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Farmer Cooperation in Participatory Irrigation in South Asia: Insights from Game Theory

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Abstract: Participatory irrigation, where farmers are given greater control and management responsibility, has been a topic of controversy for many years. Initially seen as a panacea for dealing with weaknesses in state-run irrigation, participatory irrigation has generated mixed results, especially in South Asia. Part of the challenge of understanding the conditions that promote and undermine participatory irrigation is that it is seldom deployed in the same way. For example, irrigation fees collected by farmers are not handled in the same manner, even within a single country. In some instances, a large portion of collected monies is retained locally and in others, only a small portion is kept for local use. In this paper, we use game theory to contemplate how the portion of irrigation fees retained locally might impact on the effectiveness of participatory irrigation. We show that there are multiple plausible equilibria, and that allowing farmers to retain more funds locally might shift behaviour from an uncooperative equilibrium to a cooperative outcome. However, we also find that it is unlikely for there to be a singular fix and we use empirical evidence to demonstrate the conundrums of making participatory irrigation sustainable.

Keywords: participatory irrigation management; game theory

1. Introduction

In many developing countries, irrigated agriculture has been seen as a panacea for dealing with endemic rural poverty by helping to raise living standards and improve food security [1,2]. However, institutional weaknesses in the administration of irrigation substantially reduce its effectiveness and efficiency [3]. After decades of concerns about state-run irrigation, an approach emerged in the 1970s and 1980s that involves devolving decisions to farmers. Known as participatory irrigation management (PIM) and in some cases irrigation management transfer (IMT) (we use participatory irrigation management (PIM) henceforth), such approaches have yielded mixed results, especially in India and Pakistan (see [4]).

Numerous case analyses of PIM are reported in the literature (e.g., [5,6]) with most focusing on the impacts on the water use efficiency, financing, operation, and maintenance and agricultural

productivity. There is no conclusive evidence from these studies on the success of devolved decision making or universal agreement on what drives attainment. This can be attributed to several reasons. First, the context of PIM is critical but variable, especially the political economy dimension which has not always been captured in comparative empirical analyses. Part of this is reflected in the differing institutional arrangements for the roll out of PIM. Second, there is seldom a clear “before” and “after” against which PIM can be compared—numerous other changes occur simultaneously, making it hard to unbundle the specific effects of irrigation reform. Third, not all forms of PIM are comparable; some are more modest in their approach and staged, whilst others are comprehensive and achieved quickly.

In the context of the latter, it is worth noting that the scale of devolved decision making is not always consistent across PIM. Even though the World Bank defines PIM as the involvement of users in “all aspects and at all levels of irrigation” [7], some states have taken a view that farmer involvement should be limited to smaller reaches of the system (see discussion on India and Pakistan in Section 2), whilst others have aimed at wider participation. In part, this is attributable to the agricultural landscape with larger commercial farmers often more willing to be active participants in reform [7], whilst smallholder PIM is plagued by higher transaction costs, simply due to the number of participants.

Nevertheless, the key element that ties PIM and IMT together is the overarching presumption that devolved decisions are more efficient in general, and that they simultaneously reduce the financial and managerial burdens on cash-strapped governments [8]. Whilst theoretical principles, like subsidiarity, and their relationship to efficiency are well-understood [9], as noted above, the practical analyses of PIM show a varied response. Some successes are claimed in developing countries like Mexico and Colombia, and some states in India have also witnessed success, like Maharashtra and Gujarat. Positive but more modest achievements have been found in the Philippines, but even in the successful cases, a range of second-order problems have emerged [7]. Key amongst these is the capacity to permanently secure payments from farmers for the water delivery and the vicious cycle between the under-recovery of costs, faulty infrastructure and poor service. Given that one of the primary motivations for promoting PIM has been the need to enhance cost recovery, this raises serious questions about the efficacy of the devolution approach more generally and whether there are other nuances that influence farmers’ willingness and ability to contribute to the cost of irrigation.

The actual mechanics of farmers paying for irrigation can vary considerably, even within a single jurisdiction. In most developing countries, metering and volumetric charging is not an option and irrigation fees can be charged on a per crop basis, or a flat, seasonal or annual fee can apply. Collection methods can vary and the robustness of monitoring and enforcement can also differ markedly between sites. Also, once monies are collected from irrigators, the portion that is held in local control versus passed to superordinate bodies varies. *Prima facie*, the greater the proportion of funds held locally, the more likely that spending will match local preferences and this, in turn, might make collection less onerous. Localised expenditure will also likely add to the perceived legitimacy of payments. However, there is no clear evidence that this is the case.

It is important at the outset to note that we do not advocate for holding monies locally on efficiency grounds. There may be scale economies with some decisions, thereby warranting monies and decision making power being held at superordinate levels. Rather, we contend that the portion of funds that is held locally can potentially influence the way collection occurs and attitudes to PIM generally.

These types of nuances need consideration if we are to deploy PIM and achieve the results sought by governments (we assume that governments and their agencies are genuine in their desires to move decision making to farmers and to enhance irrigation outcomes). However, analysing the complex interactions between all of these attributes is made more difficult by the potential for strategic behaviour on the part of irrigation farmers. For example, some might choose to hold off making payment, possibly because enforcement is weak and penalties are seldom invoked, whilst leaving neighbouring irrigators to carry the cost.

