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Borewell Failure in Drought-Prone Areas of Southern India: A Case Study

INTRODUCTION

Groundwater is a common property resource of vital importance to agriculture in the hard rock areas of peninsular India. It forms the lead input for agricultural development especially in the semi-arid tropics of Southern India. In Karnataka State, groundwater forms the principal source of irrigation in the dry districts of Kolar, Bangalore, Tumkur and Chitradurga. The state has witnessed three distinct phases in the pattern of groundwater development and investment. The first phase of groundwater development was dominated by manual lift-dugwells of 25 feet to 40 feet depth till the 1960s. In the second phase (between 1960 and 1980), the development was characterised by centrifugal pump led dug-cum-borewells of 40 feet to 60 feet depth (extending to even 80 feet in some cases). After the 1980s, extraction shifted towards submersible pump led deeper surface borewells of depths beyond 200 feet. The investment on borewells and water extraction structures have both grown phenomenally.

The decision to invest in borewell irrigation is characterised by two features in the hard rock areas. First, the investment is characterised by high degree of uncertainty in striking an adequate quantity of good quality irrigable water as reflected by high well failure probability. Second, the transaction cost of uncertainty measured in terms of the cost of the number of failures preceding a given number of successful wells and the cost of abandoning use of well water due to its poor quality becomes a sunken cost. Given the failure in the drilled borewell and the farmer's commitment to irrigate land by groundwater, the farmer would drill another well. If the failure rate is higher, the farmer would make more attempts till he/she gets a successful well. In this process, the farmer invests on failed well(s) as well as on the successful well. The investment on failed well cannot be left out since this investment is in the genuine process of obtaining a successful well. Hence, the investment both on failed and successful wells is considered as an economic investment. As the probability of well failure increases, it increases the number of failed wells preceding (the given number of) the successful wells. This increases the magnitude of sunken cost.

In the efforts towards getting a successful well, the farmers invariably face the problem of division of investment between 'well failure(s)' and 'well success(es)'. This calls for a pre-determined mental make up to allocate a certain proportion of the total investment required in drilling wells among failures and successes. The farmers should be made to realise that well failure is an integral part of well success, accounting for the transaction costs. The expenditure on well failure, hence, can be considered as an economic investment from this view-point. Throughout this study, the investment on failed borewell includes only the water divining and drilling charges. The investment on successful borewell includes the charges for water divining, drilling and casing pipe.

Scope of the Study

A modest attempt has been made to assess the probability of well failure by using Negative Binomial Distribution (NBD).[1] The hypotheses of the study are: (1) the NBD effectively measures the probability of well failure in hard rock areas; and (2) the NBD probabilities in 'dark', 'grey' and 'white' areas reflect the degree of groundwater exploitation in the descending order of magnitude as measured by the State Department of Mines and Geology.[2]

METHODOLOGY AND DATA BASE

Methodology

Modelling well investment at micro and macro levels calls for a careful study of the distribution of well failure preceding a given number of well successes in large hydro-geological tracts. Let us assume that a farmer drills 'n' number of wells. The 'n' Bernoulli trials in drilling comprise 'x' number of failures or failed wells preceding 'r' number of successes or successful wells. Hence, the total number of trials 'n' to be performed in drilling is equal to the number of failures plus the number of successes, i.e., n = (x + r). Empirically, the NBD is found to explain this pattern of distribution of 'x' failures preceding 'r' successes.

The NBD is a special case of binomial distribution. The key characteristic is that the variance of the distribution is greater than the mean. The number of trials (n) is a random variable, while the number of successes (r) is fixed. The probability model is given as:

$$P(X=x) = (x+r-1)C(r-1)p^r q^x$$

where the probability of well success is

P = (mean of x) / (variance of x) and q = (1-p) is the probability of failure.

The NBD recursive formula is:

$$P(x+r) = (x+r)/(x+1).q.P(X); \; P(X=0) = P(0) = p^r$$

We estimate the total investment to be set aside in order to obtain one successful well by using the expression:

{(1/p) (p) (cost of successful well) + (1/p)(q) (cost of failed well)}

= {(cost of successful well) + (q/p) (cost of failed well)}.

