networks effectively. Two solutions that are receiving increasing attention, both in the academic literature and in policy circles, are devolution of control to communities and development of water markets. This paper aims to examine the changing roles played by communities and informal markets in irrigation management in Pakistan. We highlight which institutions - whether formal laws, informal norms and customs, or decentralized and uncoordinated management - have been most relevant in influencing appropriation mechanisms at the tertiary level. The empirical data combine household surveys and participatory rural appraisal of water management by households along two watercourses in Pakistan. These have been collected and generously provided by the International Irrigation Management Institute (IIMI) in Lahore.(1)

Five main sections follow. The first section provides the context. The second section highlights that, among many possible reasons, worsening scarcity and inequitable fluctuations in scarcity led to erosion of local mechanisms of control and a reversion to legal and regulatory frameworks for establishing legitimacy of property rights over water. In the third and fourth sections, community-based adaptations that help tailor formal appropriation rules to local circumstances are discussed. Drawing on perspectives derived from the new institutional economics, the final section isolates which of various transactions costs, including those of coordination, monitoring, and enforcement, constrain community-based management to management within self-selected sub-coalitions of households.

II. Traditional Rules of Appropriation: Theory and Practice

The two watercourses that are the focus of this paper originate from the Azim and Fordwah distributaries of the Fordwah/Eastern Sadiqia irrigation system which lie in the cotton-wheat zone of Punjab province in Pakistan. The irrigation system which was developed in 1932 was designed to spread scarce water resources over as large an area as possible, on an equitable basis, with minimal maintenance and operational inputs by the irrigation department. A constant discharge at the main and secondary levels of the irrigation system was to be distributed proportionally to tertiary canals (watercourses). In order to minimize operational control, a continuous flow of water was allocated to each watercourse via ungated concrete outlets that provided constant discharges proportional to the area to be irrigated in the watercourse command.

Historically, at the watercourse level, institutions for management of water flows shared several features of a common-property regime: access was limited to households with land in the watercourse command, and rules of "provision" (canal repair and maintenance) and of "appropriation" (allocation of water flows) were decided jointly by these households. This was not the case in theory. In theory, under the 1873 Canal and Drainage Act, rules of appropriation are determined, legally sanctioned, and enforced by the irrigation department. Water is to be distributed equitably according to the warabandi system in which each household with land in the command area is allocated an amount of water time proportional to land ownership. During its pre-determined water turn, a household is entitled to all water flows -- full or otherwise -- in the canal. However, it does not possess the right of alienation -- the right to exchange, sell or lease the water turn. Any violations of this fixed, or *pucca,* warabandi schedule are punishable by law. Based on this Act, there was little scope for communal management, in theory.(2)

In practice, however, even though households had private entitlements to water turns, the *schedule* of water turns was arrived at by mutual agreement by households within the watercourse. This *kutcha* (flexible) warabandi schedule broadly followed the principle of water time allocation in proportion to land holdings but allowed for adjustments in the length of water turns to account for seepage, soil quality etc. More importantly, it was a very adaptable method of water distribution. While the length of turns was pre-determined through mutual agreement, the timing of the turn was not fixed. In the event of a temporary disruption in water flow, the cycle was resumed with the household where the water was last received. As long as the group could manage the allocation -- by consensus or at the expense of the weaker households -- this flexibility was functional and there was no need for any official intervention (Bandaragoda and Rehman, 1995).(3) In the event of a dispute, households could request a resolution to the conflict and apply for a new, *pucca* schedule from the irrigation department.

