

ASSESSING RISK IN DRILLING IN-WELL BORES : EVIDENCE
FROM A WATERSHED IN SOUTH PENINSULAR INDIA

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July 1985

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Abstract

Drilling bores is a common means to enhance water yield in dug wells in the hard-rock, granitic region characteristic of much of peninsular India. The objectives of this study are to describe in-well boring and its profitability, to validate experimentally estimated risk preferences with inferences drawn from the drilling decision, and to evaluate information from groundwater prospecting.

Results from two surveys suggest that in-well boring is a profitable but risky activity. Risk preferences inferred from the drilling decision are broadly consistent with those measured experimentally. For many farmers the value of information from electro-sensitivity soundings substantially exceeds its costs. Differences in assessed risk perceptions, particularly of the chances of successfully intercepting water bearing fissures, appear to determine actions taken in the drilling decision much more strongly than potential inter-farmer differences in risk preferences.

ASSESSING RISK IN DRILLING IN-WELL BORES:
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INTRODUCTION

Drilling bores is a common means to enhance water yield in dug wells in the hard-rock, granitic region characteristic of much of peninsular India. In a study designed to evaluate the economics of traditional irrigation, 23% of the respondents in a random sample of farmers from a study watershed mentioned in-well boring as a way of improving water yield from wells (Engelhardt, 1984). One year later 53% of the same group planned to drill in-well bores. As well densities increase it is likely that the demand for in-well boring will also rise. Despite its growing popularity, there is little if any literature analyzing this investment activity.

The decision to drill an in-well bore is very risky. Unlike many other investment decisions, drilling in-well bores is not determined by access to institutional credit or by many other non-risk factors that usually condition the diffusion cycle of awareness, trial, evaluation, and adoption. Credit is seldom constraining because dug wells are owned by richer farmers and because the cost of drilling (around Rs. 2000 or \$ US 175) is not high enough to put these farmers at severe financial or subsistence risk in the event water-bearing fissures are not intercepted by a bore. Also, unlike fertilizer and variety decisions, drilling in-well bores is a lumpy investment with a limited range of actions. Farmers also know about in-well boring which has been practised commercially for more than 20 years in the study watershed. Although information from groundwater prospecting can be used to sharpen predictions about hitting water-bearing fissures, most dug well owners consider drilling a 50-50 gamble with the size of the change in water yield also unknown. For these reasons drilling in-well bores presents an almost ideal real-world decision from which to evaluate measured risk preferences and/or perceptions.

This paper is focussed on comparing real world decisions with experimentally measured risk preferences described in Binswanger (1981 and 1982). Experimentally

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measured risk preferences have only been validated by one other study showing that differences in experimentally measured risk preferences did significantly explain interfarm differences in fertilizer adoption. However, their effect was not as large as other statistically significant ($p < .05$) determinants such as experience in using fertilizer (Binswanger et al. 1981).

The paper is organized around three objectives: (1) to describe in-well boring and its profitability, (2) to validate experimentally estimated risk preferences with inferences drawn from the drilling decision, and (3) to evaluate information from groundwater prospecting. Results pertaining to those objectives are summarized in a concluding section.

DESCRIPTION OF IN-WELL BORING

The data in this section come from a census of dug wells with and without bores in two villages in a watershed located about 70 km south of Hyderabad, India, in Andhra Pradesh State.[1] The watershed is the site of a larger study on groundwater productivity (Engelhardt, 1984). The soils in the watershed are predominantly Alfisols. The most common dryland cropping systems are intercropped sorghum/pearl millet/pigeonpea and castor during the rainy season. Smaller areas of paddy irrigated from dug wells are planted in the rainy, postrainy, and summer seasons.

In-well boring started in 1962 when a government extension program coordinated the sinking of one bore. The technology spread gradually in the two study villages and presently about 63% of the sample wells contain in-well bores. Most of these were drilled during the past 10 years.

