No. 2. THE STATISTICAL LAW OF DEMAND FOR WHEAT IN THE UNITED PROVINCES.*

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The problem of deriving statistical laws of demand in concrete cases has received considerable attention in other countries. In the United States, Prof. H. L. Moore who began his pioneer research work in this field nearly two decades ago, has followed up the subject in a number of articles and books giving a fairly complete analysis in his latest work "Synthetic Economics" (1929). With the growing interest in the statistical measurement of economic phenomena, other workers have gradually been attracted to the problem and there is already a fairly long list of studies[1] on the subject ranging from the simplest type of analysis to elaborate investigations carried to a high degree of refinement. Unfortunately, however, no attention has so far been paid to the subject in India. An attempt has accordingly been made in this paper to make a preliminary study of the subject with reference to the Wheat crop in the United Provinces which is the second largest centre of wheat production in India.

As variation in supply produces its effect on price in accordance with the law of demand, our problem is to discover the concrete relation between the size of the wheat crop in the United Provinces and its price at the most important and central market of

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[1] A fairly complete bibliography, fully annotated, indicating the nature of the studies together with the statistical methods employed in them is given by Dr. Holbrook Working of the University of Minnesota in an appendix to his article "The Statistical Derivation of Demand Curves" in the *Quarterly Journal of Economics*, August 1925, pp. 539-543. Among later contributions, the following leading studies in English may be referred to :—

(*i*) "The Statistical Determination of Demand Curves" by E. J. Working (*Quarterly Journal of Economics*, February, 1927).

(*ii*) "Statistical Analysis and Laws of Prices" by M. Ezekiel (*Quarterly Journal of Economics*, Vol. 42 (1927-28), pp. 207-12).

(*iii*) "Statistical Laws of Demand and Supply with special reference to Sugar" by Prof. Schultz (*Chicago University Press*, 1928), mostly a reprint of the articles by the author in the *Journal of Political Economy*, October and December, 1925.

(*iv*) "Interrelationships of Supply and Price" by G. F. Warren & F. A. Pearson (Bulletin 466, March 1928, published by Cornell University Agricultural Experiment Station, Ithaca, New York; also contains a very good bibliography of similar studies on pp. 122-125, including some other references quoted separately above.

(*v*) "Factors affecting the Price of Potatoes in Great Britain" by R. S. Cohen (Report No. 15, July, 1930, Farm Economics Branch, Dept. of Agriculture, University of Cambridge).

(*vi*) "The Statistical Derivation of Demand Curves" by Prof. Pigou in the *Economic Journal*, September, 1930.

(*vii*) "Notes on Pigou's Method of deriving Demand Curves" by W. F. Ferger (*Economic Journal*, Vol. 42, 1932, pp. 17-28).

(*viii*) "Studies in Demand : Milk and Butter" by R. W. Gilboy (*Quar. Jour. Econ.*, August, 1932, pp. 671-697).

(*ix*) "The Static and Dynamic in Statistical Demand Curves" by W. F. Ferger (*Quar. Jour. Econ.*, Vol. 47, November, 1932, pp. 36-62).

the province, *viz.*, Cawnpore[2]. The necessary statistical data for thirty-one years from 1900 to 1931 are given in Table 1, column 3 (production of Wheat in U. P. in million