III. Erosion of Local Control and Adoption of Official Warabandi

Since the development of the irrigation system, a combination of demographic, technological and institutional changes created stresses for both the functioning of the irrigation system and the mechanisms of local control. Over time, there was a widening gap between the demand and supply of canal water. Pressures on demand for water came from population growth, which combined with partible inheritance and land fragmentation increased the number of households entitled to appropriate water flows from tertiary canals. Rapid growth in demand was also led by the green revolution which permitted far greater cropping intensities than before and the adoption of modern crop varieties that were more water-intensive and water-sensitive. The irrigation system was not designed to cope with such drastic growth in demand. Indeed, the system was designed for low cropping intensities, in order to maximize the number of beneficiaries and to provide incentives for development of groundwater and for efficient on-farm water use (Malhotra, 1982). Moreover, the supply-based continuous flow distribution system and minimalist physical features of ungated outlets could not be adjusted to the changing crop portfolios, to the timing of crop demands, or to the availability and quality of alternative water sources.

Worsening scarcity was accompanied in many cases by random fluctuations in scarcity. Being at the tail-end of the irrigation system, Azim and Fordwah distributaries are exposed to all breakdowns that disrupt supply at the upper-reaches of the system. By default rather than by design (particularly since rules for spreading scarcity and risk are uncodified), tail-enders bear a disproportionate share of the shortages. This inequity is exacerbated by seepage losses and by siltation which results in higher water levels in the first reaches of distributaries.

Scarcity, worsening scarcity, and random fluctuations in scarcity, in turn induce a perverse response through corruption and theft by those who can afford it. At the watercourse level, there were cases of irrigators taking water out of turn, changing the dimensions of the outlet, and even changing the course of the canal (Merrey, 1986). Similar to Wade's (1984) observations in South India, even above the outlet, farmers had a considerable, if illegitimate, influence on water allocation in the main system. Water was allocated between outlets was done through a bargaining process between irrigation staff and farmers, at least at relatively low levels of the system (e.g. between the outlets of a single distributary, or between nearby distributaries). Scarcity was thus redistributed from weak to strong; random fluctuations in scarcity were amplified for the weak and reduced for the strong.

Overall, there was a situation of decay from an irrigation system designed for low maintenance, equitable and reliable water delivery to a state of disorder, both in physical dimensions (deterioration of the physical structures) and in social dimensions (irrigators struggle by any means, legitimate or not, to protect themselves from shortage). It is impossible to generalize and predict the impact of increasing scarcity and disorder on institutions for management of a resource. In some circumstances, as scarcity increases, communities are able to organize themselves to coordinate and control more tightly the use of the resource (Baland and Platteau, 1996). Cooperation tends to evolve and develop spontaneously whenever the need arises. In other cases, increasing disorder can create conditions that work against mechanisms of local cooperation and control. Growing demand and growing scarcity raise the short-run rewards to stealing water out of turn. The capacity to punish or dissuade defectors with local enforcement mechanisms (including pressures of shared norms and patterns of reciprocity) is eroded as new beneficiaries lead to larger and less cohesive groups (Ostrom, 1990). Inequity in water deliveries may also create a situation in which some households are worse off cooperating and this may further erode mechanisms of local control (Bardhan, 1993).

Bandaragoda and Rehman (1995) suggest that increased frequency of conflicts likely led to greater involvement by the irrigation department, and a shift in appropriation rules towards a more regulated, *pucca* warabandi system in many of Pakistan's watercourses. The two watercourses in our study have also switched from a *kutcha* to a *pucca* warabandi system.

IV. Skirting the Rules: Collective Management of Official Water Rights

A *pucca* warabandi schedule magnifies the deleterious impacts of exposure to variable and uncertain water supplies. The *pucca* schedule is much like the *kutcha* warabandi system, in that each household has the right to a water turn proportional to the size of its landholding. But, an important difference is that both the length and timing of turns are fixed for each household under the fixed rotations. As crop water needs vary across and during the cropping season depending on the crop portfolio, a fixed water and time allocation creates a mismatch between water delivery and water demands for most households. The mismatch is further compounded by risk in delivery as water levels fluctuate significantly in the irrigation canals. Even in the event of a temporary disruption in water flow, the rotation continues without interruption, exposing households to all *idiosyncratic* risk in water supply.