In the two study villages of the watershed, 19 out of 30 sample wells had in-well bores. For 11 wells, drilling was unsuccessful as the bores did not intercept water bearing fissures. For the other 8 wells, drilling has significantly enhanced water yield. Five farmers were entirely satisfied with their in-well bores. They had no further plans to improve their wells. Four farmers wanted to drill again. Several well owners who drilled successfully wanted to deepen their wells instead of drilling bores. This observation suggests that drilling bores is not a final activity but is regarded by farmers as a means of exploring for water in the underground strata which may warrant further digging.

[1] Note that these sample wells are not necessarily representative for all wells in the watershed.

Technical features

The wells into which bores were sunk are of roughly similar dimensions to other open dug wells in the region. They averaged 10.9 m depth, 11.8 m length and 7.3 m width.

The number of bores sunk varies but most wells have two to three bores. The depth of a bore is on average 7.2 m, but ranges from 3 m to 16 m.

Bore diameter ranges from 0.10 to 0.15 m. Water comes through the bores by artesian movement and even if the dug well has no recharge, water will still come through the bore if it has intercepted fractures. The bores yield water for 5 to 10 years before they become silted.

Bores are successful if they intercept water bearing fractures in the substrata. The presence of the fractures can be identified by aerial photo interpretation and their extent can be estimated by electro-resistivity soundings (Todd, 1980). This method makes use of the different resistivities of hard rock and water bearing fissures. Consultants charge Rs. 150 to Rs. 175 per sounding. But prospecting methods such as electro-resistivity soundings were employed in only one case. The sounding predicted no water. The farmer nevertheless drilled, but he was unsuccessful. It seems that this facility is not readily available to the farmers. There are, however, numerous contractors who offer drilling rigs. The 39 surveyed bores were sunk by 11 different contractors between 1962 and 1982. Some of the contractors live in nearby villages.

Profitability of in-well boring

The cost of bore drilling has increased with time. In 1982/83, the cost per meter drilled ranged from Rs. 100 to Rs. 150. Drilling costs depend on site specific conditions and are higher if unfractured rock is hit. The average cost of improving a well by boring in 1982 prices is Rs. 1860 assuming an average design of two bores of 7.2 m each.[2]

It was not possible to measure water yield before and after drilling because the survey was carried out on wells which already had in-well bores.[3] Therefore, to measure

[2]. Most farmers financed drilling themselves; only two farmers entered the credit market to borrow.

[3]. To test whether high yielding wells are more promising sites for boring the increase in area irrigated after drilling (in ha) was regressed on the area irrigated before drilling (in ha). The results were not statistically significant suggesting that in-well boring is indeed a risky activity as data on water yield from a well provides little information on the prospects for success from in-well boring.

benefits, information was collected on farmers' perceptions of the changes in irrigated paddy area attributed to in-well boring. The expected increase in area irrigated including both successful and unsuccessful drills is 0.83 ha during a cropping year. Forty-two percent of the well owners reported success in that their in-well bores yielded more water because they hit water bearing fissures. Fifty-eight percent were unsuccessful and could not attribute an increase in irrigated paddy area to in-well boring.

Assuming a productive life of the bore of five years and subtracting the opportunity cost of dryland crops during the rainy season gives in-well boring an expected internal rate of return of 32.5% or an expected net present value at the current 18% interest rate charged by moneylenders of about Rs. 650 per well. Despite the high incidence of unsuccessful drilling, in-well boring appears to be a profitable venture.

VALIDATING EXPERIMENTALLY MEASURED RISK PREFERENCES

Because in-well boring seems to be such an apt example of risky decision making, it represents a clear point of reference from which to validate methods designed to elicit farmer risk preferences or to assess their perceptions. This paper is focussed on preferences measured by the experimental method which is probably the most cost effective and direct approach to measuring risk attitudes; however, the method has been validated with few real world decisions. The experimental method consists of allowing farmers to choose alternatives representing trade-offs in mean and variance in monetary gains (Binswanger 1980, 1981). Farmers' choices are "reinforced" through payoffs depending on events usually determined by a coin flip. Farmers also have substantial time to reflect on their decisions.

