Rural Transformation through Resource Efficient Technologies in Gujarat, Western India: Does Subsidy Policy Matter?

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Abstract:

Over the years, water scientists, researchers and hydrologists have been constantly warning about the looming water scarcity in the state of Gujarat, western India. Given the common pool nature and absence of marginal pricing for groundwater, an unsustainable extraction and allocation is observed. This underscores the importance of adopting resource efficient technologies like micro-irrigation, while also maintaining current levels of farm production, so as to facilitate the process of sustainable rural transformation. Since there is a strong political unwillingness to implement Pigouvian taxes on externalities, these technologies are mostly subsidized in the developing countries like India. From a social point of view, subsidies can be justified as important sources of rural transformation on the basis of three types of market failures: (i) learning externalities, (ii) income smoothening, and (iii) water saving technologies reduce use of groundwater, which is a common property resource.

While differential subsidy policies adopted across the state of Gujarat to promote micro-irrigation, the water scarce region (named as dark-zone) get additional subsidy. According to previous studies, farmers in this region are likely to adopt micro-irrigation, and therefore, the pertinent research issue is 'whether the government should provide additional subsidy to enhance adoption rate in these regions?' Hence, the aim is to examine the impact of additional subsidy on the adoption and area under micro-irrigation. All the villages in dark-zone and adjacent talukas were taken for the empirical analysis of this study. The major determinants like hydrological scenario and cropping patterns are not so different in both regions, but there is a discontinuity in assessing subsidy among them; the additional subsidy could be wasteful from a public perspective if similar adoption rate would have been achieved without this. Hence, this study aims to examine the impact of discontinuity in availing subsidy on adoption of micro-irrigation. With collecting village-wise information from Gujarat Green Revolution Company Limited between 2006-07 and 2014, the empirical analysis has been undertaken in two stages: (i) all the villages in the dark-zone and adjacent talukas and (ii) border villages which share border with the adjacent talukas. Analysis based on Regression Discontinuity Design approach reveal that additional subsidy enhances probability of adoption and area expansion under micro-irrigation. Further, it is also observed that farmers living in the water critical region are preferring drip irrigation over the sprinkler irrigation.

Keywords: rural transformation, water scarcity, resource efficient technology, subsidy, discontinuity

Introduction

Across the state of Gujarat, Western India, there is a high inequality in the availability of blue water sources (fresh surface water and groundwater), and indeed, around 80% of the gross cropped area is irrigated through groundwater which led to un-sustainable resource utilization (Sekhri, 2011; Viswanathan and Pathak, 2014). Several studies, therefore, have been constantly alarming about depletion of ground water in the state (Narula et al., 2011; see Mekonnen and Hoekstra, 2016) – a negative externality for the users, resulting in loss of harvests and farm income, and in turn, threatening water and food security. Climate change may further worsen this situation. Given these welfare consequences, resource conservation technologies like micro-irrigation (MI) was introduced to meet resource preservation challenges, while also maintaining current levels of farm production. MI technologies such as drip and sprinkler are considered to be pillars of 'sustainable intensification' (Fishman et al., 2014) as it likely to reduce water and energy consumption (Saleth and Amarasinghe, 2010).

While there is always a strong political unwillingness to implement Pigouvian tax on negative externalities associated with water and energy, the resource efficient technologies are mostly subsidized across the world (Fishman et al., 2014). This could be a 'win-win' situation for the policy makers, i.e., reduce groundwater extraction and energy expenditure (both consumer and government) while also declining greenhouse gas emissions. With regards to India, the government subsidizes the irrigation capital cost to enhance diffusion of MI technologies, but the subsidy amount is not uniform across the states (IRAP, 2012). Although various subsidy policies have been adopted to enhance the adoption of MI in Gujarat, the farmers in the water scarce talukas[1] (named as dark-zone[2]) get additional 10% subsidy since 2012, irrespective of landholding and cropping patterns (Bahinipati and Viswanathan, 2016). This represents a discontinuity in the subsidy amount entitled to farmers residing in between water scarce/ dark-zone and other talukas. The additional subsidy could be wasteful from a public perspective if the similar adoption rate would have been achieved in the dark-zone talukas without additional subsidy. Moreover, previous studies find an evidence of higher likelihood of MI adoption in the water scarce region (Caswell and Zilberman, 1983; Palanisami et al., 2011). Thus, the objective of this study is to examine the impact of discontinuity in subsidy on diffusion of MI in the water scarce/ dark-zone region.

The patterns of adoption and diffusion of modern irrigation technologies is the major empirical research issue in both developed and developing countries (Genius et al., 2013). Previous studies give a clear evidence of factors related to economics, farm-organizational, demographic, extension agents, social learning and environmental conditions motivate farmers' to adopt new technologies (Foster and Rosenzweig, 2010; Zilberman et al., 2012; Genius et al., 2013; Taylor and Zilberman, 2015). In spite of having various socio-economic and environmental benefits and sustained efforts by national and respective state governments in India, the overall adoption of MI is still low, except the few states like Andhra Pradesh, Karnataka and Maharashtra – for example, around 14% of total potential area[3] as of 2013

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[1] Talukas means sub-division of a revenue district, comprising of a group of villages.

[2] The Government Resolution (GR) dated 19/9/2001 states that the ground water levels are very low in certain areas (i.e., 57 talukas), and therefore, the state government had enforced a ban on electricity connection for agricultural purposes and extraction of groundwater in these talukas in the interest of geo-hydrology and public at large. In 2003, these talukas were declared as dark-zone (see GR no. GWR-2003-14J1, dated 16/12/2003).

[3] Coverage of MI in India is about 6 million ha out of total potential area is around 42 million ha as on March 2013 (Palanisami, 2015).

(Palanisami, 2015), and alternatively, less than 5% of the net sown area in India (Mahendra Dev, 2016). According to a few studies, this can be attributed to high capital cost, complexity of technology, lack of access to credit, fragmented landholdings, cropping patterns and access to groundwater (Namara et al., 2007; Palanisami et al., 2011; see Kumar, 2016b). There is still a dearth of micro-level studies to identify factors' influencing adoption of MI across various states in India.