There are two sources of risk: natural, exogenous fluctuations in water supply in the irrigation system, and man-made, redistributive risk through mismanagement of the irrigation system (corruption) and direct interventions (theft). Participatory rural appraisal of farmers (including some in the watercourses on which we focus) by IIMI suggests that risk is very important and has drastic consequences for water users; farmers indicate that reliability and timing of supply are, by far, more important than having larger quantities but erratic water supplies (Hoeberichts, 1995).

As a result, risk induces a vast array of on-farm and off-farm responses to manage and cope with risk. On-farm, households engage in activities such as delaying sowing times to match water turns, staggering the sowing of crops, adjusting the crop portfolio (shift away from rice and sugarcane to low delta crops like wheat and cotton), adjusting the location of crops on the farm (water-sensitive crops are planted closer to the outlet), and mixing canal water with poorer quality tubewell water.(4) These measures reduce the impact of water fluctuations but are costly as they require deviations in production strategies from the optimum.

Off-farm, households adjust to the inter- and intra-seasonal inflexibility of an official schedule by mutually agreeing to a new, informal schedule on a season-by-season basis (Strosser, 1997). Some of the water rotation changes arise due to subdivision of landholdings or changes in tenure contracts that have not been accommodated in the *pucca* warabandi. Others arise when tail-enders who are unlikely to receive water during the season (due to high seepage losses in the watercourse) lease their turns to head-end farmers for the entire season. Yet others involve small farmers who give their turns to large farmers for a few weeks and in return, receive one long turn every few weeks. This is because with extremely short water turns, it becomes more difficult to do on-farm water management by staggering sowing of crops on tiny plots. Intra-seasonal differences between the ‘official’ and ‘agreed’ schedule occur primarily during pre-sowing and sowing times when farmers trade turns to either increase the length of their turns or to get a better match between optimal sowing times (which differ across households due to differences in crop portfolios) and their water turns.

Even though most of the informal adjustments are exchanges that occur between pairs of households, modification of the official schedule requires the collective agreement and coordination among several households in the watercourse command. Since flow in the watercourse is continuous, whenever there is an adjustment to the schedule that does not involve households that have turns next to each other, households with turns in between must also adjust the times at which they take their turns. The greater the water-turn distance between partners to an exchange, the greater the degree of coordination required within the watercourse.(5)

In summary, the historical experience of irrigation management at the tertiary level in Pakistan cannot be confined to the state versus community dichotomy. Although, officially, the management of water has been governed by state-devised rules and mechanisms of enforcement since the late 1800s, in practice, there has been a long history of management with varying degrees of state and community involvement. What began as a situation of low state interference and collective arrangements of management has, with increasing scarcity, evolved into greater state involvement in devising explicit allocation rules in parallel with limited collective arrangements that adapt these state-devised rules to local conditions.

V. Skirting the rules: Informal Exchange of Official Water Rights

To make matters more complicated, appropriation rules devised by the state, and modified by the community, are privately altered by informal secondary trades of water turns. Partial and full water turn exchanges are frequent on 70% of Pakistan's watercourses, despite the illegality of trading under the Canal Drainage Act (Strosser and Kuper, 1994). Trading is also important in terms of the volumes of water exchanged: in the eight watercourses of the Fordwah and Azim distributaries studied by IIMI during the kharif 1994 season, the total volumes of canal water involved in exchanges were estimated at roughly 20% of the total supplies during the season (Strosser, 1997). Since the communally agreed schedule is fixed prior to water realizations, it cannot cope with random fluctuations in water supply. Fluctuations in supply are, to a large degree, independent for different households since water levels vary considerably within short time spans. Therefore, these relatively decentralized and uncoordinated trades can fulfill extremely important functions of risk-sharing and improving the flexibility of water allocation.(6) In the absence of any limitations to private exchange, such a trading system would be able to shield households from idiosyncratic risk.

