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The dissemination of private wells and double tragedies: the overexploitation of groundwater among well users and increased poverty among non-well users in Tamil Nadu, India

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Abstract

This paper investigates the impact of the dissemination of modern irrigation systems, i.e. private wells with pumps, on the livelihood not only among the farmers who have access to wells but also among the farmers who have no access to wells and thus rely solely on traditional irrigation systems called tank irrigation systems. The analysis is based on a village and household data set collected in Tamil Nadu, India where tank irrigation systems have been managed collectively for rice cultivation. Our statistical analyses predict that once declines in collective management occur due to the dissemination of private wells, the rice yield and income of the no-well-access farmers alone will decrease, resulting in increased poverty among them. Our analyses also find that the dissemination leads to the overexploitation of groundwater, and thus results in no significant increase in rice profit among the well-access farmers. In this way, the dissemination of private wells creates double tragedies: not only increased poverty among the no-well-access farmers but also overexploitation and profit reduction among the well-access farmers.

Key words: irrigation, well, common property, poverty, India.

JEL codes: O3, O13, Q25

1. Introduction

International attention to water scarcity in developing countries has been increasing (e.g. the series of World Water Forums), and with this increasing attention has come the realization that efficient water management is crucial for sustainable development. In agricultural sectors in developing Asian countries, a major recent change in water management systems is the rapid spread of pumps and wells (modern irrigation systems) and the decline in traditional irrigation systems such as tanks in Tamil Nadu, India. Facing this transition under increasing water scarcity, people are raising questions of whether water is used efficiently under the modern irrigation systems and how the decline in the traditional systems affects the poor farmers who are usually the last group of people to adopt the modern systems. This paper aims to investigate these questions using a case in Tamil Nadu.

Tank irrigation systems collectively operated and managed by informal local bodies have been a dominant source of irrigation in South India since time immemorial (Palanisami, 2000). However, in the last two decades a massive diffusion of private wells and pumps has occurred throughout India due to sharp declines in investment and operation costs; Tamil Nadu has been no exception. There the percent share of agricultural area under well irrigation increased from 26 per cent in the 1960's to 42 per cent in the 1990's, while the share under tanks declined from 38 per cent to 22 per cent

over the same period (Fertilizer Association of India, various issues). This replacement process has been associated with significant increases in the average yield of rice, a staple crop in the area, and in the average income level of farmers.

Despite such positive effects on average, there is concern that the replacement of tanks by private wells is associated with increased poverty. Access to water from tanks is available to all the farmers in the system command area in principle. Access to irrigation water from private wells, however, is limited to owners and to those who can buy from the owners. Private wells provide freedom in irrigation water control and thus those who have access can increase their yields and incomes. Since the tank is an indivisible technology, when farmers with access to private wells exit from the collective management of their tank system — out of disinterest or loss of incentive — it becomes difficult for the remaining smaller number of users to provide a sufficient level of maintenance work. When the decline in collective management happens, farmers who are dependent on tanks suffer while farmers who have recourse to private wells can still achieve high levels of incomes and crop yields. In this way, the farmers without access to private wells suffer negative effects created by other farmers' exit from the collective management, leading to increased poverty among the without-access farmers.

The story does not end here; a problem arises also among well users. Since the groundwater is a typical example of common pool resources under open access, in his/her profit maximization, each individual user does not take account of the existence of a negative externality he/she imposes to other users, resulting in the exploitation of groundwater beyond a social optimum level. Therefore, eventually, the well users become unable to earn rice profit as much as they used to do.

Based on the argument above, we advance two hypotheses. First, the dissemination of private wells leads to the decline in collective management, and, then, once the decline occurs, the rice yield and income of the non-well users alone will decrease, resulting in increased poverty among them. It has been already empirically shown that the dissemination of private wells leads to the decline in collective management (Kajisa et al., 2004). Hence, this paper focus on an empirical question of whether the decline leads to increased poverty or not. The second hypothesis to be tested is that the dissemination leads to the overexploitation of groundwater, resulting in no significant increase in rice profit among the well users.