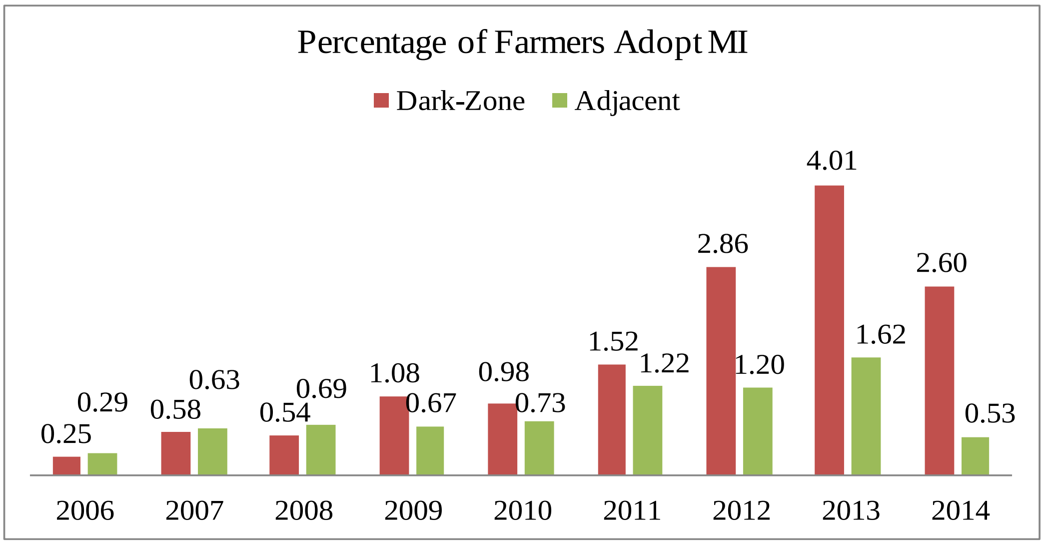
Although the existing studies justify subsidy through social learning and credit constraint, none of them have directly investigated the effects of subsidy on diffusion and adoption of MI while the irrigation capital cost is highly subsidized in India. All the Indian farmers are entitled to get subsidy but the amount varies across as well as within states (IRAP, 2012; Bahinipati and Viswanathan, 2016), and therefore, the effects of additional subsidy on diffusion of MI could be studied. A recent study by Fishman et al. (2014) finds an evidence of additional subsidies enhance adoption of MI in Gujarat state, i.e., drip irrigation by 32%, the area installed with drip by 30% and the probability of having at least one purchase by 11%. As outlined above, an additional 10% subsidy is provided to the farmers in the water scarce regions where they are more likely to adopt MI; the hypothesis is does additional subsidy enhance adoption of MI in these areas. In order to capture the effects of extra subsidy on diffusion of MI in water scarce region, all the villages in water scarce talukas and its counterpart adjacent talukas, except the tribal talukas, were considered for the empirical analysis; only the neighbourhood talukas were taken to control the influence of major determinants like hydrological and cropping patterns. In sum, around 8073 villages and towns in 110 talukas were covered for empirical analysis, and the information related to diffusion of MI in these villages were collected from Gujarat Green Revolution Company Limited (GGRC) between 2006-07 and 2014. A Regression Discontinuity Design (RDD) approach was adopted to do the empirical analysis. While Fishman et al. (2014) focus on whole Gujarat, this study concentrates on water deprived talukas, and specifically looked into to what extent additional subsidy injects diffusion of MI in these region.

The paper is organized as follows. Section I discusses about the diffusion of MI in water scarce and adjacent talukas of Gujarat. Section II discusses the effects of additional subsidy on diffusion of MI in the water scarce region; this section includes data and methods and results and discussions. Section III provides the conclusions.

Diffusion of MI across Dark-Zone and Adjacent Talukas

A special purpose vehicle (SPV) like GGRC was set up in 2004-05 to act as a nodal agency to promote MI within the state, and according to Palanisami (2015), the model adopted by GGRC shows better performance in the context of diffusion of MI as compared to the other Indian states. Moreover, this section briefly discussed about MI adoption status in both dark-zone and adjacent talukas in the state. Figures 1 and 2 show year-wise percentage farmers adopted MI and percentage of net sown area (NSA) under MI, respectively. While an increasing trend was found for percentage of farmers and NSA in both dark-zone and adjacent talukas, the rate of increase was heightened in the dark-zone talukas since 2012 as compared to the adjacent talukas, i.e., the difference between both the talukas is significantly widened – extra subsidy could be one of the major determinant. The percentage of farmers, for instance, adopted MI was 0.25% and 0.29% during 2006-07 in both dark and adjacent talukas, respectively, and it is increased to 1.52% and 1.22% during 2011-12. Whereas almost same percentage of adoption is observed in the adjacent talukas in the year 2012-13 (i.e., 1.2%) compared to the previous year, a significant enhancement is found in the case of dark-zone talukas, i.e., 2.86% of farmers adopted MI. Similarly, the gap was further widened afterwards, i.e., 4.01% and 2.6% of farmers adopt MI in the dark-zone talukas in the year 2013-14 and 2014 (this includes data between April and December), respectively; these figures were 1.62% and 0.53% in the adjacent talukas. On the other hand, a similar result also observed in the case of percentage of NSA under MI. While the percentage of NSA increased from 1.37% in 2011-12 to 2.44% in 2012-13 in the dark-zone talukas, it was marginally declined in the adjacent talukas during the same reference period, i.e., 1.07% to 1.03% (Figure 2). Around 3.17% and 2.11% of NSA under MI in the dark-zone talukas during 2012-13 and 2014, and these figures were 1.32% and 0.47% in the adjacent talukas. This reveals the fact that the difference between dark-zone and adjacent talukas has significantly widened during the extra subsidy period for percentage of adoption and NSA under MI since 2012-13, and in fact, the additional subsidy was given from this year.

