Wells, Water, and Welfare: The Impact of Access to Groundwater on Rural Poverty and Conflict

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Online Appendix

1 Appendix I : Robustness Tests and Ancillary Findings

1.1 Adding Control variables to the Parametric Specification

Table 5 shows the results from parametric specifications using the full sample and demonstrates that the results are robust to a variety of functional forms. Appendix Table 1 presents results from additional robustness tests. In column (i), I add a range of covariates with a quadratic control function of depth to groundwater. These include geographical controls including rainfall and temperature; demographic characteristics of the village including number of households, fraction of literate population, fraction of scheduled caste population, fraction of females in the population and fraction of literate females in the population; geological features like elevation and slope; and infrastructure variables of the villages including electrification status, availability of schools, medical facilities, banking service, distance to nearest town and total expenditure of village panchayat (council) on public goods. The coefficient on the indicator is 0.065 and is statistically significant at 1 percent.[1]

1.2 Adding Block Fixed Effects to the Parametric Specification

The poverty data are from a survey conducted by the state that identifies the below poverty households based on a criterion. The below poverty line status might be misallocated. However, there is no reason to believe that the status will be differentially accorded above and below the threshold of 8 meters. One concern might be that due to corruption or administrative reasons, the states use some discretion over how to apply rules across administrative blocks, and hence the measurement error is systematic across such areas. In order to address this, I include block fixed effects in the regressions so that villages within same blocks that are above and below the threshold are compared.

[1] The demographic and infrastructure data are from the year 2001. These variables could be affected by groundwater depth, in which case these would be indicative of the mediating pathways.

The results are reported in column (ii) of Appendix Table 1. Reassuringly, the results are very similar to the first column.[2]

1.3 Falsification Test for the True Discontinuity

If 8 mbgl is indeed the cutoff at which the feasibility of the surface pumps changes, and if there is a relationship between poverty and access to groundwater, then we should see an effect at 8 mbgl. We should not observe an effect at other cutoff values lower than 8. I perform this falsification test by synthetically changing the cutoff to hypothetical values of 4,5, 6, 7, 9, 10, and 11 mbgl. The identical regression specification for each regression includes demographic, geographical,and infrastructure covariates and a quadratic control function of depth to groundwater. However, the indicator variable indicates depth exceeding a different cutoff in each case. The resulting coefficient from each of the separate regressions is reported in Appendix Table 2 and plotted in Appendix Figure 2 along with the 95 percent confidence interval. The coefficient on the indicator for depth exceeding the cutoff becomes positive and statistically significant for the true value of 8 mbgl and is near 0 and insignificant for all cutoff values below this.

1.4 Spatial Correlation

In order to allay concerns over inter-connectedness of aquifers, I follow Conley (1999) and estimate the covariance matrix allowing for spatial correlation. Appendix Table 3 reports the results using a range of cutoff at which the the correlation is allowed to fall to 0. Typical village in the sample has a neighbor within 2.14 KMs. I use three cutoffs 1.5, 3 and 4.5 kilometers. The errors allowing for spatial correlation are reported along with the coefficient in columns (ii) through (iv). Column (i) restates the coefficient and standard error from column (i) of Table 5 for sake of comparison. The results are unchanged. As in Table 5, the estimates indicate an increase in poverty that is statistically significant at conventional significance levels.

[2]The smallest block in the sample has 27 villages and the largest has 416 villages.

1.5 Effect on Irrigated Area

I examine the change in irrigated area around the discontinuity. I replicate the non-parametric specifications in which bandwidth is sequentially changed as used in Table 6 and I present the results in Appendix Table 4. I observe a very large statistically significant reduction in groundwater irrigated area as a share of total sown area. Groundwater irrigated area as a share of total sown area reduced by around 25 percent (Panel A) , whereas there is no change in the surface water irrigated area (Panel B). To the extent that returns to irrigation are positive, this would reduce farm profitability. [3]

1.6 Use of Other Inputs in the SLC data

I show that use of complimentary inputs in agricultural production such as fertilizers falls in villages to the right of the discontinuity. The parametric specifications similar to those used in Table 10 are reported in Appendix Table 5. Quantity of fertilizer applied by farmers per acre falls by 14.31 kgs. This is highly statistically significant at 1 percent and is around 0.13 of a standard deviation. Individual farmers also report a reduction in their percentage of irrigated land. Percentage of land irrigated falls by 6.65 percent. This is highly significant at 1 percent and is 0.7 of a standard deviation which is a large effect. This is consistent with the large effects detected in the village level analysis of poverty and groundwater irrigation using the main sample. One concern might be that the farmers are different in their abilities to farm on either side of the cutoff. For example, agriculturally enterprizing farmers may have migrated to areas with water abundance. In order to allay this concern to some degree, I examine the amount of land cultivated on either side of the cutoff. If farmers are more able or agriculturally enterprizing, then we should observe more area being cultivated in water

[3]Using data from India, Duflo and Pande (2007) show that agricultural output for most crops increases with dam irrigation. Jin et al (2012) use the nationally representative REDS data and use farmer fixed effects to document that irrigated plots result in higher yields, high land use intensity, higher input use and higher land prices. Irrigation increases plot level production of rice and wheat between 9-15 percent. Bhattarai and Narayanamoorthy (2003) and several studies mentioned therein document productivity enhancing effects of irrigation.

abundant areas. The first panel in Appendix Table 5 shows that there is no difference in area cultivated around the cutoff. The small coefficient is statistically insignificant and is 0.02 of a standard deviation. Hence, this seems unlikely although I cannot fully rule this out.