However, there are transaction costs that arise from the physical infrastructure and the underlying warabandi system that limit the extent to which households can shield themselves from risk. First, transferring water time in the absence of a centralized institution requires substantial coordination. Since flow in the watercourse is continuous, water exchanges require adjustment of the warabandi schedule. For example, suppose farmer A receives a low water realization and the next farmer in line, farmer B, as a member of A's insurance group, provides a transfer of water time equal to 10 minutes. Farmer A continues to water for 10 extra minutes and farmer B delays receiving water for that amount of time. This is a straightforward transfer of water time. Suppose instead, that farmers A, B, and C are in an informal exchange agreement and farmer C is two turns away from farmer A. If B and C transfer water to A for 5 minutes each, farmer A takes the 10 extra minutes transferred to him, B receives water 10 minutes later, but takes water for an extra 5 minutes and C delays receiving water for 5 minutes. This requires coordinating the activities of three farmers (A, B and C) rather than just two farmers (A and B) as in the first case. Regardless of the size of the transfer (measured in the number of minutes), the same amount of coordination is required. As the water turn distance between partners, and therefore, the number of partners involved in a transfer increases, so does the cost, irrespective of the size of the transfer.(7)

Apart from distance in water turns, there is an added cost proportional to the physical distance between farms. Most often, transfers are partial turn exchanges in which the receiving household, realizing that it needs 5-10 minutes more water, walks over to a partner household to arrange for a turn.(8) The importance of this physical distance is apparent when one considers a water exchange between two households, one located at the head of the watercourse and the other at the tail. Even though these households are neighbors in terms of water turn distance, the 5-10 km walk to request a partial turn transfer from a head user in the midst of one's warabandi turn is impractical for the tail farmer. In addition, if households are physically close to each other, the losses due to drainage (or filling) time during an exchange are minimized.

How well secondary trades perform in spreading risk across households also depends acutely on supporting local institutions such as social norms of reciprocity, systems of sharing information, and mechanisms of enforcement at the local level: efficient risk pooling within an informal insurance group is possible only with complete information and perfect enforcement (Coate and Ravallion, 1993; Ligon, 1997). The important idiosyncratic risk which is insured by this mechanism is certainly observable to all members of the watercourse. The problems of information asymmetries within the watercourse, therefore, seem relatively unimportant with respect to this source of risk. However, there remain problems of enforcing the obligation of temporarily lucky households to transfer water to members with poor realizations. Since water allocations occur sequentially through time, and the unit of transfer is water time, trading between households does not occur simultaneously. That is, a household that receives water time today does so understanding that a reciprocal transfer may be required in the future. Such enforcement issues and problems of establishing partnerships may be more easily resolved between kinship groups. Kinship groups have an established relationship of trust which helps resolve the inherent time consistency issue in an informal system of exchange. These groups can be defined at the level of the cultivator household or at the level of the landowner's family; the former is likely to be relatively more important in explaining reciprocity between households.

While the success of secondary trades is constrained by various transactions costs, it depends also on the benefits that different households derive from trade. The benefits of trade vary across households with factors that affect mean water levels, the degree of risk aversion, and the risk in water delivery. Households located at the tail reaches of the watercourse receive less water, on average, due to seepage losses in the water channel. Controlling for other factors, tail-enders are then more likely to engage in risk sharing. We use a measure of average location of potential partners to control for this. The effects of recipient and benefactor locations are likely to be symmetric if exchanges are reciprocal. Risk in water delivery is similar for households in the watercourse since a substantial portion of the risk stems from variable deliveries to the head of the watercourse. Azim 43-L and Fordwah 14-R are located at the tail end of the irrigation system, with wide exposure to maintenance and other problems all along the distributary. Since tail-enders within these watercourses are at the bottom of the watercourse channel, they face an added risk of delivery problems within the watercourse; but these problems are likely to be small compared to variations in delivery to the mouth of the watercourse. It is, therefore, our contention that households face similar degrees of uncertainty and variability within the watercourse. However, the ability to cope with losses varies with the size of loss relative to the length of water turns. Households with longer water turns have more flexibility in their water management strategies and are therefore, less likely to demand insurance.