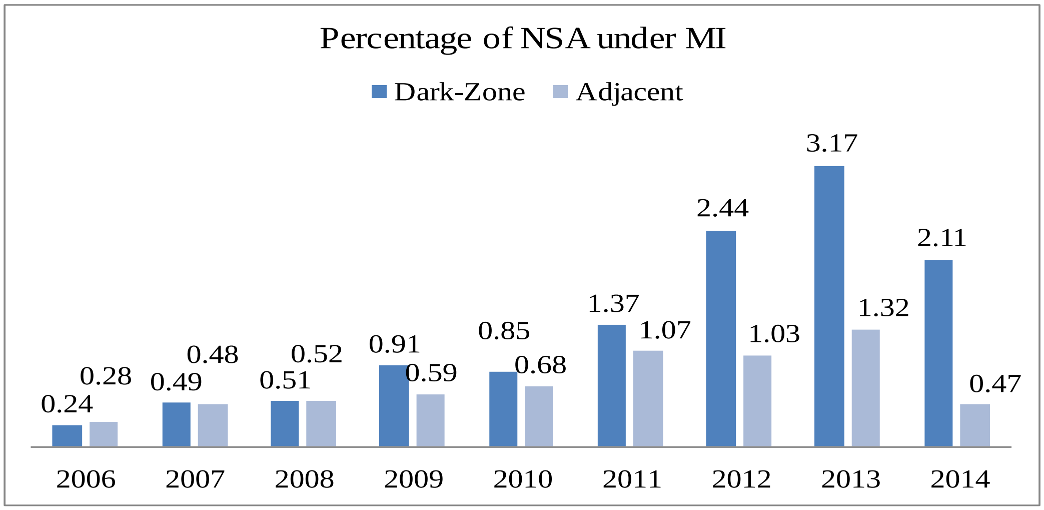
Figure 1. Year-wise percentage of farmers adopted MI



Source: Authors' figure
Note: no. of farmers in '000; the year 2006 represent the financial year from April 2006 to March 2007, and it is same up to the year 2013, and the year 2014 includes data between April and December

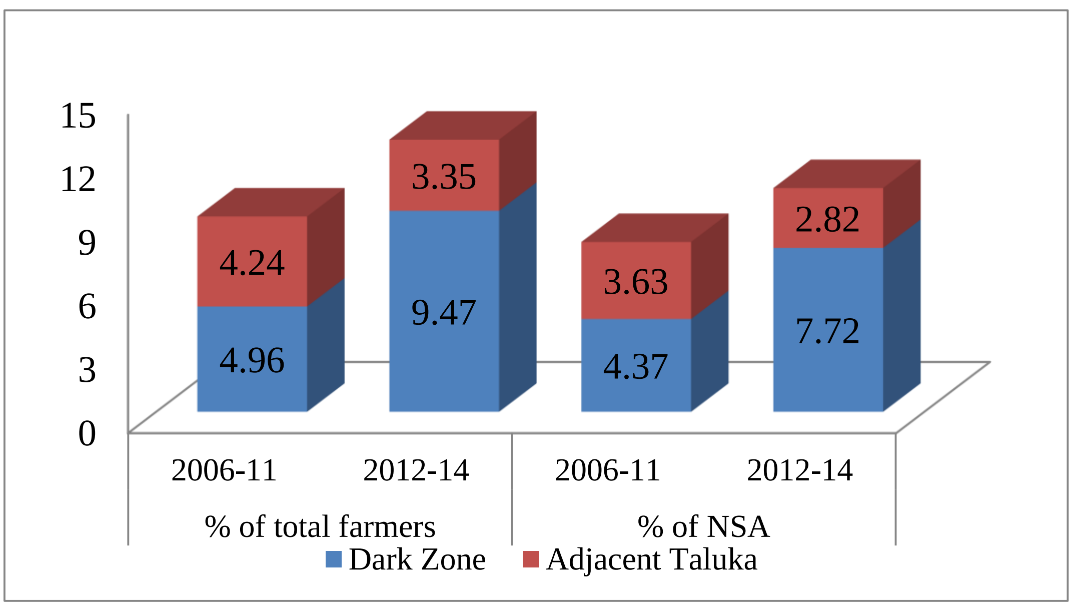
Further, a period-wise percentage of farmers and NSA under MI was calculated to strengthen above arguments (see Figure 3); the estimation was done for two time periods, i.e., 2006-11 (pre-extra subsidy) and 2012-14 (extra subsidy period). While the percentage of farmers adopted MI in the dark-zone talukas increased from 4.96% during 2006-11 to 9.47% in 2012-14, a marginally declined scenario was found in the adjacent talukas, i.e., around 4.24% of farmers undertaken MI during pre-extra subsidy period and which was decreased to 3.35% in the treatment period. A similar result is also obtained in the case of percentage of NSA under MI. Whereas the percentage of NSA was increased from 4.37% to 7.72% in the dark-zone talukas, it was reported to be decreased in the adjacent talukas, i.e., 3.63% to 2.82%. In fact, the findings are also same while we are taking the sample of only the border villages in the dark-zone and adjacent talukas (see Appendices 1 and 2); those villages were considered which share administrative boundary with the adjacent talukas. From the Appendix 3 (which reports the mean difference of adoption and area under MI), it is observed that the mean differences between dark-zone and adjacent talukas are significant, but a higher mean difference is observed during 2012-14 ad compared to the 2006-11 period. Evidently, this reveals that additional subsidy provided to the farmers in the dark-zone talukas could have positively influenced the observed increasing adoption and area under MI in the dark-zone talukas. The empirical analysis with adopting RDD approach was carried out in the next section.