1.7 Link to Prior Literature

Note that in Sekhri (2011), I used the discontinuous change in feasibility of surface pumps to examine the effects of public wells on groundwater depth. This study used a triple differences framework for identification. I compared villages that received a public well to ones that did not (treatment to control) in both type of areas- those where water is accessible by surface pumps and those where it is not. The theoretical framework implied that the discontinuity will make farmers worse off to the right of the discontinuity where surface pumps become infeasible, but the farmers in the treated villages with access to public wells will be better off than the ones in the control areas without access to public wells. The empirical tests confirmed this finding. Intermediate farmers in treated areas to the right saved the fixed cost of sinking private wells and switched to using public wells. This behavior revealed higher profitability. Thus, the findings of Sekhri (2011) are consistent with my current findings that access to groundwater impacts poverty. I use the SLC data and show evidence supporting this argument in Appendix Table 6. I show that annual wage earnings and yield-per-acre in value terms is lower in villages where depth to groundwater exceeds 8 meters. But the interaction of the depth indicator with government wells is positive and statistically significant for both variables. The sum of the two coefficients is positive and large. Hence, public wells offset the impact of higher groundwater depth on yields-per-acre and annual wage earnings.

The IDTP program studied in Sekhri (2011) required electricity for operation of the public wells. Therefore, I controlled for electrification. This paper relies on the identifying assumption that otherwise similar villages that differ on dimension of whether surface pumps can operate or not have different poverty rates. Differential rate of electrification would be a concern but as I show in Appendix Figure 4, electrification is smooth around the cutoff. The results do not change with or without controlling electrification status of the village in either parametric or non-parametric analysis. [4]

1.8 Do Rich Areas Extract Less Water?

I use the 1983 poverty status of districts in India and compare the average difference in the depth to groundwater between 2010 and 1983 across poorest 25 percent and richest 25 percent districts. I do this using three measures of poverty- poverty rate, poverty gap, and log of mean per capita expenditure. Irrespective of the measure of poverty used, the depth has fallen much more in richer districts than poorer ones. Appendix Table 8 shows the averages. Fall in depth in richer districts is around 4-5 m, while it is around 1-1.5 m in the poorest ones. This suggestive evidence indicates that richer places are not extracting less.

1.9 Seasonal out-migration in SLC data

I examine seasonal out migration using SLC data. I replicate the parametric specifications of Table 10 and report results in Appendix Table 9. Percentage of households with atleast one seasonal out-migrant falls by 5 percent. The coefficient is significant at 5 percent significance level but is only 0.1 of a standard deviation. Hence, this is economically a small effect. Ability to out-migrate can be an outcome if households are liquidity constraint in areas with higher poverty. On the hand, it is possible that higher seasonal out-migration from water abundant areas leads to a reduction in poverty in these areas.[5] Examining the effects of water scarcity on migration -both temporary and permanent- is beyond the scope of this study and is an important avenue of future research.

[4] Sekhri (2013) controls for district specific trends to account for changes in electrification over years.

[5] Since yields are higher, if less labor is required for production in such areas, people can have higher propensity to out-migrate.

1.10 Smoothness of other Variables Around the Discontinuity in the RD framework

A significant concern about the validity of the the design is the manipulation of the underlying depth to groundwater. No welfare programs are implemented taking into account this cutoff.[6] Therefore, farmers do not have an incentive to manipulate the depth. In addition, in this context, there is very little scope for manipulation of the distribution as depth to groundwater is objectively measured for the villages at the time of the Minor Irrigation Census survey. Appendix Figure A3 shows the distribution of groundwater depth which appears smooth around the cutoff. There is no systematic pattern that indicates a sharp jump at the cutoff.

One other concern might be whether or not covariates such as the demographic, geographical, and infrastructure characteristics of the villages are smooth around the cutoff, as a jump in these can lead to spurious attribution. [7] Appendix Figure A4 plots regression functions from regressions of these variables on the average value of the normalized groundwater depth bins around the cutoff of 8 meters. Results are not sensitive to including or excluding these from the regressions. using survey sample in Tables 7 and 8, I show that including the demographic, geographical, and infrastructure characteristics of the villages does not significantly change the coefficient or the standard error across the last two columns. The parametric specification in Appendix Table 1 is also robust to including these control variables. These results are unchanged if I exclude individual geographical characteristics or allow elevation to be discontinuous around the cutoff.[8]

[6] Million Wells Scheme or Free Boring Scheme that subsidized well construction in early 1990's targeted poor populations irrespective of the geography or geology of the village they came from.

[7] Elevation can be correlated with groundwater depth and can also affect productivity of various crops through its affect on other geographical features like rainfall, temperature, moisture, and humidity. Rainfall can also independently affect productivity and groundwater depth.

[8] These additional results are available on request.

Appendix Figures

Sensitivity Analysis

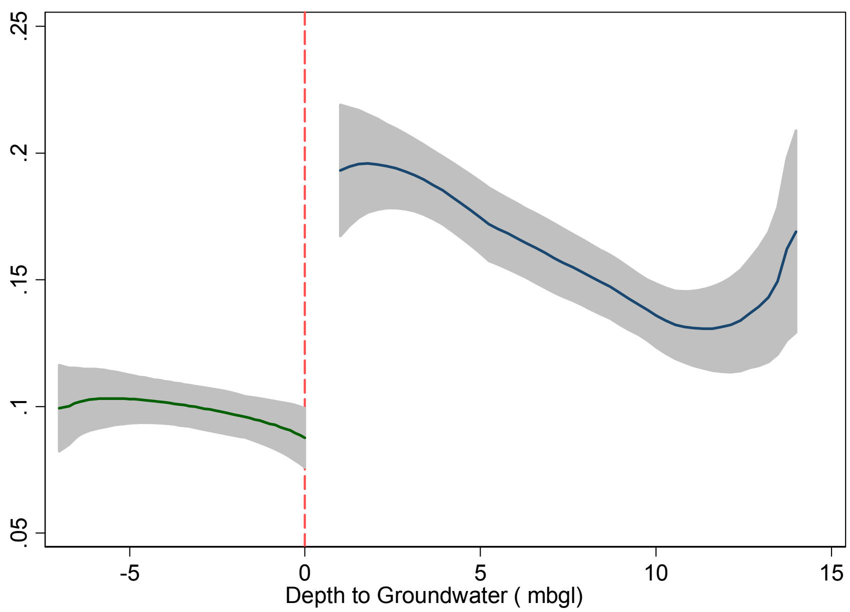


Figure A1 (PanelA): This figure graphs the regression functions from local polynomial regression of headcount on deviation of depth to groundwater from the cutoff that determines feasibility of surface pumps on either side of the cutoff. The 5 percent confidence bands are included.