In this paper we consider the complex interactions that circumscribe farmers’ decisions to pay for irrigation. The analysis uses a game theoretic approach to explore the alternative scenarios that

might arise when the portion of irrigation fees retained locally varies. While our analysis reveals the complexity of the decision process, we purposely concentrate on a variable that is malleable for state agencies (i.e., the portion of fees retained locally), and thus offers insights into how PIM might be made more effective by the state. Although the exploration is applicable for multiple jurisdictions, the analysis itself stems from case studies undertaken in the Sindh and Punjab provinces in Pakistan and the states of Assam and Bihar in India.

The paper itself comprises six parts. In Section 2, we provide a synoptic overview of irrigation in the four jurisdictions in order to contextualise the work. A description of the game theoretic approach is presented in Section 3, where a stylised model is developed and explained. In Section 4, general scenarios are considered by using the model developed in Section 3 to explore the strategies used by irrigators. The mechanisms for parameterising the model are discussed in Section 5 along with offering the direction for further research. Brief concluding remarks are offered in the final section.

2. The Irrigation Context—Punjab, Sindh in Pakistan and Assam, Bihar in India

There is significant potential to increase agricultural production and thereby improve the livelihoods in the Indus and Ganges river basins. However, there are major challenges. In Pakistan, for example, rural poverty is endemic, and the potential in the Indus is either unharnessed or misdirected through poor policy and management choices. There is also widespread poverty and weak social development in the eastern states of India, particularly amongst rural communities. Against that background, Ghosh et al. [10] found (specifically in Bihar) that “improved irrigation management with proper institutional and infrastructure support can contribute to poverty reduction and a better standard of living”. Given the poverty of a state like Bihar, concerted efforts to enhance irrigation institutions promise significant gains for the poor.

The expansion of PIM as a means of improving irrigation remains a cornerstone in India, with the Ministry of Water Resources including a commitment to promote PIM and further empower the water users’ associations (WUAs) in its *National Water Mission*. However, progress is highly variable across India [11,12].

In Bihar, the Water Resources Department (formerly the Irrigation Department) remains responsible for the construction, maintenance and regulation of major and medium irrigation projects, and is in control of command area development. The department also plays a role in flood control. WUAs were expected to progressively take control of distributaries by managing operation and maintenance, and collecting water charges, with 70% of revenues retained locally and 30% transferred to the central department. However, as noted above, there is a gap between the ambition to formulate functioning farmer organisations and the reality. For example, Sinha [13] observes that by 2011, Bihar had substantiated only 80 WUAs covering 200,000 hectares, well short of the 800,000 hectares and 400+ WUAs anticipated under the Tenth Five-Year Plan for the state.

Although numerous high-order reasons have been proposed to explain this gap, ranging from differences in the capability of state governments through to the bio-physical challenges, few studies have specifically interrogated the impact of how state-based decisions translate to local acceptance, like the portion of fees controlled locally. It has often been assumed that decentralised decision making is preferable regardless of the setting or the types of decisions and the focus has been on barriers to a “better system of governance” (e.g., [14]). If Bihar is to successfully progress PIM, then targeted reform that deals with the key constraints is preferable.

The picture in Assam mirrors Bihar, with over 700 WUAs claimed to exist in line with the *Assam Irrigation Water Users Bill* of 2000. However, around half of these WUAs have failed to formally register and many do not function effectively. The Government of Assam’s Department of Irrigation also directly attributes the limited utilisation of irrigation potential to the slow progress of PIM. The department notes that cost recovery is weak and this continues to act as a barrier to better agronomic outcomes.

As with India, Pakistan manages water resources at the sub-national level (in this case, provinces) with considerable faith (at least outwardly) in the policies of PIM. In the Sindh province, the Sindh

Irrigation and Drainage Authority (SIDA) was established in 1997, with the aim of having 5.8 million hectares managed under PIM. Almost 20 years later, the irrigation systems in the province are still described as “in transition” to a more decentralised model (Dedja 2014).

Progress on PIM in Sindh is, at best, partial, with only three Area Water Boards in place by 2011 to assist in the management of main canals, and only 8% of WUAs reported as fully functional and less than half (40%) engaged in the collection of fees, i.e., Abiana [15]. All barrages and related infrastructure were to have been under the control of SIDA by 2005 and 14 Area Water Boards established. In practice, most barrages continue to be managed by the Irrigation Department, and although boards have legal authority over the expenditure of funds, SIDA retains close control, in part by meeting the salaries of officials.

In addition, the assessment of irrigation fees has not altered since the creation of SIDA, so that a major gap exists between revenue collection and the cost of rehabilitating and maintaining the irrigation network (let alone upgrading the network). Although good institutions can close such gaps and/or prevent their formation, and the willingness of farmers to pay higher rates in return for an improved water supply has been demonstrated [16], SIDA continues to rely on government subsidies to operate the irrigation system [15].

Despite the slightly longer history of PIM in Punjab, the outcomes have been worryingly similar to those witnessed in Sindh. The emphasis has again been on decentralisation as a default means of gaining efficiencies. At the watercourse level, WUAs (or khal panchayat) have been formed to deal with maintenance and conflict issues. Each khal panchayat is expected to elect a chairperson to sit within the farmer organisation, which holds responsibility at the distributary level. Representatives from farmer organisations then make up Area Water Boards, formed at the canal command level. Bell et al. [17] observed that less than one-fifth of commands areas across Punjab and Sindh have managed to transition to this structure. More recently, the Punjab Irrigation Minister announced a shake-up of the Punjab Irrigation and Drainage Authority, the entity created to manage PIM in the province. The proposed revamp stems from the ongoing concerns about the dysfunctional nature of farmer organisations and the poor compliance around the payment of charges and water theft [18].