This study is based on our survey of 79 tank irrigated villages randomly selected from four contiguous districts (Madurai, Ramnad, Virudunagar, and Sivaganga) in southern Tamil Nadu state, India in 1999. In these districts rice is the dominant crop,

irrigated mainly by tanks supplemented by wells. In each village, we conducted a group interview to collect information on the management of tank irrigation as well as on village characteristics. We also interviewed 450 rice-farming households, randomly selected with a sample of 5 or 6 households from each village.

2. The impact of the decline in collective management on poverty

Measuring collective management

To evaluate the impact of the decline in collective management, the first step we have to take is to measure the overall status of the collective actions devoted to tank management in the survey year as compared with the past. There are two approaches: (1) evaluating the condition of irrigation systems as a resulting indicator of effective collective management; and, (2) evaluating the degree of cooperation within the collective management.¹ The former approach is not appropriate for our case due to difficulties in isolating the current status of irrigation from the influence of exogenous environmental conditions and from accumulated past successes or failures in collective

¹ Examples of the former approach include Bardhan (2000) where he uses the index of quality of maintenance of distributaries and channels and Dayton-Johnson (2000) where he uses the conditions of canals as the proxy for the existence of collective action. Bardhan (2000) also uses the latter approach where he uses the number of conflicts and the frequency of rule violations among beneficiaries. Another example of the latter approach is Fujiie, et al. (2005) where they measure cooperation in terms of the success or failure in organizing several water management related activities.

management. Therefore, we use the latter approach, although this approach, also, presents difficulties. Past studies generate a dichotomous variable because of the difficulty in objectively ranking the degree of cooperation. We could generate a dummy for each of the three tasks of collective management: de-silting, channel cleaning, and the arrangement of water distribution. However, evaluating each separately will not necessarily provide useful information regarding overall status because the activities may be mutually substitutable, so that the lack of one activity will not necessarily mean an overall decline (Fujiie et al., 2005). Moreover, a lack of de-silting and channel cleaning does not necessarily mean that management declined in the survey year because those activities are carried out according to need. In order for the second approach to produce appropriate measurements, we must be able to measure the overall status in the survey year.

The approach we take is to use the dichotomous response of key village informants to the question of whether the informal water users' organization (WUO) is active or inactive in the survey year; the dummy takes the value one if inactive. We consider this dummy variable to be an appropriate proxy for measuring tank management activity because firstly, it evaluates the overall status of the collective management, and secondly, it evaluates the status in the survey year. Although this

variable is somewhat arbitrary, it is the best available proxy that we could think of, having high correlation with other proxy variables and performing better in the regression analysis than other proxy variables.²

Using this dummy as our measure, we classified the villages into those with and those without active collective management, and we found that the number of “inactive villages,” (that is without active collective management) is 31 (39%) and the number of “active villages” is 48 (61%).

Binary comparison

In order to develop an understanding of the impact of the decline in collective management, we compare the yield, the per capita monthly income, and the per capita monthly consumption value among 171 households in the 31 inactive villages and 279 households in the 48 active villages.³ These data are displayed in Table 1. The

² This inactive WUO dummy has a high correlation (correlation coefficient 0.75) with a dummy that becomes one when channel cleaning had not been conducted in the last three years, indicating the consistency of villagers’ cleaning behavior and the subjective evaluation of the overall status. The inactive WUO dummy is consistent also with water supply conditions. Among the inactive villages according to the classification of our variable, 48 per cent of the villages claimed that the availability of tank water had worsened, whereas the corresponding percentage goes down to 29 per cent in the active villages. Moreover, in the active villages, even in those which claimed that the situation had worsened, the majority claimed that the reason was bad rainfall rather than the poor management of irrigation facilities, whereas this was reversed in the inactive villages.

³ The weights used for computation of adult equivalent household size are 0.5 for a child of age below 5 years, 0.73 for a child 6-10 years, 0.83 for a child 11-14 years, 0.83 for a female above 14 years, and 1.0 for males above 14 years (Rao, 1983). Household members living outside of the household because of work are excluded but members living outside because of educational

difference in rice yields is clear: row (1) shows that rice yield in kg per hectare is lower in the inactive villages than in the active villages and the difference is statistically significant. The lower average yield leads to lower average income and consumption level as shown in rows (2) and (3).⁴ The comparison of poverty indexes shows that not only the incidence of poverty but also the poverty gap is higher in the inactive villages.⁵ These poverty indexes are consistent with the villagers' subjective assessment of their poverty conditions presented in row (4); a larger percentage of villages in the inactive villages judged that they are in serious poverty than villages in the active villages. These results imply the existence of impacts of the decline on increased poverty.