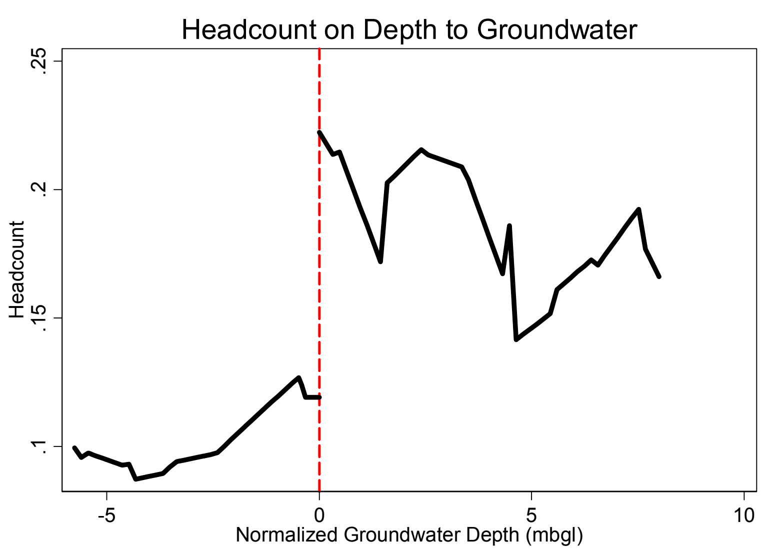
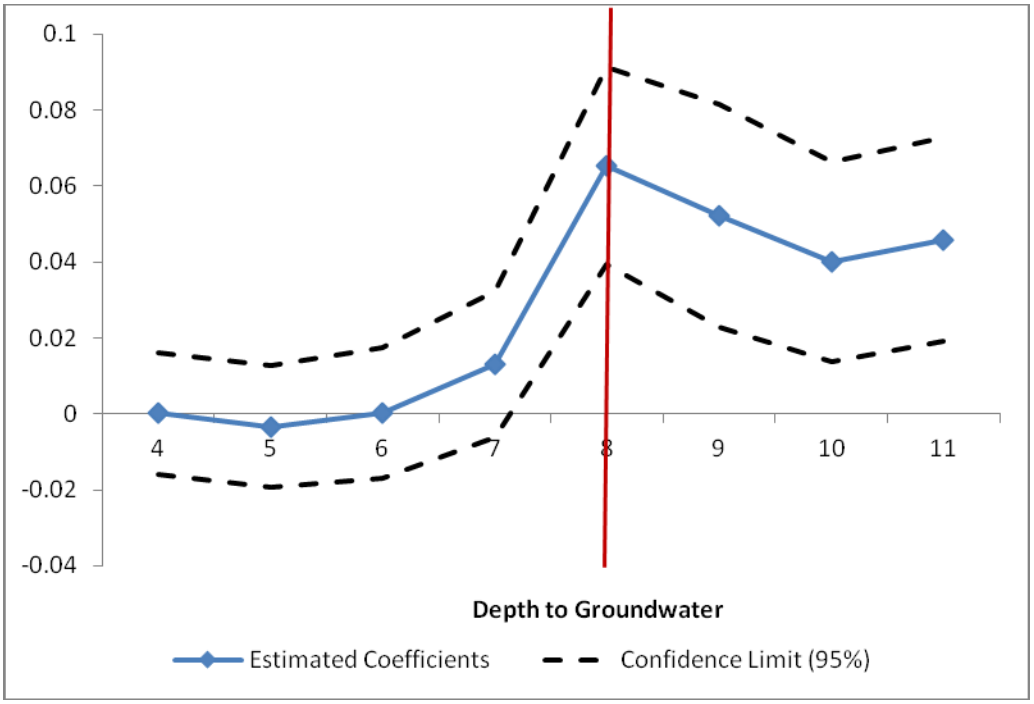


Figure A1(Panel B): This figure graphs the regression functions from the local polynomial regression of headcount on deviation of depth to groundwater from the cutoff that determines the feasibility of surface pumps on either side of the cutoff for the *survey sample*.



Appendix Figure A2: This figure plots the estimated coefficients from separate regressions in which different cutoffs for the feasibility of surface pumps have been used over the entire sample. The dashed lines indicate the 95 percent confidence interval. The estimated effect becomes positive and statistically significant at the true cutoff.