Most studies of PIM in the region have focused on the reasons for the slow progress of uptake (e.g., [19]), without considering the possibility that some centralised decisions may actually be relatively more efficient in particular contexts, and this might explain the reluctance to switch to PIM. Arguably, decentralization should proceed to the lowest “appropriate” scale, rather than the lowest possible scale, but identifying appropriateness may not be straightforward. Nonetheless, it follows that the portion of farmer-paid monies transferred to the state/provincial departments should reflect this nuance; in locations or circumstances where it is inappropriate to make decisions at the farmer level, more funds should be transferred to superordinate bodies and vice versa.

However, what needs to be understood is that there are likely feedback effects and path dependencies embedded in this principle. If more monies are transferred to the state/province, then the incentive for local payment and collection might be weakened, thereby increasing the reliance on support from general revenue and strengthening the role of centralised departments. Transferring a large portion of farmer-generated funds to the state/province could assure the continued failure of PIM, as well as undermine the revenue generation itself, even though an increased revenue generation is often touted as a reason for moving to PIM.

To make this relationship clear we invoke the equation below:

$$\text{Irrigation fees to government} = f(F; GS; P/N) \quad (1)$$

The monies from farmers to fund the government provision of irrigation is related to the fees faced by farmers (F), the pre-determined share of fees to be transferred to the government (GS) and the portion of farmers who comply with the payment (i.e., payers (P) divided by total farmers (N)). If the fees remain unchanged (as has occurred in many jurisdictions for several years), then the portion transferred and the rate of compliance are the determining influences. Moreover, if the portion

transferred is inversely related to the compliance behaviour of farmers, it follows that an increase in the share of fees transferred to the state/province could yield a net decrease in the irrigation fees received by the government, if compliance subsequently declines.

What is missing from the above equation is the cost of collection and who bears that cost. Again, this is considered one of the strengths of PIM; devolved collection is presumed cheaper than that requiring state/provincial intervention. Thus, PIM in some cases might be expected to yield more revenues, but again the portion of funds transferred might itself have some impact on the effort exerted locally to collect revenues, a point explored later.

We have hypothesised that the portion of funds held locally could impact on the effectiveness of fee collection. However, predicting those impacts requires consideration of the broader decision context and the potential for strategic responses. We describe the farmer’s decision context and introduce game theory as a means of exploring strategic behaviours within that context in the following section.

3. Farmer Decision Context and Game Theory

Figure 1 seeks to describe the complex decision context for many farmers in the study regions.

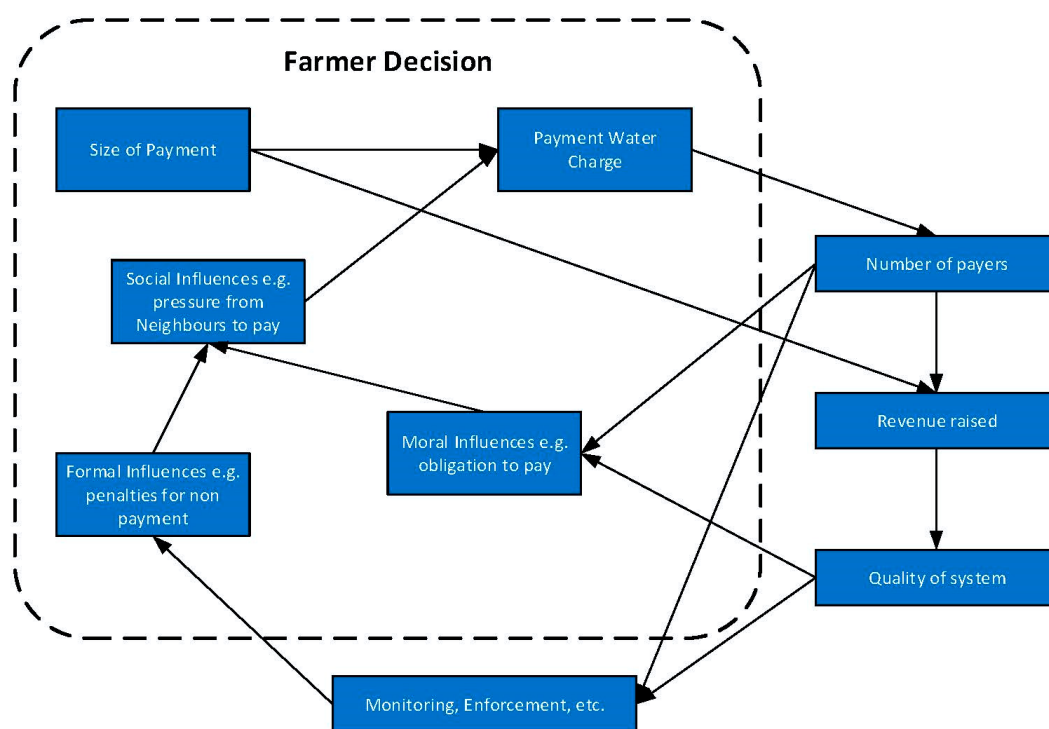


Figure 1. Farmer’s decision context.

The farmer’s decision lies within the dotted lines where he/she weighs up the option to pay (or not pay) irrigation fees, i.e., be compliant or not. The size of the payment, the financial rewards and penalties for non-payment, the potential for social acceptance or sanctions being applied for non-compliance and moral influences all come to bear. Clearly, some of these considerations are driven by calculative issues, whilst others have societal and moral overtones. The monitoring and enforcement effort from the circumscribing environment (e.g., the behaviour of other water users in the village and/or government officials) is key to the calculative and social considerations taken into account by the farmer. Further, having an indirect influence on this decision environment is the number of other farmers currently making payment which, in turn, drives the revenue on hand, and impacts, in part, on the quality of the irrigation system.