VI. Decomposing the Effects of Transactions Costs on the Probability of Informal Exchange

Table 1 presents descriptive statistics of water transfers between the 35 households which received water from the Azim 43-L watercourse during the *kharif* 1994 season. Among the 1190 potential household pairs, 10% exchanged water at least once during the season. Exchanges between pairs which cultivate land belonging to the same family are more likely than those between households with different landowner families. This difference is much more pronounced for cultivator families. 50% of the household pairs belonging to the same cultivator family exchanged water at least once during the season. In contrast, only 8% of unrelated cultivators engaged in transfers. Interestingly, however, once households choose to exchange, there is no significant difference in the average number of transfers between related and unrelated pairs of households. The probability of transfers also falls off dramatically as the water turn or physical distance between households increases.

These patterns of exchange are broadly similar to those observed in Fordwah 14-R (Table 2). However, on the whole, trading is less frequent with only 2.4% of the households exchanging full or partial turns at least once during the season. Several factors may be at play. First, due to operational preference for the Fordwah distributary, there is greater variation in water availability in Azim which provides greater incentives to trade and insure water realizations. Second, joint management of water turns is a common practice in the Fordwah area but not in the Azim region. Azim has a much more inequitable land distribution and a more fragmented and competitive social structure than Fordwah (Strosser and Kuper, 1994); this may explain the observed differences in the importance of joint management. In the absence of joint management in Azim, private exchange can be an alternative mechanism to spread risk. However, as discussed earlier, as with community management, there are factors that limit private exchange as well.

The importance of these factors on the probability of exchange is examined econometrically through probit regressions. The results in Tables 3 and 4 confirm the negative effects of both water turn and physical distance on the probability of exchange between households. Kinship of the cultivator household is a powerful explanatory factor: belonging to the same family of cultivators increases the probability of exchange by more than 20% in Azim. In contrast, landowner kinship does not have a significant effect on the probability of exchange in Azim and has a smaller, but significant impact in Fordwah. This is not surprising if landowners do not play an important role in the day to day irrigation decisions of their cultivator tenants. In Fordwah, the length of water turn has a significant negative impact on the probability of exchange but the marginal effect is relatively small.

To examine potential differences between recipient and sender locations on the demand for insurance, we ran a second probit with these variables instead of an average location variable. The results demonstrate an asymmetry: in both watercourses, the probability of exchange between households is higher for pairs which have recipients closer to the tails and transferring households closer to the head reaches of the watercourse. These results are, perhaps, not surprising when one moves beyond a social and economic realm of interactions limited to transactions in water. Households located at the head are fortunate in receiving more water, on average, than those located below them. Head households, thus, have less to gain from a risk-pooling arrangement, but more to contribute in terms of being able to shield partners from risk. They may be encouraged to participate in an arrangement of water exchange with a promise (or need) of reciprocal obligations in ways other than water. It suggests a need for information on other exchanges between the households to develop a fuller understanding of the system of exchange. The asymmetry in exchange also points to insurance arrangements where exchange operates in networks rather than in mutually exclusive groups of individuals: a more communal mode of private exchange.

The evidence for Azim 43-L and Fordwah 14-R, though hardly conclusive, is suggestive. It indicates that reciprocal exchanges are localized to small social spaces or sub-coalitions smaller than the entire watercourse community. These social spaces are constrained and shaped by various factors of distance and most prominently, by kinship. It suggests that examining how kinship groups sustain interactions would be a fruitful way to understand the impetus for localized reciprocity and decentralized, uncoordinated management of water flows.

