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Considering the imperfections of competition and the possible range of local market price fluctuation which could still be consistent with integrated markets, it is not implausible that the overall correlation coefficient for the group of markets could be much lower than has been indicated in some studies.

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DEMAND FOR IRRIGATION: A CASE STUDY OF GOVERNMENT TUBE-WELLS IN UTTAR PRADESH

SCOPE OF THE STUDY

The purpose in this short paper is to present some estimates of elasticity of demand for irrigation water with respect to four variables, namely, (1) price of farm output, (2) price of irrigation water, (3) normal rainfall, and (4) deviation fiom normal rainfall. A single-equation linear model has been employed to the time-series data in respect of State tube-wells in Uttar Pradesh. The study provides a basis for important policy implications which are spelt out towards the end of the paper.

THE DATA

The basic data about the level of utilization of tube-wells are obtained from the Office of the Chief Engineer, Irrigation Department, Uttar Pradesh. Another useful source has been the administration report of the Irrigation Department, U.P.[1] Instead of using the all-India statistics of wholesale prices of agricultural commodities, the index numbers of wholesale prices of agricultural commodities compiled by the Office of the Director of Economics and Statistics, Uttar Pradesh, have been used to represent farm prices received by U.P. farmers drawing water from State tube-wells. Other sources of data are listed at appropriate places in the text. The measurement of the irrigation rate for tube-well water needs three observations. First, it is an effective rate, in the sense that any rebate or surcharge on basic rate is fully taken into account. Second, only the basic rates for electricity-driven tube-wells could be considered. Third, till September, 1967 tube-well water in U.P. was sold under one-part tariff based on volume of water alone. Thereafter, a two-part but optional tariff has come into force. This, however, does not affect our results because our time-series analysis is confined to 1946-67 during which period strictly volumetric basis of rate fixation prevailed. In point of fact, it is this volumetric basis of irrigation rates, unlike the crop basis of rates prevailing in most major and minor irrigation works, that makes it possible to undertake a study concerning demand for irrigation water.

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1. Published annually under the title Irrigation Administration Report of Uttar Pradesh by the Superintendent, Printing and Stationery, Uttar Pradesh, Allahabad.

The measure of water consumption in this study is the average annual running hours per tube-well. It has been possible to use running hours as a proxy for tube-well water consumption because of the fact that all the tube-wells, in terms of their water discharge rate, are of the same size, namely, 1.5 cusecs or 30,000 gallons per hour. We believe that this is decisively a better measure of demand for irrigation water than the conventional measure of acreage irrigated, whereby the intensity of irrigation is ignored.

Finally, a few words may be said about tube-wells being in development phase. A newly commissioned tube-well, from which water is being released for irrigation, according to the State Irrigation Department, is deemed to be in development phase for three years after the date of its commissioning. This development stage is essentially a formative stage in the sense that any one or more of the following situations may prevail since the commissioning of a tube-well.

1. The full complement of its water courses for the entire command area is not constructed due to difficulty in acquiring land for the main water courses.

2. The water courses, though complete, are not fully lined because of (*a*) shortage of lining materials and (*b*) lack of synchronization in constructing water courses and the central installation of a tube-well.

3. The farmers have not fully constructed their own field channels for some reasons.

THE MODEL

A linear multiple regression model of the following type has been used:

$$Y = a + \sum_{i=1}^{5} b_i X_i$$

where Y = annual running hours per tube-well in operation in mid-year.

X_i = 'i' th explanatory variable.

b_i = the regression coefficient of X_i.

a = constant.

The model has been estimated by the method of least squares. Being a single-equation model, the estimates do suffer from the single-equation bias of an unknown magnitude. The expected signs of the regression parameters are that all b_i's other than b_2 are negative if X_i's are defined as follows:

X_1 = Index of actual rainfall with normal rainfall (X_3) equal to 100
or
actual rainfall in millimetres in the case of Etah district study.

$X_2 =$ Index number of agricultural wholesale prices with 1953=100.

$X_3 =$ The weighted average of districtwise normal rainfall in millimetres; the weights being proportional to the number of tube-wells in a district.

$X_4 =$ Effective irrigation rate in nPs per 10,000 gallons of water.