Regression analyses

In order to confirm that the decline in management is the reason for the increased poverty even after controlling for other possible determinants, we estimate the reduced form regression functions explaining the rice yield, the income, and the consumption value. For this purpose, we include the village level inactive

pursuit are included as members of the household, on the assumption that students receive financial support from the household.

⁴ The means of consumption values are not statistically different, presumably due to the existence of consumption smoothing mechanisms to some extent.

⁵ Use of the national poverty line of Rs. 324 monthly per capita for 1993-4, instead of US\$ 1, does not change the qualitative results. The same applies to the comparison of the consumption value.

management dummy as one of the explanatory variables. Also important is the household level variable which measures the inaccessibility to private wells. This is a dichotomous variable: non-well-owners who did not buy water from well owners are classified into the no-access group (dummy=1), while the owners and the non-owners with water transaction records are classified into the access group (dummy=0). The differential impacts of the decline between the farmers with access and those without access are, therefore, captured by considering four different cases. Using the case of farmers having access to wells at an active village as the base (*Access&Active*), we construct three irrigation status dummies: (1) no-access at an active village (*No-Access&Active*), (2) no-access at an inactive village (*No-Access&Inactive*), (3) access at an inactive village (*Access&Inactive*).

We must also control for the distance from the irrigation source to the farmers' fields because in gravity irrigation systems like tank systems the distance affects the availability of water. Moreover, the affect of distance may vary depending on the status of the collective management and well access. In our explanatory variables, we include not only the distance from the tank but also the interaction of distance with our three irrigation status dummies.

Consequently, our regression equations include six explanatory variables

containing information on the status of the accessibility to wells. The accessibility to wells, however, potentially entails endogeneity and measurement biases.⁶ These potential biases, if any detected, are controlled by the instrumental variable (IV) method.⁷

The other determinants included are a set of household human asset and physical asset variables, socio economic characteristics, and village level characteristics. The definitions of these variables and descriptive statistics are presented in Appendix Table A1.

The estimated yield, income, and consumption value by irrigation status are presented on the columns (1) to (3) in Table 2. These figures are based on the regression results reported in Tables A2 and A3 in Appendix. One obvious result on the column (1) is that the yields of the farmers with access to wells (first two rows) are higher than those of the farmers without access (third and fourth rows). A more important finding for our research purpose is the differential impacts of the decline in

⁶ There are two kinds of potential bias. First, under our definition of this dummy variable, the no-access group would include non-owner farmers who actually have access to well irrigation but chose not to use it because they had enough water from tanks or rainfall. These farmers presumably achieve yield and income as high as the farmers who use wells. The incorrect inclusion of them in the no-access group would result in the underestimation of the negative impact of non-access. Second, if high income farmers selectively became well owners, the impact of non-access would be overestimated.

⁷ The identifying instrumental variables that explain the six potentially endogenous variables include not only those that explain non-access to wells — such as the number of water sellers in a village, the number of water buyers in a village, the cost of well digging and its squared term, and the value of house building — but also the interactions of those variables with the inactive management dummy and further with distance from the tank (Wooldridge, 2002).

collective management. Interestingly, among the with-access farmers, the decline increases the yield from 3979 kg to 4088 kg. Nevertheless, the difference is marginal. Contrary to this result, among the without-access farmers, the decline reduces the yield from 3642 kg to 3225 kg by 417 kg. As a result of these differential impacts on the yields, the figures reported on the columns (2) and (3) shows that while the with-access farmers' income/consumption is not affected by the decline, that of the without-access-farmers drops from Rs. 342 to Rs. 262 by Rs. 80 in terms of income or from Rs. 307 to Rs. 263 by Rs. 44 in terms of consumption value. The amount of reduction in income is almost a quarter of the income before the decline. This substantial reduction makes the average income of the without-access-farmers be very close to the poverty line (Rs. 259) and thus some of them in lower income percentile group may fall into poverty.