Whilst seemingly complex as it stands, there are various nuances at the local level that can make this setting even more complicated. The proportion of irrigation fees held locally represents another potentially confounding influence.

What is clear from Figure 1 is that all farmers need not reach the same decision to pay (or not pay) as differing calculative, social and moral processes attend each farmer. Some may be more willing to take on the wrath of neighbours or the state than others by refusing to pay, whilst others may put a higher value on the sound functioning of the irrigation system, for instance. Understanding how different farmers might react to requests for payment can be usefully analysed in a number of ways. For instance, Lika, Galioto and Viaggi [20] approach the problem using the principal agent theory, but game theory has the potential to offer additional insights.

Game theory has become a popular method for analysing cooperation and non-cooperation between different entities (players). At one level, games fall into two groups: zero-sum and non-zero-sum games. In the case of the former, a player's benefit is offset exactly by the cost imposed on another player. In the case of the latter, the payoffs to each player do not sum to zero and this gives rise to more complicated outcomes, including the scope for engendering cooperation because the outcome to both players might be superior if they agree to collaborate on their choices. The current dilemma of securing payment of irrigation fees likely fits within the non-zero sum form of game.

At a different level, games can be classified as falling into non-cooperative and cooperative forms. Under non-cooperation games, players seek to maximise their own goals, whilst cooperative games encourage players to take on mutually binding agreements to meet their self-interests [21].

Games can also take on static or dynamic forms; the former gives a one-shot opportunity, while the latter allows for progressive learning and a refinement of the strategy by the players. Game theory differs markedly from many orthodox analytical tools; such conventional tools tend to use a form of optimisation model assuming rational choices to derive a single stable outcome. Arguably, game theory provides insights into more realistic conflicts inasmuch as it allows for the inclusion of different strategic behaviours from the different players, and thus has the prospect of yielding multiple outcomes.

In the case of conflicts over water, game theory has been used specifically to examine how a resolution can be reached over hydrological disputes (see, [22]). Madani [23] categorises the literature on game theory and water resources into five groups: (1) games being used to consider the benefits and costs of water allocation among users; (2) games focused on groundwater management; (3) trans-boundary considerations with games; (4) water quality analysis with games, and; (5) various other water management problems with games. In contrast, Bogardi and Szidarovsky [24] provide an earlier four-fold typology for applying games to water management covering: (1) environmental protection; (2) irrigation system management; (3) water quality management, and; (4) multipurpose water management systems. Panayotis and Yannopoulos [25] trace the historical increase in the use of game theory to examine water-related issues, noting that studies broadly fall into four groups: (1) analysis of conflicts over water and cost allocation; (2) groundwater studies; (3) literature focused on water quantity–water quality trade-offs, and; (4) studies dealing with institutional arrangements and social learning.

In addition to providing his own typology of the water contexts for the use of games, Madani [23] offers an accessible description of the basic structure of most games; this comprises prisoner's dilemma games, chicken games, assurance ("stag hunt") games and dynamic games. Prisoner's dilemma games are characterised by scenarios where two players are being "interrogated" and if one reneges on the other, she receives a payoff: a reduced sentence. If both remain silent to any crime, they escape without penalty, but if both confess, they receive a penalty, albeit less than if they are betrayed by their colleague. These types of games can be depicted in a two-by-two payoff matrix. Carraro and Sgobbi [26] note that many natural resource management questions pose as a prisoner's dilemma and we use that framework in this case to explore issues relating to the payment of irrigation fees.

We start by assuming two irrigators are approached to make payment for the use of irrigation services. For simplicity, we further assume that:

- Irrigation fees cost 6 per farmer;
- The benefit received from irrigation increases with fees paid;
- The benefit to farmers is 3 if no irrigation fees are paid;
- The benefit to farmers is 7 per farmer if one farmer pays;
- The benefit to farmers is 11 per farmer if both pay.

Using these basic cardinal values results in a payoff matrix for each farmer depicted as in Figure 2.

		A	
		Cooperation (Compliance with fees)	Non-cooperation (Non-Compliance with fees)
B	Cooperation (Compliance with fees)	5	1
	Non-cooperation (Non-compliance with fees)	7	3

Figure 2. Payoff matrix for paying irrigation fees for two farmers.

Farmer A has two choices: cooperate and make the payment or not cooperate and refuse. Likewise, Farmer B faces the same options. The way the payoffs have been constructed shows that if both farmers agree to pay, they have the same profits from farming (5 each: north-west quadrant). This is based on our assumption that both gain benefits equal to 11 but also pay costs of irrigation equal to 6. If both farmers refuse to pay, the infrastructure is assumed to deteriorate such that both farmers make a reduced profit from irrigation (3 each: south-east quadrant). If one farmer opts to pay and the other does not, then the cooperative farmer is worse off; despite improvements in the system, he/she carries more cost. The payoff for being cooperative when the neighbouring farmer is not is only 1 (i.e., 7 minus 6) compared with 7 (i.e., 7 minus 0) for the non-cooperative behaviour. This simple game demonstrates that a non-cooperative approach to paying irrigation fees can be the dominant strategy for both farmers, and hence the Nash equilibrium.