VII. Conclusions

This paper examines the role of state, communities and private enterprise in management of water flows at the watercourse level in Pakistan. There has been a long history of management with varying degrees of state and community involvement. The State plays an important, if small, role by providing a legal basis for an equitable and predictable allocation of water. Even though state-devised rules are not always followed in practice, they provide some restrictions on opportunistic behavior and a source of legitimacy for households' competing claims when communities fail to arrive at mutually acceptable rules of appropriation.

However, state-devised rules have been woefully inadequate at dealing with worsening problems of inefficient and unreliable delivery and inequitable distribution that affects much of the irrigation system. In response to State failure, in the two watercourses studied here, the community stepped in to tailor allocation rules to local conditions by developing an 'agreed' warabandi schedule different from the 'official' schedule. Interestingly, communally agreed warabandi schedules remain within the bounds of the principle of warabandi. The principle of warabandi has the decided advantage of being simple and transparent, and as a result, less susceptible to capture by the powerful. It suffers, however, from limiting the ability to respond to changes in water demands, across households and over time. And in a context of frequent, sudden, and large fluctuations in water levels, it is particularly inadequate in allowing households to cope with the uncertainty.

Decentralized and informal secondary exchanges of water turns between households help improve the flexibility and reduce the idiosyncratic risk in water supplies. Although secondary trades are decentralized, they are very much based on cooperative principles and rely strongly on the community for support. Communities provide social and economic arenas that facilitate rapid information flows, impose norms of fairness and reciprocity, and mobilize social capital for the enforcement of contracts. But as the evidence suggests, the watercourse community is too large (in terms of water turn distance and physical distance) and too heterogeneous to sustain exchange between all its members. Risk sharing occurs among self-selected sub-coalitions within the community; sub-coalitions allow better monitoring and enforcement, both by reducing the number of participants and by allowing screening. Exchange is much more likely between households which are closer by various measures of distance, particularly kinship. Institutional innovations to promote access to information, negotiation, and enforcement thus emerge as the most important areas of practical engagement.

The main lesson for policy is that management of resources cannot rely solely on either the State or the community. Many institutional functions are not fulfilled at the community level but within specialized sub-coalitions. Sub-coalitions may be organized in various, overlapping ways - by kinship, by gender, by socio-economic status, or along ethnic lines. The case of water management in Pakistan suggests that the community is not the social unit over which risk sharing and cooperation will necessarily emerge. And, reciprocally, these functions could be fulfilled in areas without functional rural communities if making private information locally public, social capital, and repeated interactions can be facilitated over alternative social units. Finally, when cooperation is limited to sub-coalitions, there is a need for special measures to enhance access to and control over resources for those households that are excluded from these social networks.

Endnotes

1. I would like to thank IIMI and, in particular, Pierre Strosser, for providing access to these data. I am grateful for extensive discussions with Alain de Janvry, Elisabeth Sadoulet and Paul Winters. All remaining errors are mine.
2. However, as Bandaragoda and Rehman (1995) point out, the basis of the legal framework underlying warabandi seems to stem, in part, from pre-existing local practices of informal community management of water allocation and provision.
3. Malhotra (1982) contends that flexible communal management does not allow flexibility and equity for all households. In many cases, appropriation rules were determined by a few big landlords, at the expense of the smaller farmers.
4. Even though tubewell water can increase flexibility in water availability, use of the official watercourse channel to transport tubewell water from the pump to the field transfers the rigidity of the fixed warabandi schedule to tubewell water as well.
5. This issue is explained in greater detail in the next section.
6. Implicitly, informal water exchanges provide insurance against short-term fluctuations in supply since they are state-contingent (amount of water given and returned depends on the needs of both the sender and the receiver). For a more detailed analysis of the limits to informal insurance in this context, see Murgai et. al. (1997). As a result, unlike tubewell water transactions which follow cycles of crop water demands, there is no clear intra-seasonal trend in canal water transactions (Strosser, 1997).
7. Since a household can receive water from partner households with turns both before and after it in the weekly warabandi, water turn distances are measured as the minimum of the warabandi distances -- measured clockwise and counterclockwise -- between households.
8. A 5-10 minute transfer can be extremely important in terms of its value to the household since these small exchanges help complete watering a field, which would otherwise have to be irrigated again.