Figure 2. Year-wise percentage of NSA under MI



Source: Authors' figure
Note: area in '000 ha; the year 2006 represent the financial year from April 2006 to March 2007, and it is same up to the year 2013, and the year 2014 includes data between April and December; NSA- Net Sown Area

Figure 3. Period-wise Percentage of farmers and NSA under MI



Source: Authors' figure

Additional Subsidies and Diffusion of MI in Dark-zone Talukas

Data and Methods

The objective, outlined in the introduction section, is to study the effects of additional subsidy provided to the farmers in the dark-zone talukas on adoption and area under MI. Previous studies pertaining to India have been pointed out that hydrological parameters and cropping patterns are the major determinants of MI adoption (Namara et al., 2007; Palanisami et al., 2011). Instead of taking all the talukas, the empirical analysis of this study has, therefore, been considered the dark-zone and adjacent talukas; the above two determinants are likely to be not significantly different between both the regions. In sum, this study covers 110 talukas[4] (52 talukas in dark-zone and 58 talukas in adjacent category) with 8073 villages and towns – while 4019 from dark-zone talukas, 4053 in the adjacent talukas (see Figure 4). Village-wise technology diffusion information, e.g., number of farmers adopted MI, drip and sprinkler adopted farmers, and total are under MI (in ha) were collected from GGRC between 2006-07 and 2014[5], and the socio-economic indicators (e.g., village area in ha, number of households and population) were gathered from district census handbooks (2011). In addition, data related to SGWD (stage of groundwater development - ratio of annual ground water draft and net annual ground water availability in percentage) were accumulated from the reports published by Central Ground Water Board, Government of India; we have used the reports published in the year 2009 and 2011.

The policy instrument of additional subsidy provided to the farmers in the dark-zone talukas since 2012 creates a sharp discontinuity in the probability of adopting MI as a function of other determinants. While the other major determinants like hydrological scenario and cropping patterns are likely to be not significantly different between dark-zone and adjacent talukas, the significant difference noted in above figures could mainly due to additional subsidy, i.e., treatment effect in this study. To do a robust check-up on the findings, this study has narrowed down the sample with focusing on only the border villages in the dark and adjacent talukas – those villages were considered who share border with a village in adjacent talukas. This analysis was based on 1456 villages and towns and of which, 855 villages in dark-zone and adjacent talukas consist of 601 villages and towns. Further, another study sample was generated based on village pair-wise difference in adoption and area under MI. In sum, the empirical analysis conducted in this study is three folds: (i) all the villages in dark-zone and adjacent talukas, (ii) border villages in both the regions, and (ii) village pair-wise difference of diffusion of technology.

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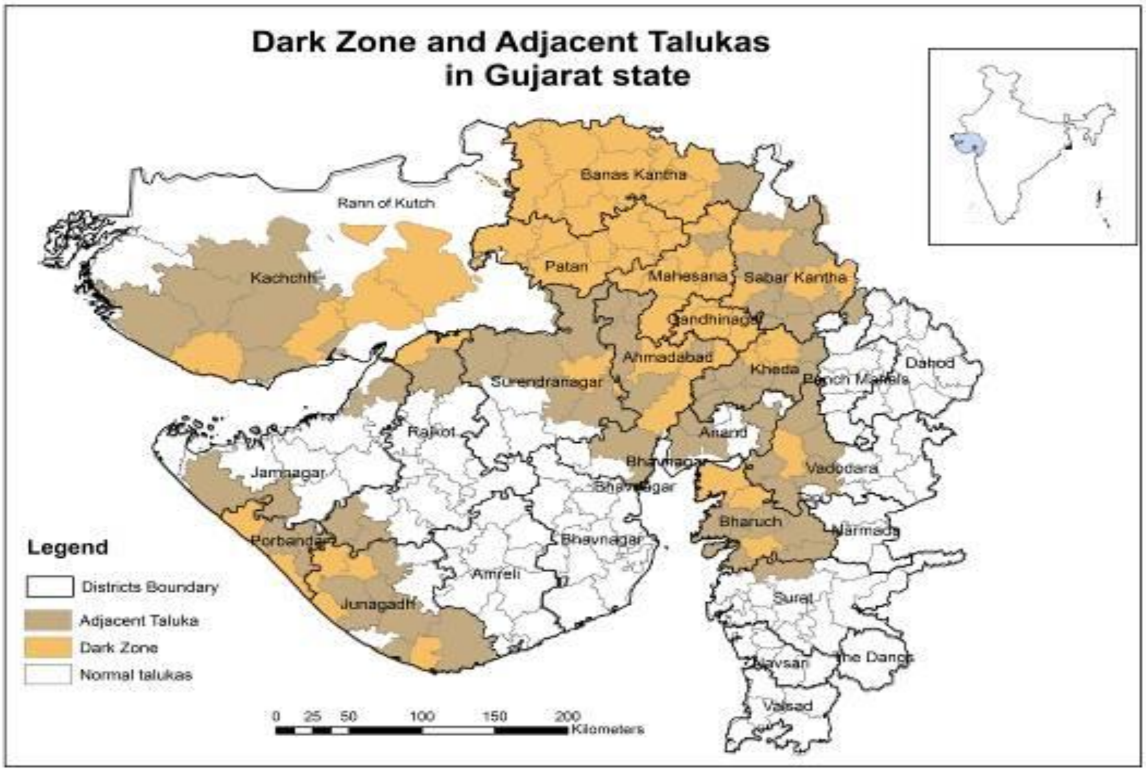
[4] As of now, there are 54 dark-zone talukas and we have found another 64 talukas are adjacent to dark-zone, and among them, 8 talukas are notified as tribal; since there is different subsidy policy for tribal farmers in tribal talukas, we have excluded tribal talukas from the empirical analysis of this study.

[5] The government has introduced a new subsidy policy in 2015, and therefore, this study's empirical analysis stick with the data collected up to 2014.