This dismal finding can be nuanced by various factors. For example, if more of the paid monies is held locally, then the farmer might have more say over how those monies are allocated. This could make the legitimacy of payment more overt inasmuch as it changes the perception of fairness and might thus sway farmers towards the cooperative outcome, even though the non-cooperative outcome is the dominant strategy in Figure 2. What is not clear is whether local retention of monies will modify the strategic behaviour and the portion of retained funds that might be required to bring about change.

4. A Model Where Farmers Control More of the Collected Fees Locally

Building from this initial model, which highlights the potential incentives to not cooperate in the payment of irrigation fees, we now turn to the impact of varying the rules around retaining

collected monies locally. As noted earlier, we have assumed that the local retention of collected fees can potentially impact compliance. To operationalise these ideas we identify two functions:

$$\text{Monitoring and enforcement effort} = g(\text{compliance with fees, per cent retained locally}) \quad (2)$$

$$\text{Compliance with fees} = h(\text{monitoring and enforcement effort, per cent retained locally}) \quad (3)$$

A brief description of the rationale for these different functions follows with the stylised representations offered in Figures 3–5. The aim is to position these functions in a space defined by the value of irrigation fees collected (vertical axis) and the effort exerted at a local level to bring compliance and improve the collection (horizontal axis). The hypothesized relationships draw from the simplified game theoretic model (Figure 2) and our observations of behaviour in the field, as depicted in the conceptual model in Figure 1.

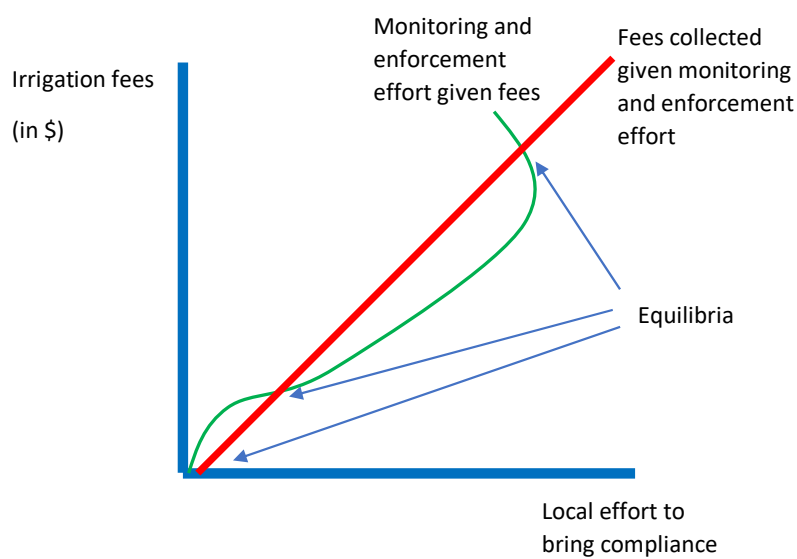


Figure 3. Hypothesised relationships between the monitoring and enforcement against fees paid/fees paid against monitoring and enforcement.

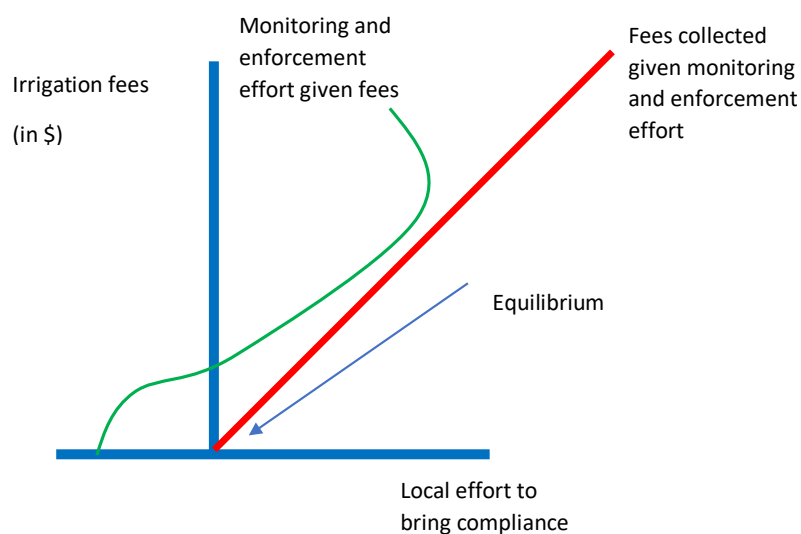


Figure 4. Hypothesised relationships between monitoring and enforcement given fees paid and fees paid given monitoring and enforcement, assuming a low local retention of fees.

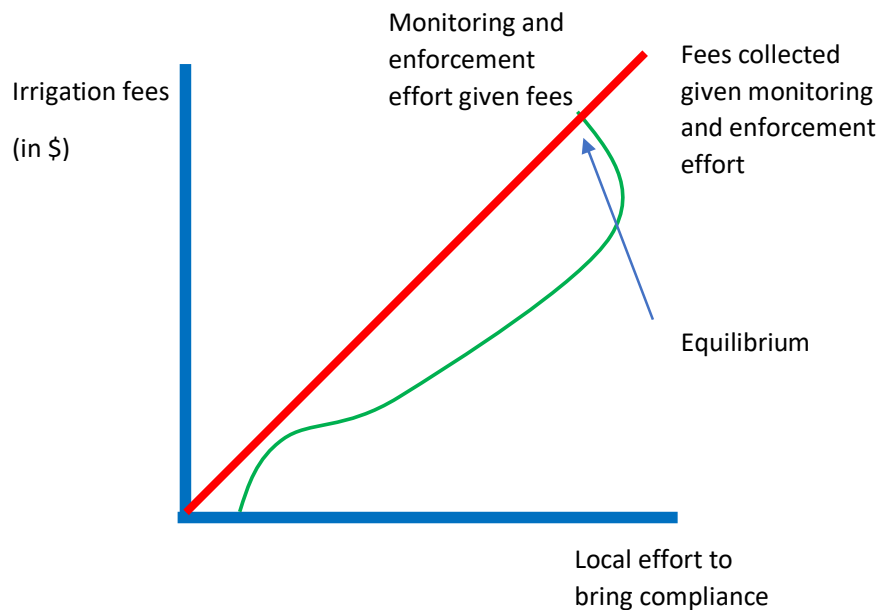


Figure 5. Hypothesised relationships between monitoring and enforcement given fees paid and fees paid given monitoring and enforcement, assuming a high local retention of fees.