Counter-factual analysis

The reduction of income is predicted in the regression analyses. However, we are not clear yet whether this reduction is large enough to increase poverty. If it is large enough, the revitalization of collective management should reduce poverty. In order to examine this, we run simulation analyses. Using the regression results and

assuming that collective management is revitalized at currently inactive villages, we predict the yield, the income, and the consumption value. The simulation results reported in Table 3 indicate that the mean values increase for either variable and that the poverty ratio and gap are reduced. A sharp reduction of poverty gap in row (2) (from 33.7 to 17.8) indicates the revitalization effectively improves poorer peoples' livelihood. These results indicate that the negative impacts from the decline in collective management on the without-access farmers are so large that the revitalization of collective management can contribute significantly to reductions in poverty.

3. The diffusion of private wells and rice profit among well users

To test the second hypothesis, we estimate the reduced form regression of rice profit per hectare. Rice profit is an appropriate measure of the degree of overexploitation and resulting welfare losses. If groundwater becomes scarcer due to overexploitation, well users have to spend higher irrigation operation costs to acquire sufficient amount of irrigation water. Our field observations indicate that the operation of valuable assets like pumps is carried out mostly by family labor. Therefore, we expect that well users' rice profit after deducting family labor costs, in comparison with that of non users, will not be appreciably large under overexploitation.

The estimated rice profit by irrigation status is shown on the column (4) in Table 2 based on the regression analysis that uses the same reduced form approach as the rice yield function (Table A2 in Appendix). A key finding from this table is that, in comparison among “Active CM” villages (first and third rows), the profit of the farmers with “Well access” is not significantly different from that of the farmers with “No well access”. This indicates that the use of well irrigation does not guarantee higher profit anymore in active villages, although farmers had adopted it for higher profit initially. Even worse is the case of the farmers with “Well access” in “Inactive CM” villages. The results indicate that once the collective management becomes inactive, rice profit turn to be negative (Rs. -123) even among well users. This result possibly stems from the fact that the groundwater scarcity becomes more serious in inactive villages because the deteriorated tanks become unable to recharge the groundwater table through percolation.

4. Conclusion and policy implications

Facing recent rapid replacement of traditional irrigation systems by modern irrigation systems, this paper investigates the efficiency of modern systems’ water management and the impact of the decline in traditional systems. A key finding is that

the dissemination of private wells results in double tragedies in that the non-well users suffer increased poverty due to the decline in collective management of tank irrigation systems and even the well users suffer reduced rice profit due to the overexploitation of groundwater. If we look at the change of rice yield only, the dissemination of well irrigation systems seems to contribute a productivity improvement. However, our research finds that abovementioned negative effects exist behind it. We call these negative effects tragedies because no individual has incentive to correct them. The negative effect on the non-well users is the one created by the well users' exit from the collective management. Since the well users do not suffer from the decline in collective tank management, they have no incentive to correct it. Likewise, the effect among well users is the negative externality from one well user to other well users, and thus no incentive mechanism exists among each of them. Without policy interventions, the correction of these tragedies is difficult.

As shown in the simulation results, supports for the revitalization of collective management can effectively reduce poverty. One possible support for the revitalization is the construction of lined channels by blocks or cement. This technology significantly reduces the labor required for maintenance work and also increases the availability of water by minimizing seepage. Even after experiencing the

exit of well users from collective management, the maintenance work becomes feasible by the remaining smaller number of tank users.

Charging an appropriate fee for electricity would also contribute to prevent double tragedies. Under the present practice of free electricity for agricultural purposes, the number of electric pumps tends to be more than the social optimum, resulting not only in the overexploitation of groundwater but also in the decline in collective management. Not only the cost of power but also the social cost due to the negative externality of groundwater overexploitation must be charged, albeit it is not easy to estimate the social cost. In order to deter the dissemination of private wells, another possible policy may be to charge a sales tax on pump sets. Then, the government may use the revenues from electricity charge or from pump sales tax for tank revitalization projects. This transfer can be considered legitimate because the well users will receive indirect benefit from the revitalized tanks in that the water from the tank permeates to re-supply the groundwater table. The amount of indirect benefit would be estimated with collaboration with engineers, which we leave for our future research.