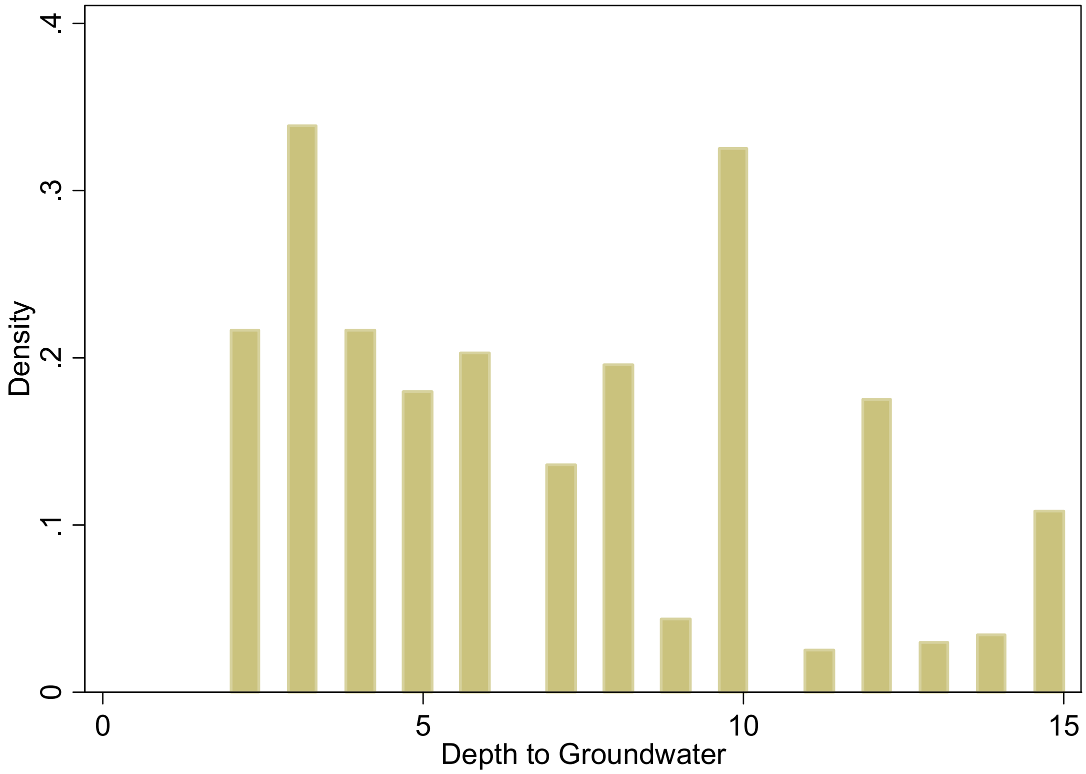
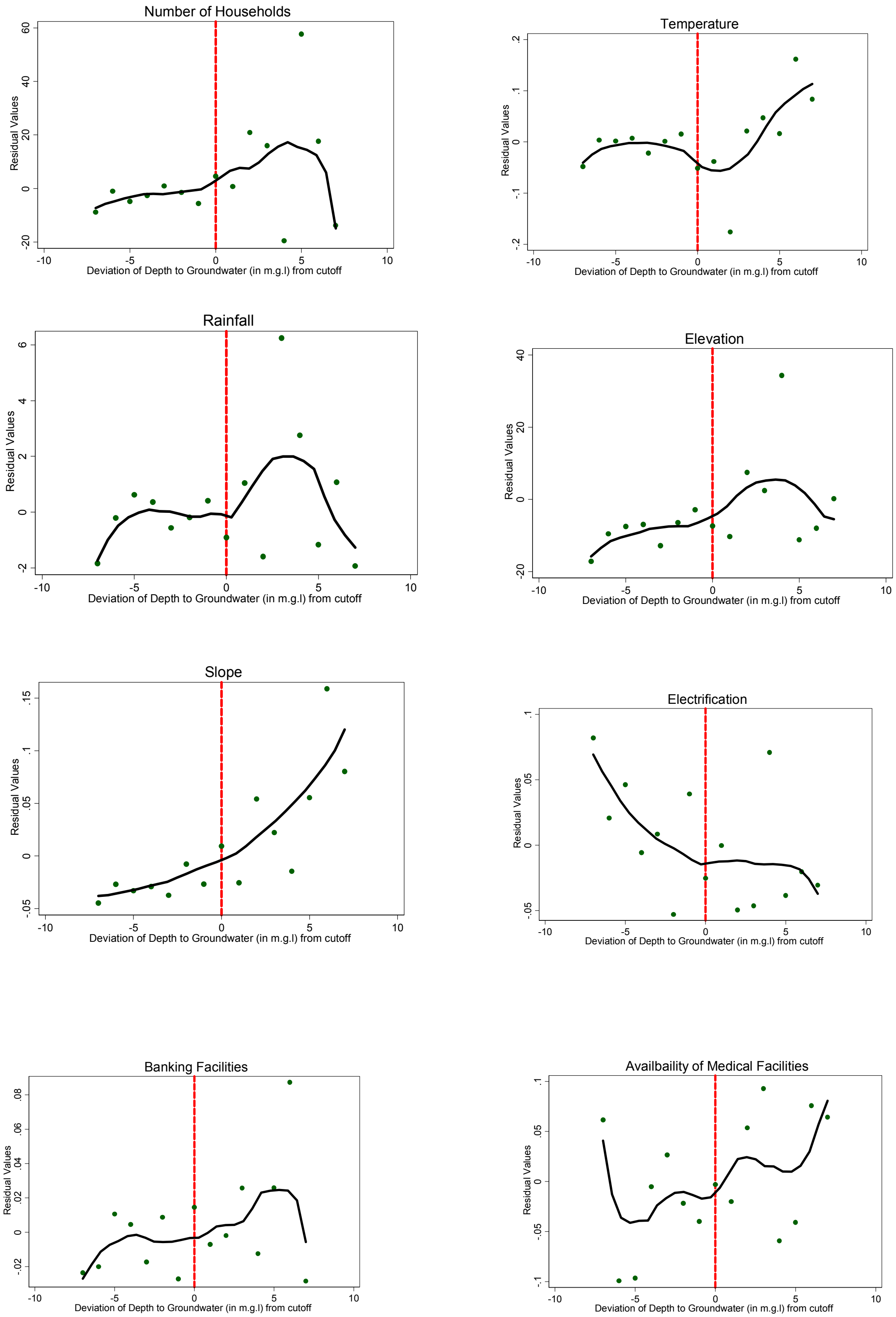
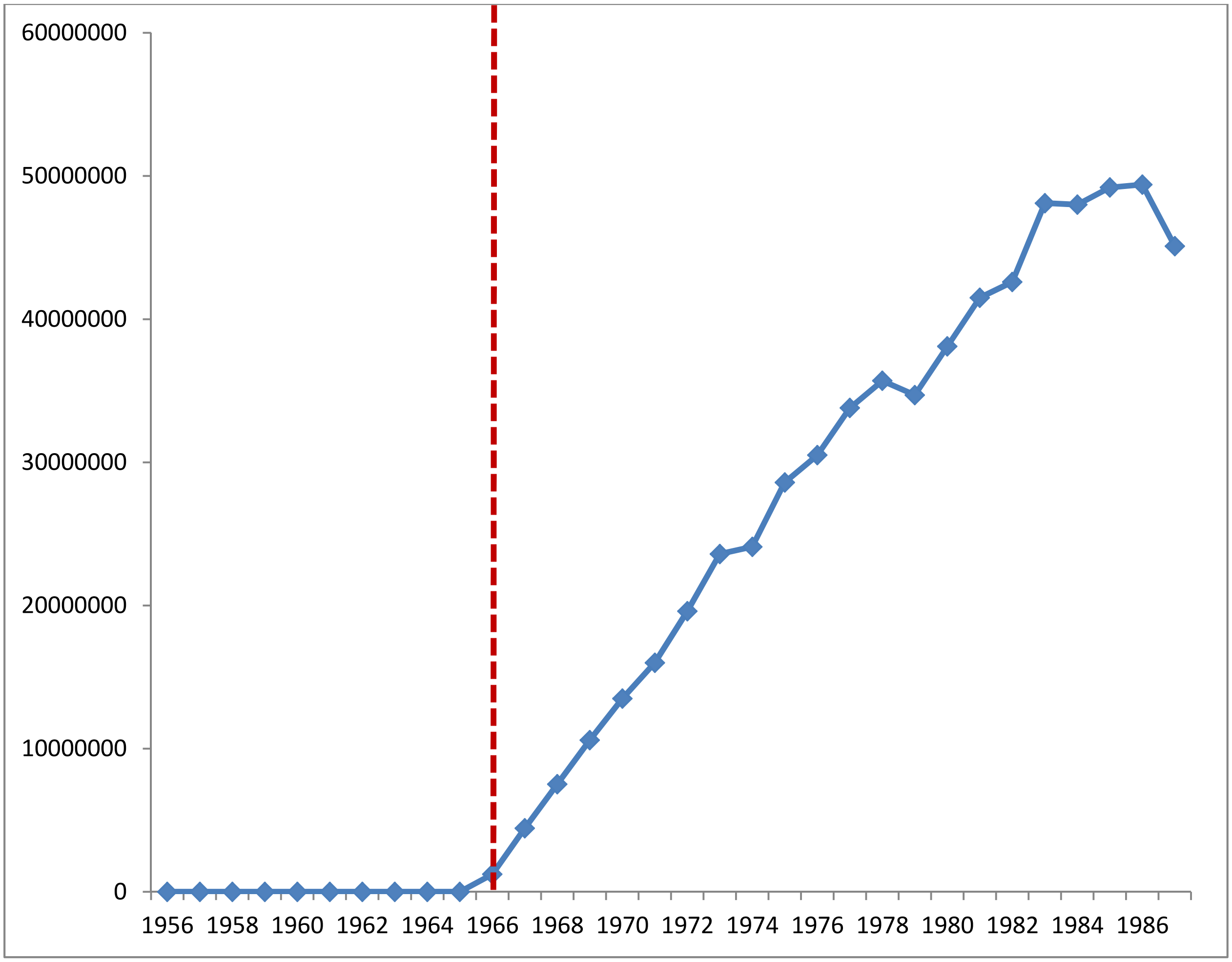