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Table 1. Water transfers between households in Azim 43-L during the 1994 Kharif season

Summary Statistics

I. Transfers between households in the watercourse			
Number of households	35		
Number of household pairs	1190		
% pairs who exchange at least once	10.2		
Avg. number of transfers	0.21		
Avg. number of transfers if transfers>0	2.06		
II. Transfers between households with the same landowner family versus Other households			
	Within family	Outside family	Test of difference
Number of household pairs	220	970	-
% pairs who exchange at least once	24.6	6.9	61.08*
Avg. number of transfers	0.65	0.11	-9.21*
Avg. number of transfers if transfers>0	2.63	1.60	-3.69*
III. Transfers between households with the same cultivator family versus Other households			
	Within family	Outside family	Test of difference
Number of household pairs	62	1128	-
% pairs who exchange at least once	50.0	8.0	113.61*
Avg. number of transfers	1.13	0.16	-9.58*
Avg. number of transfers if transfers>0	2.26	1.99	-0.80
IV. Transfers between households at different waterturn distances			
Transfers at a distance of:	% pairs who exchange at least once	Avg. number of transfers all	if transfers>0
1 turn	68.6	2.06	3.00
2 turns	30.0	0.44	1.48
3 turns	14.3	0.21	1.50
10 turns	5.7	0.06	1.00
15 turns	4.3	0.07	3.00
	chi-squared = 335.39		
V. Transfers between households at different physical distances			
Transfers at a distance of:	% pairs who exchange at least once	Avg. number of transfers all	if transfers>0
0 acres	32.8	0.76	2.31
1 acre	15.7	0.35	2.25
2 acres	11.9	0.23	1.90
10 acres	7.1	0.25	3.50
20 acres	0.0	0.00	0.00
	chi-squared = 154.97		
VI. Transfers between partner households at head and tail			
	Head	Tail	Test of difference
Number of household pairs	288	902	-
% pairs who exchange at least once	12.9	9.3	2.99**
Avg. number of transfers	0.28	0.19	-1.83**
Avg. number of transfers if transfers>0	2.22	1.99	-0.72

Test of difference between different categories of households -- t-stats and chi-squared as appropriate.

Physical distance=minimum distance between landholdings.

*=significant at 99% level; **=significant at 90% level.

Table 2. Water transfers between households in Fordwah 14-R during the 1994 Kharif season
Summary Statistics

I. Transfers between households in the watercourse			
Number of households	94		
Number of household pairs	8742		
% pairs who exchange at least once	2.4		
Avg. number of transfers	0.06		
Avg. number of transfers if transfers>0	2.61		
II. Transfers between households with the same landowner family versus Other households			
	Within family	Outside family	Test of difference
Number of household pairs	105	8637	-
% pairs who exchange at least once	16.2	2.2	87.83*
Avg. number of transfers	0.58	0.06	-9.16*
Avg. number of transfers if transfers>0	3.59	2.53	-1.49
III. Transfers between households with the same cultivator family versus Other households			
	Within family	Outside family	Test of difference
Number of household pairs	212	8530	-
% pairs who exchange at least once	10.9	2.2	67.6*
Avg. number of transfers	0.21	0.06	-3.78*
Avg. number of transfers if transfers>0	1.96	2.70	1.19
IV. Transfers between households at different waterturn distances			
Transfers at a distance of:	% pairs who exchange	Avg. number of transfers	
	at least once	all	if transfers>0
1 turn	51.1	1.8	3.5
2 turns	17.0	0.4	2.1
3 turns	9.6	0.3	2.8
10 turns	0.5	0.01	2.0
15 turns	0.5	0.01	2.0
	chi-squared = 2290.2*		
V. Transfers between households at different physical distances			
Transfers at a distance of:	% pairs who exchange	Avg. number of transfers	
	at least once	all	if transfers>0
0 acres	13.0	0.37	2.82
1 acre	7.3	0.23	3.12
2 acres	4.0	0.08	1.95
10 acres	0.0	0.00	0.00
20 acres	0.0	0.00	0.00
	chi-squared = 544.5*		
VI. Transfers between partner households at head and tail			
	Head	Tail	Test of difference
Number of household pairs	2178	6564	-
% pairs who exchange at least once	3.6	2.0	19.9*
Avg. number of transfers	0.09	0.05	-2.19**
Avg. number of transfers if transfers>0	2.37	2.77	0.99