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Table 1: Comparison of rice yield, income, consumption value, and subjective poverty assessment of sample households between collective management inactive villages and active villages

	(A) Households in Inactive Villages	(B) Households in Active Villages	Difference (A)-(B) (t-ratio)
(1) Rice yield (kg./hectare)			
Mean	3499	3786	-287 (2.59)***
Std. Dev.	1275	1049	
(2) Per capita monthly income (Rs./person) ^a			
Mean	332	395	-63 (1.77)*
Std. Dev.	370	363	
Head count ratio of poverty (P ₀) ^b	58.5	48.3	10.2
Poverty gap (P ₁) ^b	33.7	21.6	12.1
(3) Per capita monthly consumption value (Rs./person) ^a			
Mean	308	336	-28 (1.46)
Std. Dev.	194	202	
Head count ratio of poverty (P ₀) ^b	52.0	45.5	6.5
Poverty gap (P ₁) ^b	19.8	14.2	5.6
(4) Subjective poverty assessment			
Percentage of villages assessing that the current condition of poverty is serious (%)	61	29	

* significant at 10% level; *** significant at 1% level

Notes:

^a The value is converted into per capita base using the adult equivalent number of present household members. See footnote 3 for details of the conversion method.

^b International poverty line of \$US 1 per day adjusted for purchasing power parity is used.

Table 2: Estimated yield, income, consumption value, and rice profit by irrigation status

	Estimated values based on regression results			
	(1) Yield ^a (kg./ha.)	(2) Income per capita ^b (Rs./month/per son)	(3) Consumption value per capita ^b (Rs./month/per son)	(4) Rice profit per ha. ^a (Rs./ha.)
Irrigation status				
Well access Active CM ^c	3979	531	382	1032
Well access Inactive CM ^c	4088	531	382	-123
No well access Active CM ^c	3642	342	307	1032
No well access Inactive CM ^c	3225	262	263	-376

Notes:

The coefficients significant at 10% or lower are considered to have impact on the dependent variable.

^a Estimated value based on the OLS regression results in Table A2

^b Estimated value based on the IV regression results in Table A3

^c CM stands for collective management

Table 3: Simulation results of the impact of revitalization of collective management on rice yield, income, and consumption value.

	Households in Inactive Villages	Predicted Value if Active
(1) Yield (kg./hectare)		
Mean	3499	3673
Std. Dev.	1275	1174
(2) Per capita monthly income (Rs./person) ^a		
Mean	332	400
Std. Dev.	370	360
Head count ratio of poverty (P_0) ^b	58.5	48.0
Poverty gap (P_1) ^b	33.7	17.8
(3) Per capita monthly consumption value (Rs./person) ^a		
Mean	308	325
Std. Dev.	194	177
Head count ratio of poverty (P_0) ^b	52.0	47.4
Poverty gap (P_1) ^b	19.8	13.9

Notes:

^a The value is converted into per capita base using the adult equivalent number of present household members. See footnote 3 for details of the conversion method.

^b International poverty line of \$US 1 per day adjusted for purchasing power parity is used.

Appendix:

Table A1: Descriptive statistics for regression analyses of the determinants of yield, income, and consumption value

	Mean	Standard Deviation
<u>Dependent variables</u>		
Yield (kg./hectare)	3676.8	1147.7
Per capita monthly income (Rs.)	371.0	366.8
Per capita monthly consumption (Rs.)	325.4	199.1
Rice profit per hectare (Rs.)	1226.6	2965.4
<u>Explanatory variables</u>		
Variable related with collective management		
Inactive collective management (inactive=1)	0.38	
No-access-to-well (no access=1)	0.72	
Distance from tank (km.)	0.418	.464
Household characteristics		
Primary educ rate ^a	0.325	0.264
Secondary educ rate ^a	0.410	0.285
College educ rate ^a	0.024	0.086
Average age ^b	37.56	6.46
Average age squared ^b	1452.5	514.5
No. of working member	4.13	1.99
Rice plot size (ha.)	0.927	0.710
Rice plot size (ha.)	1.362	2.767
Tank-irrigable plot per working member (ha.) ^b	0.295	0.270
Tank-irrigable plot per working member sq. ^b	0.160	0.358
Tank-un-irrigable plot per working member (ha.) ^b	0.232	0.454
Tank-un-irrigable plot per working member sq. ^b	0.260	1.588
Value of animal holdings per working member (000 Rs.) ^b	3.995	5.184
Value of animal holdings per working member sq. ^b	42.77	132.81
Owner of tractor (yes=1)	0.0267	
Male HH head (male=1)	0.971	
Village characteristics		
Male wage (Rs./day)	56.03	9.57
Annual rainfall (mm)	1009.7	351.8
Average rainfall for 10 years (mm)	832.2	129.0
Accessibility by vehicle (yes=1)	1.942	0.910
Percentage of HH with electricity at home (%)	68.13	22.49