Figure 3: Study Area



Source: Authors' figure

A 'regression discontinuity design (RDD)' method (see Hahn et al., 2001; Lee and Lemieux, 2010 for a survey), which was first discussed by Thistlethwaite and Campbell (1960), was adopted to evaluate the effect of additional subsidy given to the farmers in the dark-zone talukas on diffusion of water conservation technologies. Although this approach was largely applied in the education research to evaluate the impact of summer school and scholarship on the performance of students (Matsudaira, 2008), other fields of economics recently used it to evaluate effects of various programmes and policies (see Hahn et al., 1999; Lee and Lemieux, 2010; Jacob et al., 2012). However, it is infrequently used in the economics literature as such type of data design is rare (Hahn et al., 2001). The regression model of the impacts of additional subsidy on adoption and area under MI can be written as (Hahn et al., 1999):

$$Y_{vt} = \alpha_0 + \alpha_1 T_{vt} + \alpha_2 X_{vt} + u_{vt} \ldots\ldots(1)$$

Where Y_{vt} is the outcome variable (i.e., adoption rate of MI and percentage of total area under MI[6]) in village 'v' at time 't'; T_{vt} refers to treatment variable in binary terms, i.e., equal to one if the farmers in village v are entitled for extra subsidy, otherwise 0; X_{vt} captures other

[6] While the former was estimated as dividing total number of MI adopters in a village in particular year by total number of households in the village as per Census 2011, the later was calculated by dividing total area under MI by total area in the village.

covariates that possible influence adoption of MI at the village level; and u_{vt} represents error term. The coefficients $\alpha_s^{'}$ are the parameters to be estimated and the major interest lies with α_1, as it measures causal effects of extra subsidy on outcome.

By construction, the existing data represent balanced panel, i.e., 8073 villages for 9 time periods (2006-07 to 2014). Empirically, this study employed both OLS fixed effects and dynamic panel regression (Arellano-Bover linear dynamic panel regression) models to test the impact of subsidy policy on diffusion of MI in water deprived regions.

The OLS fixed effects regression is:

$$Y_{vt} = \beta_0 + \beta_1 T_{vt} + \beta_i X_{vt} + \gamma_t + \varepsilon_v + u_{vt} \ldots\ldots(2)$$

The Arellano-Bover linear dynamic panel regression is:

$$Y_{vt} = \beta_0 + \gamma_1 Y_{v,t-1} + \gamma_2 Y_{v,t-2} + \beta_1 T_{vt} + \beta_i X_{vt} + \varepsilon_v + u_{vt} \ldots\ldots(3)$$

Where Y_{vt} represents outcome of an interest, adoption rate of MI and percentage of area under MI in village 'v' at time 't'. T_{vt} denotes the treatment effect, and X_{vt} captures other possible covariates which influence adoption (water scarcity region dummy in the present study context, i.e., overexploited, critical, semi-critical and safe category[7]). $Y_{v,t-1}$ and $Y_{v,t-2}$ represent first and second lags of the dependent variable. ε_v is the village-level fixed effects, and γ_t is the time fixed effect. u_{vt} refers to idiosyncratic error term and β_i are the parameters to be estimated and the major thrust of the analysis is β_1. Based on the equations 2 and 3, this study has estimated results for the sample of all the villages and border villages.

As outlined above, we have also reconfirmed the findings based on above equations (2 and 3) with constructing a sample of pair-wise border village matching. Following Somanathan et al. (2009), the estimated regression model is:

$$\Delta y_t = \alpha_0 + \alpha_2 T_t + u_t \ldots\ldots(4)$$

Where Δy_t is the border village pair-wise difference in adoption rate of MI and percentage of area under MI between dark-zone and adjacent talukas. In this context, the coefficient (α_2) of the variable T_t is the main interest of the analysis.

Table 1 reports descriptive statistics of variables used in the regression model. In the case of total sample, on an average 1.1% of the total households adopt MI, with minimum 0% and maximum 49% – a higher percentage of households adopt sprinkler than drip irrigation in the study area. Around 0.8% of the total village area is under MI with a maximum of 54%. Out ot the total study villages, 32%, 5.4%, 28.3% and 34.1% fall in over-exploited, critical, semi-critical and safe category, respectively.

[7] Over exploitation: SGWD > 100%; critical: SGWD is between 85-100%; Semi-critical: SGWD is between 65-85%; and safe: SGWD < 65% (Government of India, 2014).

Table 1. Descriptive Statistics of variables

Parameter	Full Sample Mean (SD)	Min	Max	Dark-zone Mean (SD)	Adjacent Mean (SD)	Border Village* Mean (SD)	Difference** Mean (SD)
Adoption Rate of MI	0.011 (0.031)	0	0.49	0.014 (0.035)	0.008 (0.025)	0.011 (0.030)	0.005 (0.060)
Adoption Rate of Drip	0.004 (0.017)	0	0.47	0.004 (0.015)	0.005 (0.020)	0.004 (0.017)	0.0001 (0.033)
Adoption Rate of Sprinkler	0.007 (0.024)	0	0.48	0.011 (0.031)	0.004 (0.015)	0.007 (0.023)	0.005 (0.040)
Adoption Rate of Area under MI	0.008 (0.021)	0	0.54	0.011 (0.025)	0.005 (0.015)	0.008 (0.019)	0.005 (0.023)
Extra Subsidy	0.163 (0.370)	0	1	0.328 (0.470)	0.00 (0.00)	0.192 (0.394)	-
Overexploited	0.321 (0.467)	0	1	0.604 (0.489)	0.041 (0.198)	0.312 (0.463)	-
Critical	0.054 (0.227)	0	1	0.045 (0.207)	0.064 (0.245)	0.046 (0.209)	-
Semi-Critical	0.283 (0.451)	0	1	0.178 (0.383)	0.387 (0.487)	0.332 (0.471)	-
Safe	0.341 (0.474)	0	1	0.173 (0.378)	0.508 (0.5)	0.309 (0.462)	-

Source: Authors' computation
Note: SD- standard deviation; *- includes villages of dark-zone and adjacent talukas; **- village pair-wise difference between dark-zone and adjacent talukas

Results and Discussions

Table 2 shows the effects of additional subsidy on adoption rate of MI, and the impact on percentage of area adopted under MI was reported in Table 3. First and third columns describe the results of OLS fixed effects for both full and border village samples, respectively. Second and fourth columns outline results of Arellano-Bover dynamic panel regression model, and fifth column demonstrates estimations of equation 4. In the case of OLS models, the goodness-of-fit is in between 12% to 13% in all the models. The values of Wald χ^2 are significant in the dynamic panel models, indicating there are no error in the estimation of the models. In order to capture unobserved heterogeneity effect at the village level, the fixed effects models were estimated and the standard errors were adjusted at the village level.