TABLE 1.—PRICE AND PRODUCTION OF WHEAT AND PRICE OF OTHER
CROPS IN THE UNITED PROVINCES

Year	Price of wheat (in Rs. per md.)	Production of wheat (in million tons)	Average of 1901~5=100			Percentage changes as compared with figures of preceding years given in					
			General price index of all crops (I_a)	Price index of wheat (I_w)	Price index of other crops (I_o)	Col. (2)		Col. (3)		Col. (6)	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = u		(8) = x		(9) = y	
						+	−	+	−	+	−
1900	3·335	2·41	133	121	137						
1901	3·160	2·38	107	115	105	...	5·2	...	1 2	...	23·4
1902	2·650	2·40	96	96	96	...	16·1	0·8	...	...	8·6
1903	2·481	2·97	95	90	97	...	6·4	23·7	...	1·0	...
1904	2·361	3·23	89	86	90	...	4·8	8·8	...	...	7·2
1905	3 115	1·00	109	113	108	31·0	...	...	41·2	20 0	...
1906	3·266	2·43	129	119	132	4·8	...	27·9	...	22·2	..
1907	3 651	2·16	137	131	138	13·1	...	...	11·1	4·5	...
1908	4·617	1·67	163	155	162	25·8	..	...	22·7	17·4	...
1909	4·733	2·12	136	154	131	...	8 5	26·0	...	...	19·1
1910	3·403	2·97	127	127	127	...	17·9	40·1	...	...	3·1
1911	3·076	2·92	120	112	122	...	11·9	...	1·7	...	3·9
1912	3·297	3·03	126	120	128	7·2	...	3 8	...	4·9	...
1913	3·700	2 94	141	134	147	12·2	...	. .	3·0	14·8	...
1914	4·391	2·72	165	150	167	18·7	...	.	21·5	13·6	...
1915	4·061	3·04	173	180	171	13·0	...	36·0	...	2·4	...
1916	4·170	2·70	160	151	163	...	15·0	...	11·2	. .	4·8
1917	4·231	3·06	138	154	139	1 5	...	13 2	...	...	2 5
1918	5·602	2·89	200	203	199	32·3	...	...	5·5	23·2	...
1919	6·833	2 80	258	219	261	22·4	...	...	29 4	31·2	...
1920	6·231	3·00	213	226	248	...	9·1	30·4	...	...	5·0
1921	7·382	2 36	258	268	235	18·5	...	...	21·3	2·8	...
1922	6·011	2·67	236	231	231	...	6·4	13·1	...	...	9·4
1923	5·063	2 57	182	184	181	...	26·7	...	3 7	...	21·6
1924	5·017	2 61	187	183	188	...	0·3	2 7	...	3·9	...
1925	6·143	2·42	220	223	210	21·8	...	...	8·2	16·5	...
1926	6·100	2·29	230	222	232	...	0·6	...	5·4	5·9	...
1927	5·581	2·10	217	201	222	...	0·5	8·7	...	...	4 3
1928	5·661*	2·36	218*	206*	222	2 3	...	...	5·2	...	...
1929	5·450	2·48	228*	199	237	...	3·0	5·1	...	6·7	...
1930	5·623	3·31	162	137	171	...	31·0	33·3	...	...	27·8

[2] As the price quotations used in this study are wholesale prices, they do not represent what the producers get nor what the consumers pay. Accordingly the relationship under investigation is neither the usual demand function of the consumers nor the usual supply function of the producers. It is the dealers' or speculators' demand (using the term in an extended sense) *i.e.* "the demand of all those who buy or hold for future disposition."

* These corrected figures were communicated by the Provincial Bureau as a result of reference made to them. (D. O. letter dated the 25th March, 1933, from Dr. R. B. Gupta, Statistician, Provincial Bureau of Statistics, United Provinces).

tons), which have been taken from the official "Estimates of Area and Yield of Principal Crops in India" published annually by the Department of Commercial Intelligence and Statistics, India; while those relating to prices (which represent the annual average of wholesale prices of wheat at the Cawnpore market) have been extracted from Bulletin No. 1 on Agricultural Prices in the United Provinces (Provincial Bureau of Statistics and Economic Research, 1933) and are shown in column 2 of Table 1.

It is necessary to adjust the raw data so as to remove as far as possible the effects of extraneous or disturbing factors which often obscure the relation sought. Various statistical devices are available for this purpose. In this paper the method of 'percentage change', which is a variant of the link-relative method, has been adopted[2]. The percentage changes as compared with the preceding year for wheat prices (u) and those for wheat production (x) are tabulated in column 7 and 8 respectively of Table 1.

A simple correlation analysis of these figures leads to the following results:—

(1) The coefficient of correlation[4] between the percentage change in price (u) and the percentage change in the production of Wheat (x) is $r = -0.59 \pm .12$ with $n = 30$. Also $\bar{u} = 1.64$, $\bar{x} = 2.08$, and $\sigma_u = 16.45$, $\sigma_x = 19.56$.

(2) The concrete relation between price and production of the crop may be put in the form

$$u = 3.123 - 0.498 (x) \qquad \ldots \qquad \ldots \qquad \ldots \quad (1)$$

where (x) represents the percentage change in the production and (u) the most probable value of the corresponding percentage change in price.

(3) The accuracy with which the simple law stated above may be used to estimate the percentage variation in the price of wheat from that of production is given by[5]

$$s = \sigma_u . \sqrt{(1 - r^2)} = 13.3 \qquad \ldots \qquad \ldots \qquad \ldots \quad (1.1)$$

The actual and calculated prices are given in columns 2 and 3 of Table 2, and are shown graphically in Fig. 1.

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[2] There are two chief considerations in the choice of the method: firstly the nature of the demand investigated and secondly the nature of the statistical data used in the study. As Ferger has shown (Economic Journal, 1932, pp. 18) the method of trend ratio is suitable for investigation of consumers' demand while the method of link-relative is more appropriate to the treatment of dealers' or speculators' demand. In the second place owing to the gradual development of crop reporting system in India, figures for earlier years are not strictly comparable with those for later years (vide para. 2 of the introductory note to the Estimates of Area and Yield of Principal Crops in India). The least square method of fitting trend lines gives proportionately greater weight to extreme items and hence the inaccuracies in the figures for earlier years are likely to be magnified to a very great extent in the trend ratio method.

[4] The observed correlation in the sample does not give the best estimate of the 'population' value of the correlation. Suitable corrections (which depend on the size of the sample) can be applied if desired. In the present instance, the correction is of the order of ·02, and has not been taken into further consideration.