$X_5 =$ The percentage of tube-wells in development stage.

Three observations about the variables X_2, X_3 and X_5 may be in order. First, the index number of agricultural prices (X_2) is available on a calendar year basis, whereas the explained variable (Y) is on a financial year basis. An attempt is made in this paper to introduce a dynamic element in the model by bringing about a 3-month lag between Y and X_2 as follows. The value of Y in a year, say 1960-61, is regressed on the value of X_2 in 1960. In doing so, we have departed from the conventional practice of lagging X_2 by a full crop year in studies relating to farmers' response to prices. The rationale for doing so is spelt out in the following para.

The allocative decisions may be distinguished in the following way: (1) decision with regard to area to be allocated to a crop from his given holding and (2) decision with regard to the optimum quantity of a variable input for his given crop acreage. For a decision of type (1), the usual lag of one crop year has been found to be a good proxy for farmers' expectations in respect of crop prices in several studies in the literature. For a decision of type (2), the conventional procedure is questionable. The price of a crop ruling over the growth period of the crop, has a definite bearing in determining a farmer's decision on buying the quantities of the variable inputs for which he pays on a *pro rata basis.* Tube-well water is purchased variable input whose intensification would be partly determined by the course of agricultural prices since the date of sowing (or decision to sow) of a crop. For, he is buying and applying this input not in one lot at the time of sowing but in numerous lots over the entire gestation period of a crop. For instance, the decision to buy the quantum of irrigation water towards the maturing stage of a crop is likely to be influenced *inter alia* by crop prices of the immediate past rather than of a year ago.

The second observation pertains to the introduction of the variable normal rainfall (X_3). There has been a perceptible shift in the regional dispersal of State tube-wells in U.P. Back in the 'thirties the State Government started installing tube-wells in the comparatively low rainfall districts of West U.P. By the beginning of the planning era in 1951-52, 96 per cent of the tube-wells were in West U.P. The 'fifties witnessed a major locational shift in installing new tube-wells. Of the 4,000 tube-wells so added, three-fourths went to Eastern and Central parts of U.P, which experience more rainfall than the Western parts of the State. The irrigation engineers (including the administrators) have been trying to explain away the falling trend in the aggregate utilization of State tube-wells in terms of the locational shift, with the tacit assumption: the higher the normal rainfall, the lower the expected utilization of an irrigation work like State tube-wells where the rate is tied up, unlike in canal irrigation, essentially with the quantum of water purchased. The importance of the argument of locational shift is being tested here in the model. The third noteworthy observation pertains to the variable X_5. The rationale for introducing this variable, which partakes the character of a variable partly on the demand side and partly on the supply side, is that the irrigation engineers and administrators of the State Irrigation Department strongly believe that the downward trend in the level of utilization of State tube-wells is, among other things, due to the increasing proportion of new tube-wells being in a development phase.

Before closing this section, it may be pointed out that the model has two noteworthy specification errors and one noteworthy error of observation in variable X_2. The specification error emanates from the absence of two explanatory variables that could capture the intra-year variations in rainfall and the crop pattern. *A priori*, it is difficult to say how the absence of these variables affects the estimates of the regression parameters. The error of observation in X_2 arises due to the fact that temporal movements in farm prices received by farmers may not be fully captured by the index of wholesale prices of agricultural commodities.

Both the specification biases could not be rectified because of paucity of readily available data on the two missing explanatory variables and the index of farm prices for U.P. for the period under study. However, our hunch is that these biases are of tolerable magnitudes.

REGRESSION RESULTS

The linear multiple regression equation derived from the basic data in Table I is as follows :

$$Y = 14366 - \underset{(2.67)^{*}}{13.18\,X_1} + \underset{(2.35)}{9.62\,X_2} - \underset{(1.63)}{12.63\,X_3} - \underset{(5.33)}{2.26X_4} + \underset{(6.27)}{5.58\,X_5} \quad \ldots\ldots (1) \qquad R^2 = 0.97$$

(* Standard errors of regression coefficients.)