Binswanger used the experimental method to investigate the risk attitudes of a random sample of 330 individuals in six villages in India's semi-arid tropics. One of these villages was a study village in the watershed. Binswanger estimated partial risk aversion coefficients using the constant partial risk-aversion function $U(M) = (1-S) M^{1-S}$, where S is the coefficient of partial risk aversion and M is the certainty equivalent of gains from the risky prospect in the experimental games. About 82% of the farmers exhibited moderate to intermediate risk aversion with values of S between 0.32-0.81 and 0.82-1.74, respectively. Few farmers displayed slight risk aversion to risk neutrality ($0 < S < 0.32$), severe risk aversion ($1.74 < S < 7.51$), or extreme risk aversion ($S > 7.51$). Several subsequent studies reported in Binswanger and Sillers (1981) have supported the finding that most respondents are moderately risk averse.

To evaluate the results from the experimental method, the subjective expected utility theory is used here to evaluate the drilling decision. The decision consists of two acts, drilling in-well bores and not drilling with consequences conditioned by intercepting and not intercepting water bearing fissures. It is assumed that a farmer will drill if the expected utility of drilling exceeds the expected utility of not drilling.

$$U(a_1) = P(\theta_1) U(a_1|\theta_1) + P(\theta_2) U(a_1|\theta_2) \quad (1)$$

where a_1 = the act of drilling

$P(\theta_1)$ = the probability of intercepting water bearing fissures

$P(\theta_2) = 1 - P(\theta_1)$ = the probability of not intercepting water bearing fissures

The consequences $U(a_1|\theta_1)$ and $U(a_1|\theta_2)$, designating a successful and unsuccessful drill respectively, are evaluated with the constant partial risk averse utility function used by Binswanger. The certainty equivalent M is the net present value of the prospect at the opportunity costs of capital. For example, the utility of a successful drill is given in (2). An amount equal to the size

$$U(a_1|\theta_1) = (1-S) [NPV(a_1|\theta_1) + S]^{(1-S)} \quad (2)$$

where $NPV(a_1|\theta_1)$ = the net present value of a successful drill

S = a scalar

of the investment is added to each certainty equivalent M because the utility function is not defined for losses. Rosegrant and Herdt (1982) used the same approach which is conceptually motivated by the observation that the investment in in-well boring is made with a portfolio which is available for investment and speculation. Spending this amount will not affect subsistence of the household nor will failure ruin the farmer.

An ex-post analysis based on mean benefits from drilling

To arrive at inferred values for S , the acceptance frontier (Yaari, 1969) is mapped for combinations of S and $P(\theta_1)$ that would be consistent with a decision to drill (Figure 1). The expected utilities of the two acts drilling and not drilling, are calculated parametrically using values for S and $P(\theta_1)$ within a reasonable range. $P(\theta_1)$ is permitted to range from 0.1 to 1.0 and S from 0.1 to 5.0. The break-even point where the utility of drilling is equal to the utility of not drilling for all combinations of S and $P(\theta_1)$ is plotted in Figure 1 which suggests that the drilling

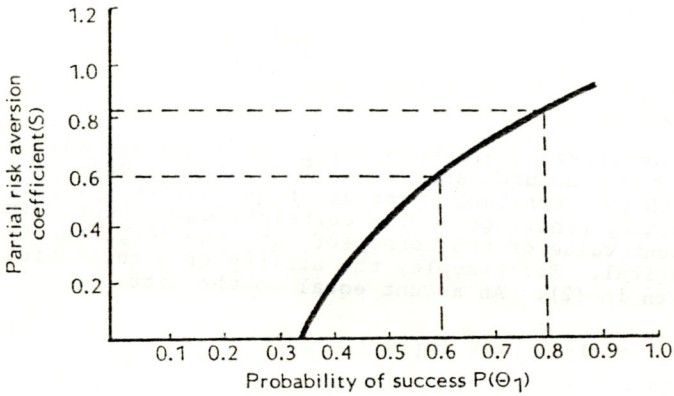


Figure 1. Acceptance frontier for drilling in well bores

decision is indeed sensitive to farmers' risk attitudes and perceptions. For a profit maximizer the break-even probability of drilling is about 0.35. In contrast, a decision maker strongly averse to risk would have to perceive probabilities of success greater than 0.8 or 0.9.