The rationale is to weigh the cost of successful well with the associated probability of success and the total number of trials required to obtain one successful well; and to weigh the cost of failed well with the associated probability of failure and the total number of trials required to obtain one successful well.

Data Base

The data pertain to wells drilled between 1980 and 1992. All the costs of drilling are at 1992 prices. Primary data for this study are collected from a random sample of 151 borewell farmers from a white taluk (Chintamani: 56 farmers), grey taluk (Srinivaspur: 45 farmers) and a dark taluk (Devanahalli: 50 farmers) of hard rock areas of Karnataka during the year 1992.

Definitions/Assumptions

Irrigation well considered in the study area is a surface borewell with 6 inch diameter fitted with a submersible electrical pumpset. A failed well is defined as one where the water yield is below 1000 gallons per hour at the time of drilling.

Since the NBD is based on independent Bernoulli trials, we assume that a farmer's well drilling activity is independent of other already existing well(s) or new wells, within the farm and between farms. The event of dry well, i.e., complete well failure (zero litres per second) in any of the drilling attempts is ignored in this study. While fitting the NBD, the number of 'successes' or 'failures' irrespective of their order of occurrence is considered.

RESULTS

The sample information on average depth of wells, cost of drilling and crops grown is presented in Table I. The information on cost of a failed well provided is on the cost of drilling alone (without the cost of pipes or casing) to a depth of 350 feet in the 'dark' area, 250 feet in the 'grey' area and 200 feet in the 'white' area. In the case of dark and grey areas, the casing cost is for 100 feet depth at Rs. 70 per foot for successful well. In the case of white area, the casing cost is for 75 feet depth at Rs. 70 per foot for successful well. The drilling cost is Rs. 50 per foot.

TABLE I. SALIENT FEATURES OF COST OF BOREWELLS IN GROUNDWATER EXPLOITED AREAS IN 1992

Particulars (1)	Dark taluk (2)	Grey taluk (3)	White taluk (4)
1. Average well depth (ft)	350	250	200
2. Groundwater exploitation (per cent)	> 85	65 to 85	< 65
3. Cost of drilling (Rs.)			
(a) With casing	24,500	19,500	15,250
(b) Without casing	17,500	12,500	10,000
4. Major crops grown with well irrigation	Mulberry, vegetables and grapes	Vegetables and mulberry	Vegetables and mulberry

Source: Primary data from the study area, 1991-92.

The estimates of the mean, variance and probability of failure and the Chi-square test of goodness of fit (see Table II) all indicate that the NBD provides the best fit for the data considered in all the three areas. The characteristics of the NBD, viz., (i) mean being less than variance and (ii) the Chi-square value of goodness of fit being non-significant, are evident for the data from all the three areas. Thus the observed data on frequency distribution of well failures is best explained by the NBD. The estimated NBD probability of well success varied from 0.55 to 0.659 across the three areas, indicating that there is no marked difference in respect of well success across the dark, grey and white areas. This indicates that on an average, for every 100 borewells drilled, 45 wells failed in the case of 'white' area as against 44 failures in 'grey' and 40 well failures in the 'dark' area. This tells us that marked differences in the probability of well failure do not exist across the three areas. But there may be dark patches in white or white patches in dark or white in grey or any other combination. This also indicates that the scientific hydro-geologic base for the declaration of dark, grey and white areas needs to be strengthened to reflect the ground truth. Such *de jure* and *de facto* discrepancies in the declaration of groundwater exploitation areas have implications on the refinance policies of the National Bank for Agriculture and Rural Development (NABARD).

TABLE II. SUMMARY OF THE PARAMETERS OF NEGATIVE BINOMIAL DISTRIBUTION FOR DIFFERENT AREAS

Area (1)	Mean (X) (2)	Variance V(X) (3)	Probability of well success (X)/V(X) (4)	Chi-square value (5)
Dark	1.11	2.54	0.6	3.81^{NS}
Grey	1.035	1.57	0.659	2.92^{NS}
White	1.2	2.16	0.55	2.16^{NS}

Note: NS = Not significant at 1 per cent level.