In all the models reported in Tables 2 and 3, a highly significant coefficient is observed for the variable like extra subsidy, and this reveals the fact that an additional subsidy provided in the dark-zone talukas has positively influenced the diffusion of water conservation technologies. For instance, an extra subsidy enhanced the likelihood of adoption rate by 1.5 to 1.8 times (Table 2). As previously expected, the farmers in the over-exploited region are more likely to adopt MI as compared to the other regions like critical, semi-critical and safe. Looking at column (v) of Table 2, one can derive the conclusion that the extra subsidy increases the adoption rate difference by 2.3 times, i.e., additional 1.84% of the total households in the village adopt MI. On the other hand, the percentage of total area under MI increased by 0.7 to 1.2 times due to extra subsidy. Likewise, the larger percentage of area under MI in overexploited region, following critical and semi-critical region.

Table 2. Effects of Additional Subsidy on Adoption Rate of MI

	Adoption Rate of MI				Δ adoption rate of MI
Independent Variables	(i)	(ii)	(iii)	(iv)	(v)
Extra Subsidy	0.018***	0.015***	0.016***	0.018***	0.023***
	(0.001)	(0.003)	(0.001)	(0.003)	(0.003)
$(\text{ARMI})_{t-1}$	-	0.090	-	0.367***	-
		(0.073)		(0.065)	
$(\text{ARMI})_{t-2}$	-	0.073*	-	0.105***	-
		(0.041)		(0.020)	
Region Dummy[a]					
Overexploited	0.005***	0.037***	0.002	0.021***	-
	(0.001)	(0.009)	(0.002)	(0.008)	
Critical	-0.001	0.028***	-0.007***	0.019**	-
	(0.001)	(0.008)	(0.003)	(0.008)	
Semi-Critical	-0.000	0.027***	-0.002	0.024***	-
	(0.001)	(0.006)	(0.002)	(0.007)	
Constant	0.001*	-0.008	0.003*	-0.010**	-0.0003
	(0.001)	(0.005)	(0.002)	(0.005)	(0.001)
R^2	0.125	-	0.133	-	0.049
Wald χ^2	-	1569.99***	-	1038.08***	-
No. of Obs.	72,597	56,460	13,080	10,172	8,550
No. of Villages/ Pairs	8073	8073	1456	1454	950
F Test	217.13***	-	45.73***	-	47.98***
Hausman (FE/RE)	255.43***	-	167.22***	-	-
Village FE	Yes	-	Yes	-	-
Year FE	Yes	Yes	Yes	Yes	Yes
Model	OLS(FE)	Arellano-Bond	OLS(FE)	Arellano-Bond	OLS(FE)
	Full	Full	Border	Border	Border

Source: Computed from primary data

Note: a- the omitted category is safe; village level cluster robust standard errors are in the parentheses; the higher orders of the first difference are not significant, so we accept the null hypothesis as there is no serial correlation; column (ii): z-values of order 2 is 0.498 (Prob.>z = 0.618); column (iv) z-values of order 2 is 1.370 (Prob.>z = 0.171); *** p<0.01, ** p<0.05 and * p<0.1 respectively.

Table 3. Effects of additional Subsidies on Adoption Rate of Area under MI

	Adoption Rate of Area under MI				Δ Area under MI
Independent Variables	(i)	(ii)	(iii)	(iv)	(v)
Extra Subsidy	0.012***	0.007***	0.010***	0.010***	0.008***
	(0.0003)	(0.001)	(0.001)	(0.002)	(0.001)
$(\text{AreaMI})_{t-1}$	-	0.400***	-	0.240***	-
		(0.022)		(0.037)	
$(\text{AreaMI})_{t-2}$	-	0.107***	-	0.053*	-
		(0.017)		(0.027)	
Region Dummy[a]					
Overexploited	0.005***	0.018***	0.004**	0.017***	-
	(0.001)	(0.002)	(0.001)	(0.003)	
Critical	0.005***	0.012***	0.002	0.014***	-
	(0.001)	(0.002)	(0.002)	(0.003)	
Semi-Critical	0.001**	0.012***	0.00003	0.015***	-
	(0.0005)	(0.001)	(0.001)	(0.003)	
Constant	-0.0004	-0.011***	0.001	-0.006***	0.001*
	(0.0005)	(0.001)	(0.001)	(0.002)	(0.000)
R^2	0.128	-	0.122	-	0.095
Wald χ^2	-	4674.44***	-	737.15	-
No. of Obs.	71,927	55,944	13,034	10,136	8,424
No. of Villages/ Pairs	7993	7992	1450	1448	936
F Test	224.22***	-	48.09***	-	42.95***
Hausman (FE/RE)	321.99***	-	141.81***	-	-
Village FE	Yes	-	Yes	-	-
Year FE	Yes	Yes	Yes	Yes	Yes
Model	OLS(FE)	Arellano-Bond	OLS(FE)	Arellano-Bover	OLS(FE)
	Full	Full	Border	Border	Border

Source: Computed from primary data

Note: a- the omitted category is safe; robust standard errors are in the parentheses; the higher orders of the first difference are not significant, so we accept the null hypothesis as there is no serial correlation; column (ii): z-values of order 2 is 0.715 (Prob.>z = 0.475); column (iv) z-values of order 2 is 4.084 (Prob.>z = 0.000); *** p<0.01, ** p<0.05 and * p<0.1 respectively.