We begin by assuming the non-cooperative Nash equilibrium as the status quo and focus on the local effort likely to be exerted at the different levels of the fee collection. When the fees paid are low in monetary terms, it follows that the local effort to monitor and enforce is also low, since there is little to be gained when the returns from any effort to enforce on neighbours are so low. As the value of fees paid increases, there is a greater incentive to monitor and enforce collection, although this is not likely to be strictly linear. Since we are assuming a low level of cooperation to begin with, the transaction costs of introducing and gaining greater compliance initially will be high. It seems plausible, for instance, that a non-trivial increase in fees will be required initially to stimulate interest in raising the monitoring and enforcement effort at a local level. Thus, the level of irrigation fees is initially shown as increasing at a faster rate than the monitoring and compliance effort. Once the revenue from fees reaches a material sum, the effort to continue the collection and enforcement correspondingly increases. We further hypothesise that once the revenues collected are quite high and the irrigation system functions relatively well, then the monitoring and enforcement effort might wane, since the marginal gains from securing additional compliance relative to the sums already being collected is low. This gives rise to the backward bending curve depicted in Figure 3.

Turning to the fees paid and the monitoring effort, it seems reasonable and parsimonious to assume that the greater the monitoring and enforcement effort, the higher the revenue collected will be and this is depicted with the upward sloping line in Figure 3. The combination of these two functions results in multiple equilibria, some with high compliance, high fee payment and high local enforcement effort and others with low compliance, collection and enforcement effort.

As noted earlier, the proportion of monies retained locally varies markedly across the study region both in terms of the administrative rules and local practice. In some cases, local irrigation groups are expected to expend the effort of monitoring and enforcing the collection of irrigation fees only to then pass the proceeds to a higher authority. In Assam, the administrative arrangements are that all fees are expected to be passed to the state and in Sindh, 60% is passed to the provincial government. In Bihar, 70% is kept locally and in Punjab, the collections are halved between the local and provincial authorities. In practice, there appear to be multiple variations and understandings of these arrangements at a local level. Of course, the rationale for passing monies to the state or provincial governments is not in question; after all, irrigators are enjoying the benefits of a wider network and the costs of that network might rationally be assigned to users. However, what is worth noting is that the portion of monies

retained locally might be expected to impact the monitoring and enforcement effort of local groups and also the amounts paid/level of compliance. The rationale here is that local retention of monies increases the capacity of local irrigators to direct expenditure towards their preferred outcomes and this, in turn, increases the monitoring and enforcement effort for all fees paid. It is also likely that local retention increases the perceived legitimacy of the payment. In contrast, asking local water user organizations to collect fees and pass the entire proceeds to the state/province is unlikely to be perceived as a legitimate role.

Given these relationships, different equilibria become plausible to those presented in Figure 3. Take the case where the local retention of fees is so low such that the monitoring and enforcement efforts for any given level of fees are displaced leftward compared with that depicted earlier. This scenario is depicted in Figure 4. In this situation, the monitoring and enforcement effort becomes negative; that is, local farmers actively agitate against payment altogether. Here, the equilibrium that results is zero collection and a very poor performance (consistent with the prisoner's dilemma).

We contrast this with a scenario where a large portion of fees collected from irrigators is retained locally and the perceived legitimacy is greater. In this instance, we hypothesise that the monitoring and enforcement against fees function is displaced rightward (see Figure 5). The upshot is an equilibrium with high payment, compliance and enforcement, analogous to the north-west quadrant in the prisoner's dilemma in Figure 2.

5. Parameterising the Model

The previous section was used to develop potential scenarios around the performance of PIM, where the portion of irrigators' fees held locally impacts on the strategic choices made by farmers. We contend that whilst the models are theoretical in nature, the outcomes are also reasonably plausible. Why would farmers willingly and cooperatively offer to pay for irrigation services and self-enforce collection with no influence over the decisions made about the spending of those monies? Why would they regard collecting fees and handing all funds to a superordinate body as legitimate?

Knowing the threshold at which the low local retention of funds leads to poor outcomes and a higher local retention leads to better outcomes offers an insight into how states might consider their approach to PIM. To reiterate, we make no claim that a localised monopoly over decisions about how to spend irrigation fees is more efficient than a complete redistribution to the state. Rather, we are solely interested in the capacity of a policy adjustment to shift the behaviour of farmers towards a cooperative equilibrium.

Clearly, to accomplish this task, information is needed on how the local monitoring and enforcement effort relates to fees paid under the different rates of local retention. In addition, information on how fees paid relate to monitoring and enforcement under the different rates of local retention is required.