It is to be noted that the NABARD offers refinance for drilling irrigation wells only in 'white' area after meeting the technical norms. The NABARD also offers refinance in the 'grey' area only after confirmation that the yield of the borewell is above 1000 gallons per hour at the time of drilling. In the 'dark' area, the NABARD does not provide any refinance, because of over-exploitation of groundwater. The anomaly in the methodology used in the classification of groundwater use areas results in areas which were actually declared as 'dark' showing promises of good groundwater potential (for example, Molkalmur taluk in Chitradurga district, Karnataka). On the other hand, some other taluks which were declared as under-exploited, for example, 'white' area (Srinivaspur taluk of Kolar district, Karnataka) or 'grey' area (Mulbagal taluk of Kolar district, Karnataka) present over-exploitation scenario.

Estimation of Total Investment for Obtaining Successful Well(s)

The total investment to be set aside to obtain a successful well considers the cost of successful well as well as the cost of well failure with weightages, since well failure is an integral part of the well success in hard rock areas. As evident from Table III, the total cost of well drilling differs with each block and varies with the probability of well failure and the number of successful wells envisaged to be drilled.

A farmer in dark area has to set aside a sum of Rs. 27,850 to obtain one successful well which includes weightages given to the probability of successful as well as the probability of failed well and the corresponding costs involved. In the grey area, a sum of Rs. 21,729 has to be set aside to obtain a successful well. In the white area, a sum of Rs. 23,440 has to be set aside to obtain a successful well.

TABLE III. ESTIMATION OF TOTAL INVESTMENT IN DRILLING SUCCESSFUL WELL

Area	Cost of successful well (Rs.)	Probability of well success	Cost of failed well (Rs.)	Probability of failed well	Total number of wells to be drilled to obtain one successful well	Total investment (Rs.) (2)+(5)*(6)*(4)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dark	19,500	0.60	12,500	0.40	1.67	27,850
Grey	15,250	0.659	12,500	0.341	1.52	21,729
White	15,250	0.55	10,000	0.45	1.82	23,440

In the dark area, about 40 per cent of the wells were more than 350 feet deep. In the grey area, about 40 per cent of the wells were 250 to 300 feet deep. About 50 per cent of the wells in the white area were 200 to 250 feet deep. The analysis shows that the probability of failure does not differ to a great extent among the dark, grey and white areas. Hence, the classification of areas according to well failure probability does not match with the classification by the Department of Mines and Geology. In all the dark, grey and white areas, the farmers' drilling behaviour is myopic as they feverishly drilled the wells and experienced high failure rates.

IMPLICATIONS

The study describes interesting dimensions of the well drilling behaviour of farmers in the hard rock areas. With the probability of well failure around 0.4, the estimation of total investment in drilling borewells for irrigation purposes is crucial as it provides vital information (1) at micro level for the farmers to set aside sufficient funds for borewell drilling and (2) at macro level for policy makers in earmarking adequate funds for programmes like '100 Wells Scheme' and 'Ganga Kalyan Yojana'. Such macro irrigation well drilling programmes and other macro level schemes of the Government can properly estimate the total (budget) cost of drilling as suggested, instead of just assuming that they would be able to provide a successful well in the very first attempt. Such an assumption would under-estimate the magnitude of investment in drilling irrigation wells, given the fact that in the hard rock areas the well failure probability is as high as 0.4. The well failure probability for different classes of farmers could be a worthwhile information useful for the refinance policies of the NABARD in white and grey areas so that these programmes could be made more effective and purposeful to have pervasive welfare implications. The unit costs of NABARD for borewell irrigation should be based on the total investment concept used in this study which gives proper weightage to the cost of successful and failed well. This will enable the farmer for better utilisation of the sanctioned loan for investment in borewell irrigation. The well failure probability provides a better indicator of the extent of groundwater exploitation in hard rock areas. The classification of groundwater areas by the Department of Mines and Geology can also consider incorporating the probability of well failure in addition to the other hydro-geological variables they consider.

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NOTES

1. Associated studies are Chandrakanth *et al.* (1986) and Engelhardt (1985).
2. The State Department of Mines and Geology annually classifies the different taluks into 'white', 'grey' and 'dark' categories depending upon the degree of groundwater utilisation. The taluks with utilisation below 65 per cent are 'white', those with utilisation between 65 per cent and 85 per cent are 'grey' and those with more than 85 per cent are classified as 'dark' taluks.

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