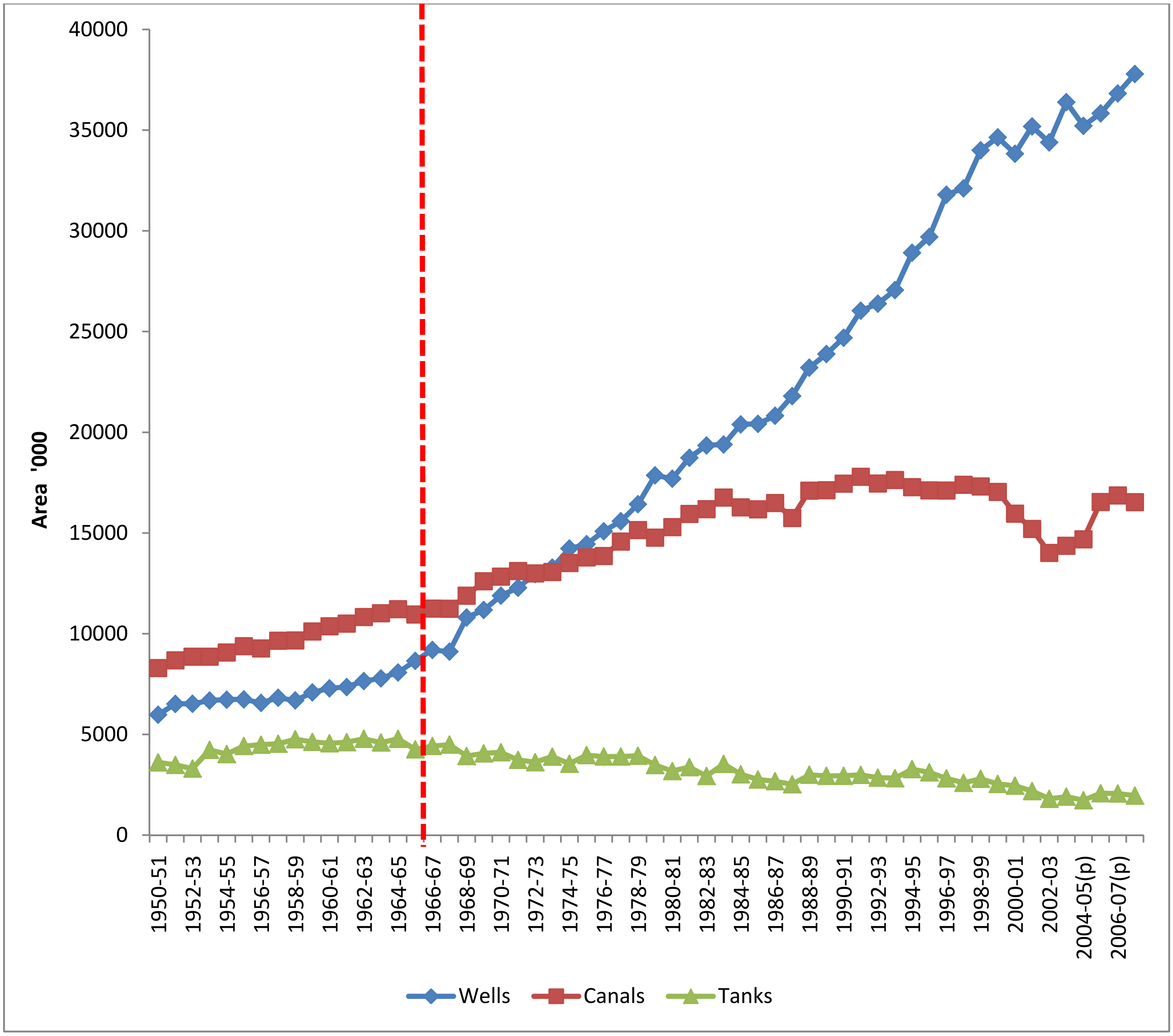
Figure A3: This figure shows the distribution of the Depth to Groundwater.