In an effort to progress this, we explore data from two states in India (Assam and Bihar) and two provinces in Pakistan (Sindh and Punjab). Across the study jurisdictions, there are variations in how irrigation fees are charged, how revenues are collected, enforcement mechanisms and the revenue-sharing arrangements with the state/provincial departments. These jurisdictions were chosen because the history of PIM is extensive in each state/province; there are acknowledged weaknesses to PIM in each jurisdiction, and an improved irrigation performance is critical to the future prosperity of the rural poor in each state/province.

Ideally, reliable state-held data would be available on each of these variables but field analysis shows that the reporting of fees collected and the actual monitoring and enforcement that takes place is not always consistent. An alternative is to collect primary data directly from farmers about their payment, enforcement and monitoring experiences. These data could then be adjusted to provide empirical estimates of the equilibria that relate to the cooperative and non-cooperative behaviours.

With that in mind, we examine the data collected directly from farm households across those jurisdictions in early 2018. The data related to a wider project that was exploring water institutions and their effectiveness, but with specific questions asked about compliance and payment. The survey

was administered across several villages in each of the jurisdictions. The locations were chosen to represent the head, middle and tail reaches of the irrigation network and on the basis of the reported variation in the performance of PIM, as identified by officials from the Punjab Irrigation and Drainage Authority, Sindh Irrigation and Drainage Authority and the Departments of Irrigation in Assam and Bihar. The agricultural outputs varied slightly across each site, although staples like wheat and rice were common in most cases (see, [27]). Districts where PIM had not been trialed were not included in the sample. A little over 800 surveys were administered and the data collection occurred using mobile tablets. Some difficulties with the tablet application in the field meant that a sample of 797 usable responses is on hand for this analysis.

In the process of developing the suite of surveys for the project, it became clear that local variations and interpretations were common in the field, even though some states/provinces had specific rules about how water institutions should operate, including the proportion of funds to be held locally. Accordingly, the administrators of the survey asked respondents for their perceptions/understanding of the local status quo, rather than presuming the state/provincial edict held true.

Within the same survey, the respondents were presented with a Likert scale measure to indicate the extent to which their neighbours currently complied and made payment. The levels covered “all of the time”, “about three-quarters of the time”, “about half the time”, “about a quarter of the time” and “hardly ever”.

In terms of estimating the local effort exerted to achieve compliance, we use the reported mechanisms for (a) assessing the fees due, (b) collecting the irrigation fees and (c) the application of sanctions for non-compliance. For simplicity, we develop an index based on assigning a value of 2 where an activity is reported to be solely undertaken by local farmers, a value of 1 is assigned where the activity is jointly undertaken by local water users with a government official and 0 is used to represent instances where the task is solely fulfilled by the state/provincial authority. Maximum local effort in the context of monitoring and enforcement is thus rated at 6.

The compliance with fee payment variable is derived from the reported compliance witnessed by neighbours and assumes a value between 0 and 5, representing each of the Likert measures. The percentage of revenue held locally is taken from the respondents’ claimed understanding of the status quo.

As noted above, Equations (2) and (3) represent a simultaneous system, and hence we estimate the models using a two-stage least squares instrumental variable technique, where we develop instruments for the endogenously determined variables. Tables 1 and 2 report the estimates for the local level of compliance (modelled as 2SLS tobit models, with monitoring and revenue kept locally as the explanatory variables) and monitoring (using a 2SLS probit model, with local compliance and revenue kept locally as the instruments).

Table 1. 2SLS Tobit regression of index of perceived local monitoring and enforcement effort against revenues retained locally and the rating of neighbours’ compliance with paying fees.

Index of Local Monitoring and Enforcement Effort				
Variable	Coefficient	Std Err	t	P > t
Revenue retained	0.142	0.009	15.70	<0.001
Rating of neighbours’ compliance with fees	−4.460	0.489	9.13	<0.001
Constant	14.147	1.730	8.18	<0.001
N	797			
Log Likelihood	−1687.2096			
Wald test of exogeneity Chi squared (1) = 268.51 $p < 0.001$				

Table 2. Ordered logistic regression of compliance (measured as reported neighbours' compliance) as a function of the local monitoring and compliance effort index and proportion of fees retained locally.

Rating of Neighbours' Compliance with Fees				
Variable	Coefficient	Std Err	t	P > t
Revenue retained	0.024	0.002	9.94	<0.001
Index of local monitoring and enforcement effort	−2.293	0.036	8.10	<0.001
Cut point 1	−1.857	0.155	11.96	<0.001
Cut point 2	−1.245	0.137	9.11	<0.001
Cut point 3	−0.438	0.130	3.36	=0.001
Cut point 4	0.944	0.139	6.77	<0.001
N	797			
Log Likelihood	−1874.1154			
Wald test of exogeneity Chi squared (1) = 34.18 $p < 0.001$				

As with the Tobit model reported in Table 1, the percentage of funds retained locally is statistically significant and positively related to the reported compliance of neighbours, i.e., the higher level of revenue retained locally, the greater the level of compliance. The local monitoring and enforcement effort is also statistically significant in this model. However, unlike the hypothesised model, where greater local monitoring and enforcement is positively related to compliance behaviour, in this case, local monitoring and enforcement is negatively related to the reported compliance of neighbours. Put differently, this model supports the view that the more monitoring and enforcement that is left solely at the local level, the lower the compliance will be, at least as captured in these data.

Overall, the model explaining the level of the local monitoring effort and enforcement is significant. The proportion of irrigation fees retained locally is significant at the 1% level and positively related to the monitoring and enforcement index. That is, as more monies are retained locally, the index on monitoring increases. The level of compliance with irrigation fees (as measured by the perceived level of compliance of neighbours) is negatively related and also statistically significant in this model, suggesting that, as compliance increases, the monitoring and enforcement effort at the local level falls.