Contrary to *a priori* expectations, the regression coefficient of tube-wells in development phase (X_5) has a positive sign. However, it need not cause any concern because it is insignificant, with a low t-value of 0.9. What is really noteworthy is the insignificance of the coefficient of irrigation rate for tube-well water (X_4), as its standard error is more than double its own value. All the other three explanatory variables are highly significant at 1 per cent level of significance.

TABLE I—BASIC DATA FOR TIME-SERIES ANALYSIS OF THE STATE TUBE-WELLS : 1946-47 to 1966-67

Year	Y	X_1	X_2	X_3	X_4	X_5
1946-47	3,402	112	72	826	29	14
1947-48	3,355	97	84	826	29	17
1948-49	3,051	128	105	826	29	14
1949-50	3,671	101	124	826	29	12
1950-51	3,536	112	103	826	29	11
1951-52	3,805	90	106	826	44	10
1952-53	3,650	86	103	839	44	12
1953-54	2,967	105	100	864	63	18
1954-55	2,659	88	83	890	63	29
1955-56	2,184	136	68	908	50	38
1956-57	1,751	132	86	925	50	40
1957-58	2,234	92	95	941	50	37
1958-59	1,937	131	108	939	50	31
1959-60	2,306	85	106	940	50	25
1960-61	2,005	114	101	939	50	19
1961-62	1,623	128	99	938	63	14
1962-63	2,151	90	104	940	63	12
1963-64	2,124	108	112	937	63	14
1964-65	2,389	103	150	933	63	14
1965-66	3,088	75	164	935	63	13
1966-67	3,369	79	169	938	63	11

Notes: (1) Y stands for annual running hours per tube-well in operation in mid-year.
(2) X_1 stands for the index of actual rainfall with normal rainfall taken as 100.
(3) X_2 stands for the index number of agricultural wholesale prices, with 1953=100.
(4) X_3 stands for the weighted average of districtwise normal rainfall in millimetres, the weights being proportional to the number of tube-wells in a district.
(5) X_4 stands for irrigation rate for tube-well water in nPs per 10,000 gallons.
(6) X_5 stands for percentage of tube-wells in development stage.

Deleting X_4 and X_5 variables from the regression, the equation (1) assumes the following shape:

$$Y = 14298 - \underset{(2.49)^*}{12.55\,X_1} + \underset{(1.85)}{8.34\,X_2} - \underset{(0.83)}{12.48\,X_3} \quad .. \quad .. \quad (2)$$

$R^2 = 0.9461$

$\bar{R}^2 = 0.9334$

(* Standard errors of regression coefficients.)

Normal rainfall variable X_3 carries the largest explanatory power, with a value of —0.96 for its partial correlation coefficient with Y. One possible reason for this high explanatory power of X_3 is its relationship ($r = 0.78$) it has with X_4. In point of fact, the statistical insignificance of X_4, noted earlier, could as well be attributed to this problem of multi-collinearity. In order to have a firmer idea about the role of X_4 in influencing the farmers' demand for water, it is desirable to look into another set of data that is free from this problem of multi-collinearity. The following analysis based on the Etah district data satisfies this statistical criterion. The data in respect of Etah district analysis are set out in Table II. The data for the ten tube-wells are culled from a mimeographed study entitled "Economic Study of State and Private Tube-wells in Varanasi and Etah Districts of U.P." prepared by the Planning Research and Action Institute, Lucknow, in May, 1968.

TABLE II—BASIC DATA ABOUT TEN TUBE-WELLS IN ETAH DISTRICT

Year	Average running hours per tube-well (Y)	Rainfall (millimetres) (X_1)	Index number of agricultural whole sale prices (X_3)	Irrigation rate per 10,000 gallons (X_4) nPs
1952-53	4,286	596	103	39*
1953-54	3,430	657	100	63
1954-55	2,919	611	83	63
1955-56	2,519	837	68	50
1956-57	1,782	897	86	50
1957-58	2,130	621	95	50
1958-59	2,010	1,076	108	50
1959-60	3,075	572	106	50
1960-61	1,972	1,168	101	50
1961-62	2,119	945	99	63
1962-63	2,813	533	104	63
1963-64	3,359	828	112	63
1964-65	3,842	695	150	63
1965-66	3,953	544	164	63
1966-67	5,128	539	169	63

* In view of the fact that cane is an unimportant crop in the irrigated agriculture of Etah district, this rate refers to the effective irrigation price for crops other than sugarcane.