Appendix Figure A4: Continuity of Variables at the cut-off

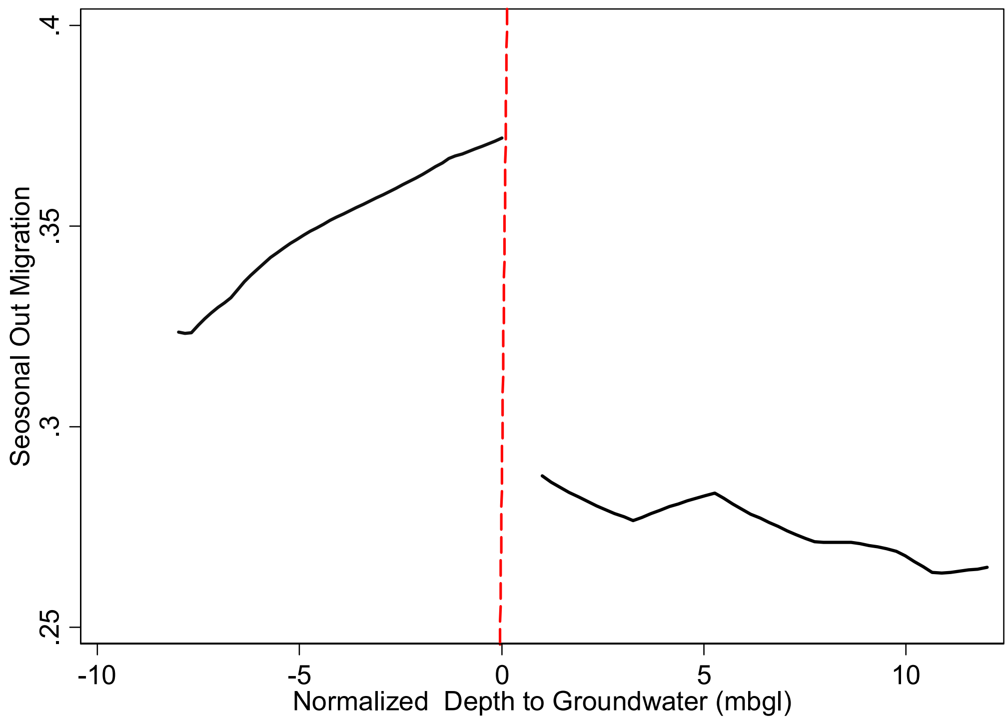




Appendix Figure A5: Overall Area under High Yielding Varieties



Appendix Figure A6: Area Irrigated by Different Sources of Irrigation Before and After the Arrival of High Yielding Varieties



Appendix Figure 7: This figure graphs the regression functions from local polynomial regression of seasonal out-migration on deviation of depth to groundwater from the cutoff that determines feasibility of surface pumps on either side of the cutoff.

Robustness Checks

Appendix Table 1: Impact of Access to Groundwater on Poverty

	Dependent Variable: Headcount	
	(i)	(ii)
Indicator for Depth to Water > 8	**0.065*** (0.013)**	**0.07** (0.014)**
Water Level Linear	Yes	Yes
Water Level Squared	Yes	Yes
Rainfall and Temperature	Yes	Yes
Demographic Controls	Yes	Yes
Slope and Elevation	Yes	Yes
Village Infrastructure	Yes	Yes
Block Fixed effects	No	Yes
Observations	1171	1171

*** denotes significance at 1 percent level, ** at 5 percent, and * at 10 percent.

Notes: Robust standard errors are reported in parentheses. Demographic controls include number of households, fraction of literate population, fraction of scheduled caste population, fraction of females in the population, and fraction of literate females. Village Infrastructure includes availablity of banking facilities, medical facilities, schools, electrification, distance to nearest town, and total expenditure of the village panchayat council.