Table 2 reports the results of the 2SLS-ordered probit model of perceived compliance.

In both models, the assumption of exogeneity is rejected, supporting the use of the IV (instrumental variables) approach.

6. Local Versus State/Provincial Responsibilities

This analysis was motivated by the long-held view that PIM represents one of the few options for increasing the sustainability of irrigation in some parts of the world, including in countries in South Asia. We noted that the evidence on the success of PIM is mixed and there are numerous explanations as to why this is the case, including some that can be gleaned from theoretical insights drawn from game theory. This theoretical perspective led us to speculate that the lack of local control over the monies collected to fund irrigation was potentially acting against the desire to make irrigators more self-reliant and to support ongoing maintenance of the system through fees.

The empirical evidence explored offers some support for this view. Increasing the amount of irrigation fees that are retained at a local level was shown to be positively and significantly related to compliance behaviour. The portion of monies held locally was also shown to be positively and significantly related to the amount of effort exerted locally to bring compliance, at least as captured by the index constructed from these data.

However, there are also clearly other factors at work in this complex decision environment and simply adjusting the local take from irrigation fees upwards is unlikely to generate long-term sustainable irrigation in its own right. This important caveat stems from the critical finding that higher rates of local monitoring and enforcement are associated with lower rates of compliance, as seen in Table 2.

There are at least two possible reasons for this result. First, this result could stem from the fact that local monitoring and enforcement is associated with a range of other norms and values, some of which might actively discourage the full payment of irrigation fees. For example, local norms might dictate that non-payment is an acceptable behaviour or even an expectation of farmers. Moreover, social norms at the local level may be insufficient to bring a level of compliance and the state/provincial authorities still have an important role in this regard. Smallholder irrigators might also be reluctant to comply for a range of other reasons, some of which have no bearing on actions at a local level.

Second, we have constructed the index of the monitoring and compliance effort solely on the basis of the assigned responsibilities. The important thing to note here is that simply assigning responsibility may not capture local effort *per se*. Local authorities might not have the capacity to bring enforcement such that simply assigning this task to them counts for little in enhancing compliance. This needs to be borne in mind when designing PIM institutions.

Thus, whilst we have partially shown that the portion of monies held locally can shift farmers to a more sustainable and cooperative state, it is also worth noting that there is a myriad of other factors that can influence the strategic choices made by farmers, and simultaneously assigning monitoring and compliance to local authorities may counter the incentive to cooperate. Rather, it is clear from these data that at least some decision-making authority must continue to be exercised at the superordinate level, at least to support local actions related to monitoring and compliance.

PIM is generally premised on the view that devolving decisions to local farmers will enhance the irrigation performance. These data clearly show that not all decisions can be assigned to local water users. Assigning more monies to the local responsibility may help raise compliance but ensuring compliance and enforcement around payment of fees remains an important task for higher authorities, at least in the four jurisdictions analysed. The point is that the state cannot simply abandon irrigation to local users; instead, it must continue to offer support to ensure a degree of orderly behaviour on the part of farmers.

We contend that this finding is particularly relevant in those parts of South Asia where local capacity is limited through a range of constraints. These include low literacy and education levels, a reliance on traditional agricultural practices, poorly developed marketing chains for agricultural outputs and a deference to customary power relations. Whilst these conditions are not universal across the region, those areas struggling to develop will continue to need input from the state.

7. Concluding Remarks

The expansion of irrigated agriculture remains a policy ambition for many developing countries, including those in South Asia. However, to achieve the benefits of irrigation requires more than engineering interventions. Studies have repeatedly shown the need for institutional settings that are conducive to making the most of the opportunities offered through irrigation and it is in that context that enthusiasm for PIM emerged.

Subsequent to the introduction of PIM, some successes have been witnessed but these are far from universal. This leaves open the question about what leads to successful PIM and indeed whether the nuances that attend some PIM are conducive to cooperative behaviours.

We have argued that game theory is particularly helpful in highlighting why irrigation farmers may have a dominant strategy to not cooperate. This has been considered against a complex background of decision making where the motivation to pay irrigation fees is shaped by social, calculative and moral influences.

It was also possible to show that non-cooperation is even more likely when the monies generated from the collection of local irrigation fees are not controlled and deployed locally. Moreover, adjusting the portion of monies that is held locally may have the potential to shift farmer behaviour from non-cooperative to cooperative responses. This has been used as the focus of the game theoretic approach, but it is also possible that other factors could be explored in future research.

The data collected from farmers in Assam, Bihar, Punjab and Sindh were used to explore these issues empirically. The results show that the local retention of monies does have an important influence on compliance behaviours. However, a confounding relationship between the local monitoring and enforcement effort and compliance was also evident. This suggests that adjusting the portion of monies held locally is unlikely to singularly transform PIM to a cooperative and sustainable state. Rather, additional support from the state/provincial governments is likely to be required to bring the levels of compliance needed for some semblance of sustainability. This finding is likely to be particularly relevant in regions where economic and social development remain a challenge.

There are clearly gaps in this analysis and further opportunities for refinement and development exist. The data used for this investigation are far from complete and parsimonious choices have been made in an effort to parameterise the theoretical model, with the index of local monitoring and enforcement being a case in point. There are also opportunities to build on this work using different theoretical developments, including experimental economics.

The extent to which these results are generalisable also needs to be tested, although we have argued they are likely applicable in areas characterised by a limited local capacity, and we thus advocate that greater attention be given to local constraints when embarking on additional PIM reforms.

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