From the survey results, the mean probability of finding water from in-well drilling is about 0.6. Figure 1 suggests that the value for the partial risk aversion coefficient is approximately 0.6. This in turn is roughly consistent with Binswanger's results of moderate (0.51) to intermediate risk aversion (1.189).

Conclusions based on the inferred risk preferences are subject to three important caveats. First, revealed risk preferences only provide an upper bound estimate on the level of farmer risk aversion. Second, the assumed utility function is not defined on losses and is indexed with respect to changes in income as final states of wealth are not the carriers of value. Investment options other than drilling are not considered. Third, benefits are measured from village average values and not from individual farmer's perceptions. About the most we can say is that the preferences revealed in drilling decision weakly suggest that farmers are at most moderately to intermediately averse to risk.

An ex-ante analysis based on individual farmer perceptions

To generate more information on the distribution of risk preferences revealed from the real-world decision of in-well boring, perceptions were assessed for a sample of owners of 30 dug wells in the study villages. For 16 of these wells farmers planned to drill in-well bores in the future.

Some comparative information on resource endowment and perceptions is presented in Table 1 for the farmers (interviewed in the first survey) who have drilled and for the two subsamples of farmers interviewed in the second survey who do and do not plan to drill. On average, farmers who have drilled are richer, own more land, and have more individually owned wells than those who have not drilled. But these mean differences are not statistically significant ($P < .01$). The mean cost estimates are about the same for the three groups. Although the expected increase in paddy area is higher for those who plan to drill -- indeed these estimates seem optimistic and inconsistent with the past experience of those farmers who have drilled -- the mean differences in expected area expansion are not statistically significant between the two groups. What is significantly different ($P < 0.1$) are the mean probabilities of success of those who plan to drill and those who do not. The differences in the perception of the probability of success appear to be the dominant force in determining the decision to drill in-well bores.

Table 1. Comparing resource endowments and perspectives of farmers who have drilled, who plan to drill and who do not plan to drill

Resource endowment perceived costs and benefits	Farmers who		
	Have drilled	Plan to drill ^c	Do not plan to drill ^c
Resource endowment			
Farm size (has)	15.98	5.99	9.91
Wealth (Rs) ^a	33,000	22,000	16,900
Number of shareholders in the well	1.30	1.90	3.60
Perceptions			
Drilling cost/well (1982 Rs.)	1,860	3,150	2,964
Chance of success	0.61	0.78	0.54
Increase in rainy season paddy (has)	1.11	2.48	1.86
Increase in postrainy season paddy (has) ^b	0.89	0.92	0.71
Certainty equivalent (Rs)	-	5,809	1,876
Number of observations	19	16	14

a. Capitalized net income from crop production

b. For a successful drill

c. ** indicates significantly different means between those who plan to drill and those who do not plan to drill in a two-tailed t test at (P .01).

Repeating the method described in the previous subsection, the value of the constant partial risk aversion coefficient that would lead to indifference between drilling and not drilling have been estimated for each of the 30 farmers. The mean estimate for the coefficient is 0.87 with a standard deviation of 0.30. This result confirms Binswanger's finding from experimental games that most farmers are moderately to intermediately risk averse. Again, these results are weak because the assumptions made to arrive at them are fairly strong.

EVALUATING THE VALUE OF ELECTRO-RESISTIVITY SOUNDINGS

All but one of the respondents who planned to drill knew about the possibility of employing electro-resistivity soundings to predict water bearing fissures. They had faith in electro-resistivity soundings and thought that it would give a correct prediction about 67% of the time.