Appendix Table 2: Falsification Test -Varying the Cutoff

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
cutoffs	4	5	6	7	8	9	10
Indicator for Depth to Groundwater Above the Cutoff	0.00014	-0.00331	0.000388	0.013033	**0.065*** **	**0.052*** **	**0.04*** **
	(0.008)	(0.008)	(0.008)	(0.009)	(0.013)	(0.015)	(0.013)
Observations	1171	1171	1171	1171	1171	1171	1171
R-Sqaured	0.14	0.14	0.14	0.15	0.16	0.15	0.15

*** denotes significance at 1 percent level, ** at 5 percent, and * at 10 percent.

Notes: Each column reports the estimated coefficient from a regression in which the cutoff has been changed to the value reported in the row above. The true cutoff for the feasibility of surface pumps is 8 meters. Robust standard errors are reported in parentheses. Each also controls for demographic, geographical and infrastructure covariates. Demographic controls include number of households, fraction of literate population, fraction of scheduled caste population, fraction of females in the population, and fraction of literate females. Village infrastructure includes availablity of banking facilities, medical facilities, schools, electrification, distance to nearest town, and total expenditure of the village panchayat council. Geographical controls include annual rainfall , temperature, slope, and elevation. Control function includes linear and squared groundwater levels.

Appendix Table 3: Impact of Access to Groundwater on Poverty Allowing Spatial Correlation in Errors

	Dependent Variable: Headcount			
	No Spatial Correlation	Threshold 1.5 KM	Threshold 3 KM	Threshold 4.5 KM
	(i)	(ii)	(iii)	(iv)
Indicator for Depth to Water > 8	**0.065***** **(0.013)**	**0.065***** **(0.013)**	**0.064***** **(0.013)**	**0.064***** **(0.014)**
Water Level Linear	Yes	Yes	Yes	Yes
Water Level Squared	Yes	Yes	Yes	Yes
Rainfall and Temperature	Yes	Yes	Yes	Yes
Demographic Controls	Yes	Yes	Yes	Yes
Slope and Elevation	Yes	Yes	Yes	Yes
Village Infrastructure	Yes	Yes	Yes	Yes

*** denotes significance at 1 percent level, ** at 5 percent and * at 10 percent.
Notes: Conley Standard errors are reported in parentheses. Demographic controls include number of households. fraction of literate population, fraction of scheduled, caste population, fraction of females in the population, and fraction of literate females. Village Infrastructure includes availablity of banking facilities, medical facilities, schools, electrification, distance to nearest town, and total expenditure of the village panchayat council.

Appendix Table 4: Non-Parametric RDD Estimates of the Impact of Access to Groundwater on Irrigated Area

	Dependent Variable: Groundwater Irrigated to Sown Area		
	Bandwidth 5	**Bandwidth 2**	**Optimal bandwidth**
	(i)	(ii)	(iii)
Indicator for Depth to Groundwater > 8	**-0.48*** (0.05)	**-0.23** (0.14)	**-0.25**

	Dependent Variable: Surface Irrigated to Sown Area		
	Bandwidth 5	**Bandwidth 2**	**Optimal bandwidth**
	(i)	(ii)	(iii)
Indicator for Depth to Groundwater > 8	0.01 (0.007)	0.01 (0.01)	0.01 (0.01)
Covariates	No	No	No

*** denotes significance at 1 percent level, ** at 5 percent, and * at 10 percent.

Notes: Each column reports the estimated coefficient from a regression of percentage of submersible pumps on indicator for depth to groundwater greater than 8 mbgl. The non-parametric specifications with different bandwidths are reported in Columns (i) through (iii). Optimal Bandwidth proposed by Imbens and Kalyanaraman (2009) is used in Column (iii).

Appendix Table 5: OLS Estimates of Impact of Access to Groundwater on Agricultural Outcomes

Panel A

Dependent Variable: Land Cultivated

	(i)	(ii)	(iii)
Indicator for Depth to Groundwater >8	0.18	-0.15	-0.19
	(0.52)	(0.5)	(0.55)

Panel B

Dependent Variable: Fertilizer applied per acre

	(i)	(ii)	(iii)
Indicator for Depth to Groundwater >8	-19.84***	-14.77***	-14.31***
	(6.03)	(5.03)	(5.27)

Panel C

Dependent Variable: Percentage Irrigated Land

	(i)	(ii)	(iii)
Indicator for Depth to Groundwater >8	-9.02***	-6.8***	-6.65***
	(1.5)	(1.38)	(1.38)
Infrastructure and Demographic controls	Yes	Yes	Yes
Elevation and Rain Shocks	No	Yes	Yes
Caste Homogeneity in the village	No	No	Yes

*** denotes significance at 1 percent level, ** at 5 percent, * at 10 percent

Notes: Indicator for Depth to Water >8 is an indicator variable which takes the value 1 if groundwater level in year 1993 is at a depth greater than 8 meters below ground level. Infrastrucre and demographic controls include village electrification, availability of banks, school, and medical facilities, and the share of scheduled caste population in the village. Robust standard errors are reported in parentheses.

The household survey data is from the World Bank Survey of Living Standards in Uttar Pradesh and Bihar, 1997.