^a The rate to the number of working members.

^b Divided by the number of working members.

Table A2: Results of regression analyses of the determinants of rice yield, agricultural labor income, and non-agricultural income

Dep. Var.	Rice yield	Rice profit per acre
	OLS	OLS
Variables related with irrigation status		
No-access&Active	-337.0 (1.70)*	-326.3 (0.81)
No-access&Inactive	-754.4 (2.11)**	-2,607.2 (5.33)***
Access&Inactive	773.2 (2.37)**	-1,155.7 (1.82)*
Distance from tank (km.)	120.3 (0.67)	-2,026.2 (3.97)***
No-access&Active*Distance	-296.5 (1.14)	986.1 (1.52)
No-access&Inactive*Distance	-155.2 (0.41)	2,219.9 (3.23)***
Access&Inactive*Distance	-1219.4 (3.51)***	614.9 (0.55)
Household characteristics		
Primary educ rate ^a	376.1 (1.36)	979.7 (1.67)*
Secondary educ rate ^a	668.0 (2.59)**	1,522.7 (2.81)***
College educ rate ^a	1,033.6 (1.78)*	1,668.6 (1.19)
Av. age ^b	11.1 (0.19)	66.8 (0.45)
Av. age sq. ^b	-0.3 (0.37)	-1.1 (0.58)
Rice plot size (ha.)	-502.9 (2.36)**	2,989.1 (7.61)***
Rice plot size sq. (ha.)	81.5 (1.58)	-509.0 (5.02)***
Av. Value of animal holdings ^b (1000 Rs.)	60.9 (3.16)***	69.5 (1.54)
Av. Value of animal holdings sq. ^b	-1.3 (2.32)**	-0.6 (0.33)
No. of working member	43.6 (1.50)	-30.0 (0.47)
Owner of tractor (owner=1)	37.3 (0.08)	418.7 (0.54)
Male HH head (male=1)	366.6 (1.26)	953.2 (1.40)
Village characteristics		
Male daily wage rate (Rs./day)	10.6 (0.89)	-35.9 (2.84)***
Annual rain fall (mm)	-0.1 (0.86)	-0.5 (1.48)
Accessibility by vehicle (yes=1)	-12.8 (0.11)	164.7 (1.20)
Percentage of HH with electricity (%)	-7.1 (1.62)	-10.2 (1.83)*
Const	3274.1 (2.49)**	381.5 (0.12)
<i>F</i> -stat for endogeneity test	0.88 [0.51]	0.96[0.45]
R ²	0.20	0.38

Clustering robust *t*-statistics in parentheses

* significant at 10% level; **significant at 5% level; *** significant at 1% level

Notes:

Since endogeneity is not detected in the functions above, only the OLS results are shown. See *F*-stat for endogeneity test at the bottom of the table.

^a The rate to the number of working members.

^b Divided by the number of working members.

Table A3: Results of regression analyses of the determinants of household consumption value and income