Concluding Observations

While several studies have been constantly warning about the looming water scarcity in the state of Gujarat, an unsustainable extraction of groundwater is being observed due to common-pool nature and absence of marginal pricing. Since there is a political willingness to implement Pigouvian tax on externalities, both the national and state governments provide subsidy for wise scale adoption of resource efficient technologies like MI. There is no uniform subsidy policy which varies with respect to caste, landholdings and geographical locations. In fact, water scarce regions (named as dark-zone) get additional 10% subsidy where farmers mostly depend on groundwater based irrigation. It is widely known that farmers in these regions are more likely to adopt micro-irrigation, and therefore, the research issue is whether the government should provide additional subsidy to enhance adoption rate. All the villages in dark-zone and adjacent talukas were taken for the empirical analysis of this study. The major determinants like hydrological scenario and cropping patterns are not so different in both regions, but there is a discontinuity in subsidy among them; the additional subsidy could be wasteful from a public perspective if similar adoption rate would have been achieved without this. Collecting the information about adoption and area under MI, the present study has undertaken the empirical analysis in two stages: (i) all the villages and (ii) border villages.

The empirical analysis finds three conclusions: (i) the adoption rate of MI has significantly increased since the year 2012 as compared to the counterpart adjacent talukas, (ii) additional subsidy act as a major determinant to enhance the adoption rate of MI, and (iii) farmers in the high water scarcity region are more likely to adopt MI.

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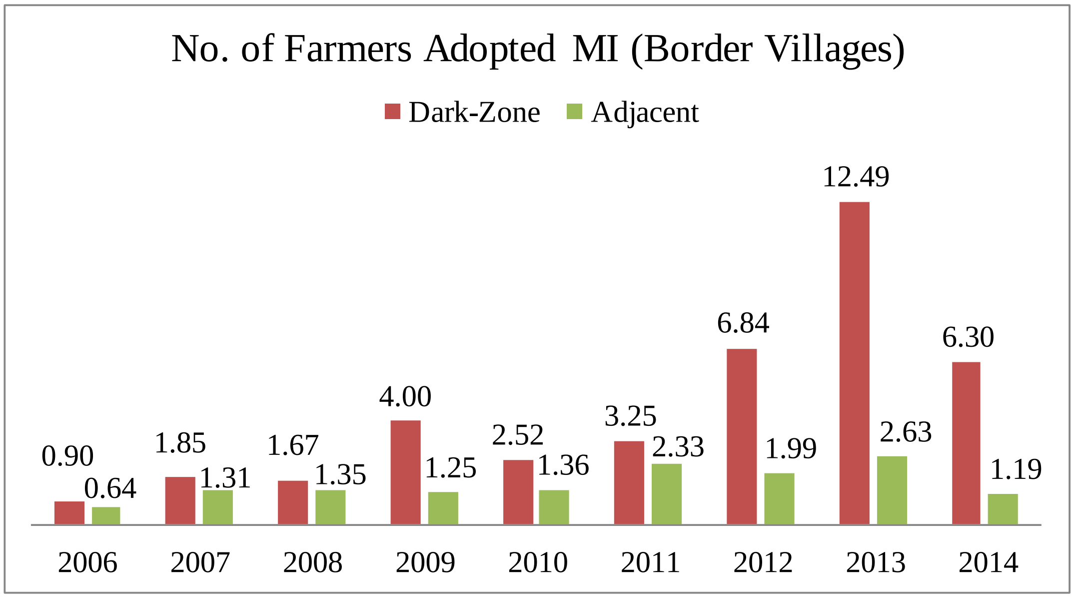
Appendices

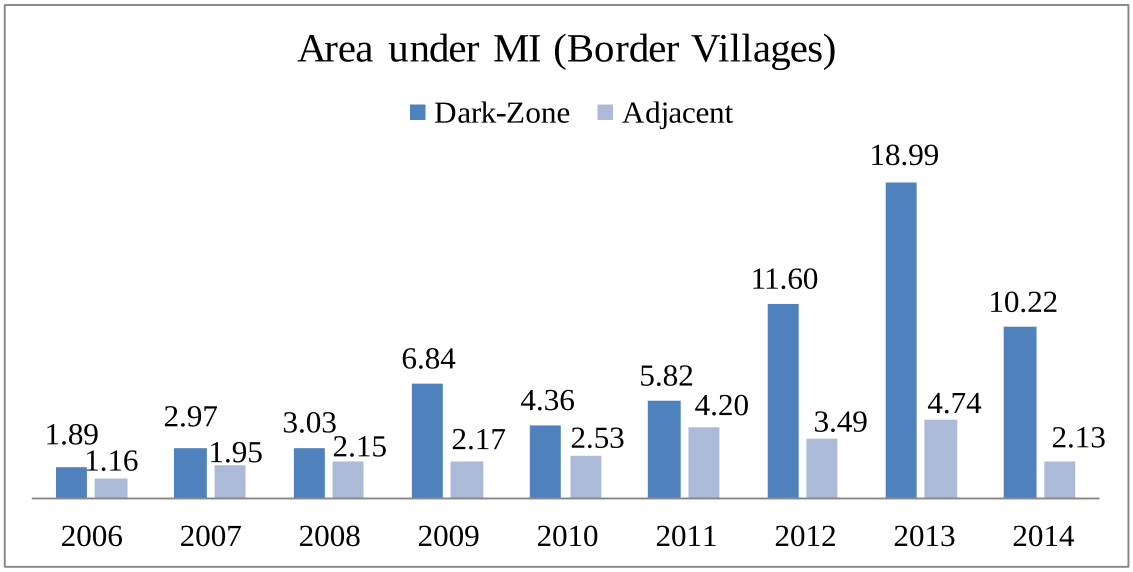
Appendix 1. Year-wise no. of farmers adopted MI in border villages



Source: Authors' figure

Note: no. of farmers in '000; the year 2006 represent the financial year from April 2006 to March 2007, and it is same up to the year 2013, and the year 2014 includes data between April and December