Test of difference between different categories of households -- t-stats and chi-squared as appropriate.

Physical distance=minimum distance between landholdings.

*=significant at 99% level; **=significant at 90% level.

Table 3. Factors which influence the probability of exchange between households, Azim 43-L
Probit Analysis

	Coefficient	t-stat	Marg. effect	Coefficient	t-test	Marg. effect
Association and Extraction costs: kinship						
Same landowner family	0.215	1.30	0.028	0.189	1.11	0.022
Same cultivator family	0.986	5.14*	0.211	1.001	5.19*	0.201
Association costs: distance						
Water turn distance	-0.088	-5.58*	-0.010	-0.091	-5.66*	-0.010
Physical distance	-0.023	-2.79*	-0.003	-0.028	-3.14*	-0.003
Benefits of insurance: average water levels and risk aversion						
Average location of pair	0.004	0.46	0.0004	-	-	-
Length of waterturn	0.004	0.32	0.001	0.000	0.03	0.000
Location of recipient	-	-	-	0.019	2.75*	0.002
Location of transferring hhold	-	-	-	-0.018	-2.21*	-0.002
Constant	-0.716	-3.14*	-	-0.621	-2.65*	
Number of obs	1190			1190		
Pseudo R2	0.23			0.24		
Log likelihood	-302.6			-297.2		
Percent correct predictions	90.2			90.3		

Location of recipient or transferring household=continuous variable from 1 to 35, from head to tailenders.
Marginal effects computed at the means of the explanatory variables.
Marginal effects computed as discrete changes for dummy variables (kinship).
* indicates significance at 10%.

Table 4. Factors which influence the probability of exchange between households, Fordwah 14-R
Probit Analysis

	Coefficient	t-stat	Marg. effect	Coefficient	t-test	Marg. effect
Association and Extraction costs: kinship						
Same landowner family (A, B)	0.315	1.75*	0.002	0.316	1.74*	0.001
Same cultivator family (A, B)	0.691	4.82*	0.007	0.706	4.88*	0.006
Association costs: distance						
Water turn distance (B)	-0.066	-10.79*	-0.000	-0.068	-11.17*	-0.000
Physical distance (B)	-0.056	-5.13*	-0.000	-0.064	-5.89*	-0.000
Benefits of insurance: average water levels and risk aversion						
Average location of pair (μ)	0.002	1.08	5.9e-06	-	-	-
Length of waterturn (ϕ)	-0.115	-3.96*	-0.000	-0.117	-4.05*	-0.000
Location of recipient	-	-	-	0.010	3.44*	0.000
Location of transferring hhold	-	-	-	-0.009	-2.90*	-0.000
Constant	-0.776	-7.02*	-	-0.747	-6.67*	-
Number of obs	8742			8742		
Pseudo R2	0.32			0.32		
Log likelihood	-669.3			-663.8		
Percent correct predictions	97.6			97.6		

Location of recipient or transferring household=continuous variable from 1 to 94, from head to tailenders.

Marginal effects computed at the means of the explanatory variables.

Marginal effects computed as discrete changes for dummy variables (kinship).

* indicates significance at 10%.