Dep. Var.	Adult equivalent per cap. monthly consumption value		Adult equivalent per cap. monthly income	
	OLS	IV	OLS	IV
Variables related with irrigation status				
No-access&Active ^c	-84.1 (2.87)***	-75.1 (2.54)**	-210.9 (3.65)***	-189.9 (3.40)***
No-access&Inactive ^c	-124.6 (3.05)***	-119.1 (3.06)***	-286.8 (3.79)***	-269.5 (3.60)***
Access&Inactive ^c	83.9 (1.37)	101.7 (1.57)	-5.8 (0.06)	17.3 (0.16)
Distance from tank (km.)	-46.1 (1.32)	-50.7 (1.30)	-125.4 (2.00)**	-119.1 (1.70)*
No-access&Active*Distance ^c	15.2 (0.37)	26.4 (0.49)	37.3 (0.52)	33.7 (0.36)
No-access&Inactive*Distance ^c	23.5 (0.52)	26.5 (0.55)	41.2 (0.53)	29.9 (0.35)
Access&Inactive*Distance ^c	-95.6 (1.49)	-96.5 (1.40)	-55.7 (0.55)	-70.0 (0.63)
Household characteristics				
Primary educ rate ^a	105.0 (2.44)**	107.7 (2.50)**	-34.7 (0.50)	-30.5 (0.44)
Secondary educ rate ^a	61.4 (1.65)	60.6 (1.59)	-23.9 (0.39)	-23.0 (0.37)
College educ rate ^a	476.6 (3.57)***	475.9 (3.55)***	684.3 (2.32)**	685.3 (2.32)**
Av. age ^b	-0.9 (0.10)	-1.4 (0.14)	9.8 (0.72)	9.3 (0.69)
Av. age sq. ^b	-0.0 (0.15)	-0.0 (0.10)	-0.2 (1.24)	-0.2 (1.22)
Av. Tank-irrigable plot ^b (ha.)	287.9 (3.65)***	293.2 (3.76)***	442.8 (2.96)***	453.7 (3.05)***
Av. Tank-irrigable plot sq. ^b	-76.7 (1.39)	-76.9 (1.41)	0.2 (0.00)	-2.0 (0.02)
Av. Tank-un-irrigable plot ^b (ha.)	74.3 (1.64)	71.9 (1.61)	440.7 (5.35)***	440.5 (5.32)***
Av. Tank-un-irrigable plot sq. ^b	-16.6 (1.67)*	-16.6 (1.68)*	-94.3 (4.19)***	-94.8 (4.22)***
Av. Value of animal holdings ^b (1000 Rs.)	-0.9 (0.23)	-0.9 (0.25)	6.3 (1.10)	6.3 (1.09)
Av. Value of animal holdings sq. ^b	0.1 (0.66)	0.1 (0.65)	-0.2 (0.71)	-0.2 (0.72)
No. of working member	1.9 (0.39)	2.2 (0.43)	20.6 (2.26)**	21.2 (2.33)**
Owner of tractor (owner=1)	-0.5 (0.01)	-2.9 (0.05)	155.8 (2.24)**	151.4 (2.10)**
Male HH head (male=1)	-14.1 (0.24)	-14.1 (0.25)	74.9 (0.76)	75.9 (0.78)
Village characteristics				
Male daily wage rate (Rs./day)	1.7 (0.83)	1.7 (0.83)	-0.7 (0.30)	-0.7 (0.30)
Average rain fall for 10 years (mm)	0.0 (0.11)	0.0 (0.06)		
Annual rain fall (mm)			-0.0 (0.65)	-0.0 (0.64)
Accessibility by vehicle (yes=1)	-12.4 (0.81)	-13.6 (0.87)	-11.7 (0.53)	-12.7 (0.57)
Percentage of HH with electricity (%)	-0.1 (0.13)	-0.1 (0.19)	0.6 (0.77)	0.6 (0.76)
Const	238.4 (0.75)	246.1 (0.77)	180.1 (0.51)	170.7 (0.50)
F-stat for endogeneity test	2.41 [0.03]		2.10 [0.05]	
Joint significant test on instruments (First stage F test)			[0.00] for all six end. vars.	
χ^2 stat for over identification test			20.1 [0.07]	
R ²	0.29		0.45	
			18.0 [0.11]	

Clustering robust *t*-statistics in parentheses. * significant at 10% level; **significant at 5% level; *** significant at 1% level
Notes: Since F-stat for endogeneity test show a possibility of endogeneity in the two functions above, both the OLS and the IV results are shown. For these two functions, the *F*-tests on the instruments in the first stage regression are highly significant for all six endogenous variables, indicating high predictive power. The over-identification tests show the difficulty of rejection of exogeneity of the instruments at the 5 per cent significance level, adding confidence to the validity of our IV specifications.

^a The rate to the number of working members.

^b Divided by the number of working members.

^c Instrumented variable.