Appendix 2. Year-wise total area under MI in border villages



Source: Authors' figure

Note: area in '000 ha; the year 2006 represent the financial year from April 2006 to March 2007, and it is same up to the year 2013, and the year 2014 includes data between April and December

Appendix 3. Dark-zone and Adjacent Taluka Sample: Summary Statistics

		Full Sample	Border Village
Parameter	Sample Period	Difference (Adjacent – Dark) Mean	Difference (Adjacent – Dark) Mean
Adoption Rate of MI	2006-14	-0.006***	-0.005***
Adoption Rate of MI	2006-11	-0.0001	0.0001
Adoption Rate of MI	2012-14	-0.018***	-0.016***
Adoption Rate of Drip	2006-14	0.001***	0.0002
Adoption Rate of Drip	2006-11	0.002***	0.001***
Adoption Rate of Drip	2012-14	-0.001*	-0.002***
Adoption Rate of Sprinkler	2006-14	-0.007***	-0.006***
Adoption Rate of Sprinkler	2006-11	-0.002***	-0.001***
Adoption Rate of Sprinkler	2012-14	-0.017***	-0.014***
Adoption Rate of Area under MI	2006-14	-0.006***	-0.004***
Adoption Rate of Area under MI	2006-11	-0.002***	-0.001***
Adoption Rate of Area under MI	2012-14	-0.014***	-0.011***

Source: Authors' computation

Note: *** p<0.01, ** p<0.05 and * p<0.1 respectively

Appendix 4. Effects on Adoption Rate of Drip Irrigation

	Adoption Rate of Drip Irrigation				Δ adoption rate of Drip Irrigation
Independent Variables	(i)	(ii)	(iii)	(iv)	(v)
Extra Subsidy	0.002***	0.004***	0.003***	0.005***	0.006***
	(0.0003)	(0.001)	(0.001)	(0.002)	(0.001)
$(\text{ARDRIP})_{t-1}$	-	0.229***	-	0.177**	-
		(0.060)		(0.083)	
$(\text{ARDRIP})_{t-2}$	-	0.057	-	-0.017	-
		(0.064)		(0.051)	
Region Dummy[a]					
Overexploited	0.005***	0.002	0.006***	-0.002	-
	(0.0004)	(0.001)	(0.001)	(0.004)	
Critical	-0.001*	0.002	-0.004**	0.006**	-
	(0.001)	(0.001)	(0.002)	(0.003)	
Semi-Critical	0.002***	0.003**	0.003***	0.006***	-
	(0.000)	(0.001)	(0.001)	(0.002)	
Constant	-0.001**	0.003***	-0.001**	0.002	-0.000
	(0.000)	(0.001)	(0.001)	(0.002)	(0.000)
R^2 Overall	0.036	-	0.054	-	0.012
Wald χ^2	-	607.86***		211.19***	-
No. of Obs.	72597	56460	13080	10172	8550
No. of Villages/ Pairs	8073	8073	1456	1454	950
F Test	81.68***	-	19.55***	-	12.41***
Hausman (FE/RE)	539.22***	-	181.42***	-	-
Village FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	-	Yes
Model	OLS(FE)	Arellano-Bond	OLS(FE)	Arellano-Bond	OLS(FE)
	Full	Full	Border	Border	Border

Source: Computed from primary data

Note: a- the omitted category is safe; robust standard errors are in the parentheses; the higher orders of the first difference are not significant, so we accept the null hypothesis as there is no serial correlation; column (ii): z-values of order 2 is -0.974 (Prob.>z = 0.330); column (iv) z-values of order 2 is 0.978 (Prob.>z = 0.328); *** p<0.01, ** p<0.05 and * p<0.1 respectively.

Appendix 5. Effects on Adoption Rate of Sprinkler Irrigation

	Adoption Rate of Sprinkler Irrigation				Δ adoption rate of Sprinkler Irrigation
Independent Variables	(i)	(ii)	(iii)	(iv)	(v)
Extra Subsidy	0.015***	0.015***	0.013***	0.014***	0.017***
	(0.0005)	(0.002)	(0.001)	(0.002)	(0.002)
$(\text{ARSprinkler})_{t-1}$	-	0.036	-	0.299***	-
		(0.077)		(0.061)	
$(\text{ARSprinkler})_{t-2}$	-	0.044	-	0.062***	-
		(0.035)		(0.019)	
Region Dummy[a]					
Overexploited	-0.001	0.049***	-0.003	0.005	-
	(0.001)	(0.010)	(0.002)	(0.014)	
Critical	0.00004	0.028***	-0.004	0.011	-
	(0.001)	(0.008)	(0.002)	(0.011)	
Semi-Critical	-0.002***	0.024***	-0.005**	0.011	-
	(0.001)	(0.007)	(0.002)	(0.008)	
Constant	0.002***	-0.017***	0.005***	-0.002	-0.0001
	(0.001)	(0.005)	(0.002)	(0.008)	(0.0005)
R^2 Overall	0.113	-	0.108	-	0.061
Wald χ^2	-	1049.03***	-	655.08	-
No. of Obs.	72597	56460	13080	10172	8550
No. of Villages/ Pairs	8073	8073	1456	1454	950
F Test	156.59***	-	31.78***	-	41.73***
Hausman (FE/RE)	63.29***	-	44.00***	-	-
Village FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Model	OLS(FE)	Arellano-Bond	OLS(FE)	Arellano-Bover	OLS(FE)
	Full	Full	Border	Border	Border

Source: Computed from primary data

Note: a- the omitted category is safe; robust standard errors are in the parentheses; the higher orders of the first difference are not significant, so we accept the null hypothesis as there is no serial correlation; column (ii): z-values of order 2 is 0.713 (Prob.>z = 0.476); column (iv) z-values of order 2 is 3.971 (Prob.>z = 0.000); *** p<0.01, ** p<0.05 and * p<0.1 respectively.