The 15 farmers who planned to drill and who knew of electro-resistivity sounding were asked how much they would be willing to pay for a forecast from this device. Unfortunately, several farmers reported the amount charged for the service instead of the amount they would be willing to pay. Still, their confidence in electro-resistivity sounding in terms of their likelihood probabilities was significantly correlated ($p < .05$) with what they were willing to pay.

To compute the value of electro-resistivity sounding, discrete decision analysis as described in Anderson, Dillon, and Hardaker (1977, p.118) was used. The value of the predictor was estimated for each respondent with the assumed utility function and with the breakeven values of S inferred in the previous section. The value of electro-resistivity sounding is plotted against what farmers stated they would be willing to pay in Figure 2, which suggest two observations. First, for many farmers the potential economic value of a forecast from an electro-resistivity sounding greatly exceeds its current cost of Rs. 150 to 175 per sounding. Second, the potential value is also greater than what most farmers are willing to pay. Why this apparent demand for electro-resistivity soundings is not fulfilled in practice should be a subject for further research.

CONCLUSIONS

Drilling bores to improve water yield in dug wells is a profitable but risky activity. An average internal rate of return of about 30% suggests a strong demand for drilling.

Inferred risk preferences estimated from the drilling decision are broadly consistent with those measured in experimental games and indicate that farmers are moderately

EVALUATING THE VALUE OF ELECTRO-RESISTIVITY SOUNDINGS

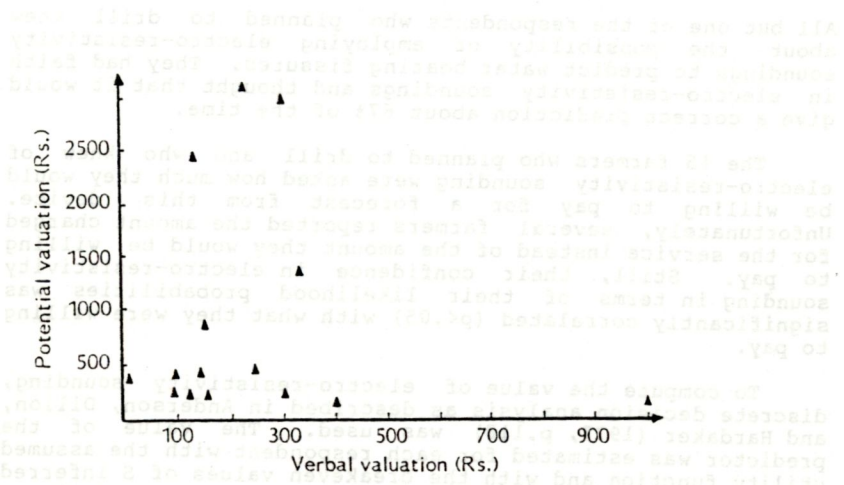


Figure 2. Verbal and potential valuation of a forecast from electroresistivity soundings.

CONCLUSIONS

Drilled holes to improve water yield in dug wells is a practicable but risky activity. An average potential rate of return of about 10% suggests a strong demand for drilling. Inferred risk preferences estimated from the drilling decisions are broadly consistent with those suggested by experimental games and indicate that farmers are moderately

to intermediately risk averse. This represents a weak validation of the experimental method to measure risk attitudes because the inferred preferences are upper bound estimates of risk aversion and are derived from a utility function measured only on gains.

Differences in risk perceptions, particularly on the chances of successfully finding water, appears to significantly condition the drilling decision. The mean subjective probability of intercepting water bearing fissures for dug well owners who had drilled was about 45% higher than for dug well owners who had not drilled.

For many farmers who plan to drill, the value of information from prospecting methods such as electro-resistivity soundings substantially exceeds its cost. Yet few farmers purchase such services. Further research is needed to better understand why farmers do not act on their beliefs about electro-resistivity soundings.

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