The level of utilization of the ten Etah tube-wells was quite high in 1952-53 as they had been constructed mainly during the first decade of tube-well development in Western U.P.[2] However, the changing pattern of utilization

2. The programme of installing State tube-wells began in U.P. in the mid-thirties.

of these tube-wells between 1952-53 and 1966-67 is broadly similar to the one found in the case of all the State tube-wells taken together. The utilization tends to fall sharply during the 'fifties and then rise during the 'sixties.

The precise influence of actual rainfall (X_1), index number of agricultural prices (X_2) and price of tube-well water (X_4) on the dependent variable Y is as follows:

$$Y=3293-\underset{(0.82)}{2.33\ X_1} + \underset{(6.23)}{19.97X_2} + \underset{(21.74)}{13.07X_4}\ldots\ldots \qquad (3)$$

The R^2 of equation (3) is about 0.7223, which diminishes to about 0.6214 when adjusted for the 11 degrees of freedom of the equation. This not too high value of the coefficient of determination indicates that some relevant variables, like crop pattern, are missing. Keeping in mind this limitation on the equation, we may proceed ahead with the interpretation of the results of this regression analysis.

All the three explanatory variables in equation (3) have the right expected signs. While rainfall (X_1) and agricultural prices (X_2) turn out to be with significant regression coefficients (at 5 per cent level of significance), the regression coefficient of tube-well water rate (X_4) does not become significant even when the level of significance is lowered to 50 per cent.[3] In the present case, the insignificance cannot be attributed to any phenomenon of multi-collinearity. For, the coefficients of correlation of X_4 with X_1 as well as X_2 are small in magnitude, as can be seen from Table III.

TABLE III—CORRELATION MATRIX FOR DATA IN RESPECT OF TEN TUBE-WELLS OF ETAH DISTRICT

X_1	X_2	X_4	Y
1·0000			
—·3569	1·0000		
—·2569	·4330	1·0000	
—·6720	·7176	·2741	1·0000

Note: X_1 stands for rainfall; X_2 stands for agricultural prices; X_4 stands for irrigation rate, and Y stands for running hours per tube-well.

The values of the elasticity of irrigation demand with respect to X_1, X_2 and X_4, at the mean levels of these variables, are (—) 0.57, 0.72 and (—) 0.24 respectively.[4] What is striking is that the demand is quite elastic with respect to agricultural prices, and not with the price of tube-well water.

3. Dropping X_4 from the equation (3), we get the following equation:

$$Y=2669-\underset{(0\cdot79)}{2\cdot27X_1}+\underset{(5\cdot61)}{18\cdot55\ X_2},\ R^2=0\cdot732,\ \bar{R}^2=0\cdot6415$$

4. These may be compared with the values of elasticity coefficients of (—) 0·48 for X_1, 0·33 for X_2 and (—) 0·41 for X_3 that emerge from the equation (2).

The values of elasticity coefficients emerging from the Etah district data are certainly not representative of the better part of Uttar Pradesh. Because of low natural precipitation (about 700 mm.) the agriculture in Etah is distinguished by a crop pattern that has two distinct features: (*i*) emphasis on millets and (*ii*) little share of commercial crops, with sugarcane accounting for a negligible proportion in the whole. These distinctive characteristics are representative of the nine districts of South-Western U.P.[5] Therefore, the above magnitudes of elasticity are relevant for this region of U.P.

IMPLICATIONS

(1) The upshot of the time-series analysis is that the level of utilization of the tube-wells is more sensitive to the state of agricultural prices rather than the price of tube-well water. This will suggest that the phenomenon of under-utilization of the newly-created irrigation potential that was noticed in the 'fifties could be attributed to the depressed price level of agricultural commodities during 1953-56 rather than the absence of right promotional price policy for irrigation water.