Appendix Table 6: OLS Estimates of Impact of Public Wells on Yields and Wage Earnings by Access status

Panel A

Dependent Variable: Annual Individual Wage Earnings (rupees)

	(i)	(ii)	(iii)
Indicator for Depth to Groundwater >8	-7152.47***	-7047.19***	-7138.94***
	(1225.97)	(1268.13)	(1278.3)
Indicator for Depth to Groundwater >8 X Public Wells	6751.75**	7816.45**	7884.32**
	(2998.97)	(3078.26)	(3081.51)

Panel B

Dependent Variable: Yield per acre in value terms (rupees/ acre)

	(i)	(ii)	(iii)
Indicator for Depth to Groundwater >8	-1084.4***	-969.16***	-944.66***
	(208)	(207.97)	(205.87)
Indicator for Depth to Groundwater >8 X Public Wells	2257.98***	2566.3***	2588.76***
	(455.8)	(472.43)	(461.01)
Infrastructure and Demographic controls	Yes	Yes	Yes
Elevation and Rain Shocks	No	Yes	Yes
Caste Homogeneity in the village	No	No	Yes

*** denotes significance at 1 percent level, ** at 5 percent, * at 10 percent

Notes: Indicator for Depth to Water >8 is an indicator variable which takes the value 1 if groundwater level in year 1993 is at a depth greater than 8 meters below ground level. Infrastrucre and demographic controls include village electrification, availability of banks, school, and medical facilities, and the share of scheduled caste population in the village. Public Wells is an indicator that takes value 1 if the village has a public well. Robust standard errors are reported in parentheses. The household survey data is from the World Bank Survey of Living Standards in Uttar Pradesh and Bihar, 1997.

Appendix Table 7- Impact of Groundwater Abdundance on Area under HYV

Year	Coefficient Thickest aquifer X year	Clustered Standard Error	T -Statistic	Coefficient Fairly Thick aquifer X year	Clustered Standard Error	T -Statistic
1957	0.00	.		0.00	.	
1958	0.00	.		0.00	.	
1959	0.00	.		0.00	.	
1960	0.00	.		0.00	.	
1961	0.00	.		0.00	.	
1962	0.00	.		0.00	.	
1963	0.00	.		0.00	.	
1964	0.00	.		0.00	.	
1965	0.00	.		0.00	.	
1966	1753.64	1597.24	1.1	**3129.57**	1585.168	1.97
1967	**21080.18**	6456.283	3.27	**16853.30**	4612.955	3.65
1968	**41820.11**	11528.83	3.63	**20149.23**	6249.213	3.22
1969	**54668.37**	13678.18	4	**35521.56**	10188.89	3.49
1970	**62425.14**	15637.98	3.99	**38776.04**	11319.32	3.43
1971	**81458.67**	18013.64	4.52	**56911.76**	13428.74	4.24
1972	**88108.33**	19703.37	4.47	**64113.69**	15813.94	4.05
1973	**90986.70**	19846.39	4.58	**59467.08**	16515.43	3.6
1974	**106326.00**	20205.58	5.26	**66779.02**	14634.78	4.56
1975	**110269.20**	21836.44	5.05	**65840.91**	16218.64	4.06
1976	**118054.80**	24783.54	4.76	**77199.29**	17719.06	4.36
1977	**119020.50**	26534.56	4.49	**73537.96**	19993.6	3.68
1978	**130589.90**	28176.23	4.63	**76271.00**	20058.56	3.8
1979	**133926.90**	29735.41	4.5	**68870.35**	20321.29	3.39
1980	**137172.60**	29130.99	4.71	**74880.22**	21501.33	3.48
1981	**140624.40**	32247.78	4.36	**75893.24**	23540.82	3.22
1982	**134512.70**	33304.72	4.04	**62019.21**	22973.66	2.7
1983	**158563.40**	34702.68	4.57	**76181.46**	23887.48	3.19
1984	**170189.80**	34637.32	4.91	**90390.77**	24115.14	3.75
1985	**167693.20**	35011.12	4.79	**83642.54**	24479.7	3.42
1986	**180565.00**	36379.92	4.96	**89845.17**	25481.77	3.53
1987	**165691.70**	32650.19	5.07	**84348.42**	23984.16	3.52

Appendix Table 8 : Difference in District Average Depth to Groundwater in 2010 and 1983

	1983 Poverty Measure		
	Poverty Rate	**Poverty Gap**	**Log MPCE**
Richest 25 percent	4.7	5.43	5.24
Poorest 25 percent	1.16	1.16	1.52

Appendix Table 9: OLS Estimates of Impact of Access to Groundwater on Seasonal Outmigration

	Dependent Variable: Any person in hh has outmigrated seasonally		
	(i)	**(ii)**	**(iii)**
Indicator for Depth to Groundwater >8	-0.07***	-0.05**	-0.05**
	(0.025)	(0.027)	(0.02)
Observations	1352	1340	
Infrastructure and Demographic controls	Yes	Yes	Yes
Elevation and Rain Shocks	No	Yes	Yes
Caste Homogeneity in the village	No	No	Yes

*** denotes significance at 1 percent level, ** at 5 percent, * at 10 percent

Notes: Indicator for Depth to Water >8 is an indicator variable which takes the value 1 if groundwater level in year 1993 is at a depth greater than 8 meters below ground level. Infrastrucre and demographic controls include village electrification, availability of banks, school, and medical faciltities, and the share of scheduled caste population in the village. Robust standard errors are reported in parentheses.

The household survey data is from the World Bank Survey of Living Standards in Uttar Pradesh and Bihar, 1997.

Appendix Table 10: OLS Estimates of Impact of Access to Groundwater on Poverty

	Dependent Variable: Headcount			
	(i)	**(ii)**	**(iii)**	**(iv)**
Indicator for Depth to Water > 8	**0.057*** (.0050)**	**0.062*** (.0060)**	**0.076*** (.0070)**	**0.08*** (.0080)**
Water Level	No	Yes	Yes	yes
Water Level Squared	No	No	Yes	Yes
Water Level Cubed	No	No	No	Yes
N	1714	1714	1714	1714

*** denotes significance at 1 percent level, ** at 5 percent and * at 10 percent.

Notes:

Indicator for Depth to Water >8 is an indicator variable which takes the value 1 if groundwater level in year 1993 is at a depth greater than 8 meters below ground level.

Robust standard errors are reported in parentheses.