(2) There is a widespread feeling that irrigation water is seriously under-priced in India, with the result that the Government incurs substantial losses in running the irrigation projects. State tube-wells in U.P. are no exception in this regard. The financial plight of the State tube-wells is summed up in Table IV. It is estimated that two-thirds of the revenue gap would remain unabridged even if all the tube-wells had worked to their capacity output of 3,800 hours per year.[6] This gap could be covered only by raising tube-well tariff by 66 per cent. If that were done, the irrigators were not likely to cut-back their demand for tube-wells water, as the demand is not found to be elastic with respect to the price of tube-well water. In point of fact, our hypothesis is that the utilization of irrigation potential of the tube-wells would have been better than what has actually prevailed. For, a concern that does not break-even financially is forced to neglect routine maintenance of plant and machinery, giving rise to untimely breakdowns. Because of paucity of funds, prompt repair is not forthcoming. Therefore, a correct price policy can remove bottlenecks on the supply side. The farmers, especially their political leaders, must realize that under-pricing of water ultimately militates against their long-term as well as short-term interests. While financial losses eat into investible funds, untimely and prolonged stoppages can be ill-afforded in agriculture where timeliness is the essence of a service.

5. It comprises of Agra, Aligarh, Badaun, Etah, Etawah, Farrukhabad, Kanpur, Mainpuri and Mathura. *Source* : Planning Commission, Resource Development Regions and Divisions of India, Delhi, 1964.

6. The basis of arriving at this capacity running hours is fully discussed in a larger study by this author : Under-utilization of Minor Irrigation Works: A Case Study of State-owned Tube-wells in U. P., prepared at the Institute of Economic Growth, Delhi, 1969 (mimeo.).

TABLE IV—FINANCIAL RESULTS OF STATE TUBE-WELLS : 1946-47 TO 1966-67

(*Rs. crores*)

Year	Capital outlay	Gross revenue	Working expenses	Net revenue (+) or deficit (—)	Simple interest during the year	Net gain (+) or loss (—)
1946-47	2·664	0·521	0·588	—0·067	0·084	—0·151
1947-48	2.912	0·696	0·673	+0·023	0·095	—0·072
1948-49	3·214	0·533	0·742	—0·209	0·104	—0·313
1949-50	3·932	0·891	0·828	+0·063	N.A.	N.A.
1950-51	4·491	0·987	0·914	+0·073	0·141	—0·068
1951-52	4·633	1·185	1·179	+0·006	0·150	—0·144
1952-53	7·124	1·012	1·145	—0·133	0·208	—0·341
1953-54	9·684	1·085	1·137	—0·052	0·312	—0·364
1954-55	13·055	1·254	1·295	—0·041	0·340	—0·381
1955-56	20·975	1·136	1·564	—0·428	0·587	—1·015
1956-57	24·766	1·285	1·989	—0·704	0·787	—1·491
1957-58	27·704	1·335	2·409	—1·074	0·930	—2·004
1958-59	28·218	1·706	2·862	—1·156	1·012	—2·168
1959-60	29·686	1·814	3·404	—1·590	1·059	—2·649
1960-61	31·180	2·103	3·809	—1·706	1·125	—2·831
1961-62	33.160	2.475	4.318	—1.843	1.211	—3.054
1962-63	36.694	2.134	5.329	—3.195	1.341	—4.536
1963-64	41.333	3.431	5.679	—2.248	1.521	—3.769
1964-65	46.171	4.297	6.430	—2.133	1.730	—3.863
1965-66	53.136	4.430	7.825	—3.395	1.992	—5.387
1966-67	58.656	4.647	8.610	—3.963	2.270	—6.233

Source : The Irrigation Department, Uttar Pradesh.

(3) The negative association between normal rainfall and demand for tube-well water suggests that extension of irrigation facilities in areas of high rainfall is bound to lead to somewhat lower utilization of irrigation potential. Thus, irrigation rates in relatively high rainfall areas have to be relatively high. The only justification for having uniform rates could be either on constitutional grounds or economic backwardness of these high rainfall areas.

(4) The elastic relation between deviation from normal rainfall and demand for irrigation water suggests that large annual fluctuations in revenue receipts of a project can be dampened only by introducing an element of fixity in water rates. The introduction of a two-part tariff for tube-well water is a step in the right direction.[7]

B. D. DHAWAN*

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7. The case for two-part tariff is strengthened by the cost structure of the irrigation industry which is dominated by fixed costs.

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