[5] For the reason explained in footnote 4, the standard error also requires correction. In the present case, the corrected value of s is 13·5.

TABLE 2.—ACTUAL AND ESTIMATED PRICE OF WHEAT IN THE UNITED PROVINCES

Year	Actual Price of wheat in U. P. [Col. (2), of Table 1]	Price as estimated by		Year	Actual Price of wheat in U. P. [Col. (2), of Table 1]	Price as estimated by	
		Equation (1)	Equation (2)			Equation (1)	Equation (2)
1901	3·160	3·458	2·718	1916	_4·170	5·393	4·041
1902	2·650	3·745	2·851	1917	4·274	4·074	3·995
1903	2·481	2·419	2·557	1918	5·602	4·484	3·212
1904	2·361	2·449	2·465	1919	6·635	6·317	7·361
1905	3·115	2·918	2·987	1920	6·231	6·032	6·170
1906	3·266	2·770	3·532	1921	7·882	7·085	6·717
1907	3·691	3·550	3·495	1922	6·911	7·131	6·651
1908	4·617	4·228	4·444	1923	5·063	7·257	5·771
1909	4·253	4·168	3·671	1924	5·047	5·151	5·710
1910	3·493	3·558	3·806	1925	6·146	5·415	5·875
1911	3·076	3·633	3·420	1926	6·100	6·762	6·370
1912	3·207	3·113	3·202	1927	5·531	6·686	5·872
1913	3·700	3·419	3·755	1928	5·661	5·816	5·612
1914	4·291	4·246	4·318	1929	5·490	5·805	5·961
1915	4·061	3·719	4·163	1930	3·623	4·743	4·859

The above results have been obtained on the simple hypothesis that the price of a crop is governed only by the magnitude of its production. But a more satisfactory way of formulating the law of demand is to express its price as a function not only of the quantity demanded or produced but also of the prices of all other commodities (and services) which enter into the particular economy under consideration. Even if we are unable to include all possible factors in the analysis, it is necessary to consider the prices of other crops to obtain a truer insight into the situation. But instead of considering the prices of other crops separately, we may conveniently combine them into one appropriate index number which may be used for further study without any great loss of accuracy. With this object, a series of index numbers of prices of crops other than wheat at Cawnpore has been constructed (by a method explained below) from the data published in the Bulletin of Agricultural Prices referred to above. The Bulletin shows the weighted general index numbers (arithmetic mean) of prices of all crops including wheat at Cawnpore in which wheat is assigned a weight of 23 out of a total weight of 100. The index numbers of prices of other crops have accordingly been derived with the help of the following formula :—

$$I_o = (100 . I_g - 23 . I_w) / (100 - 23) = I_g - 0·3 (I_g - I_w) \text{ approximately.}$$

where I_o = Index Number for other crops
$\qquad I_w$ = ,, ,, for wheat
$\qquad I_g$ = ,, ,, for crops in general

The series so constructed is shown in column 6 and the percentage changes (y) of the figures in this series are given in column 9 of Table 1.

Denoting the percentage changes in the price and production of wheat by (u) and (x) as before and those in the level of prices of other crops by (y), we obtain the following

relation by the method of multiple correlation (assumed to be linear as a first approximation).

$$u = 0\cdot824 - 0\cdot217\ (x) + 0\cdot838\ (y) \qquad \dots \qquad \dots \qquad \dots \quad (2)$$

with a value of multiple correlation coefficient $R = 0\cdot87$, and residual standard error, $s = 8\cdot1$.

This is indeed a very high coefficient, and consequently the equation stated above enables one to determine the changes in the price of the crop with a relatively high degree of precision. The standard error of the estimate is now reduced to $8\cdot1$ in place of $13\cdot3$ obtained previously. The percentage changes in the prices as derived from the above equation, when transformed into absolute prices in rupees per maund', for the entire period of thirty years from 1901 to 1930, have been plotted in Fig. 2 side by side with the actual prices. It will be noticed that the agreement between the two is very close. The improvement on equation (1) is also considerable, as is evident from a comparison between Figs. 1 and 2. Equation (2) may therefore be regarded as a fairly good approximation to the law of demand in accordance with which wheat prices in the United Provinces fluctuate.

We may derive the relation between price and production of wheat, under the usual assumption of other factors remaining equal, by putting $y = 0$ in equation (2). We thus get

$$u = 0\cdot824\ - 0\cdot217\ (x) \qquad \dots \qquad \dots \qquad \dots \quad (3)$$

and this may be regarded as more satisfactory than the relation given by equation (1).

By the theory of partial correlation, the relationship between u and x when y is held constant is measured by the coefficient of partial correlation $(r_{ux \cdot y})$, the value of which in the present case comes out as $-0\cdot42$. This coefficient measures the correlation between the price (u) and the production of wheat (x), when the effects due to changes in the level of prices of other crops (y) have been eliminated from *both* the price and production of wheat. But in economic questions like the present one, we are more interested to know the relationship between the price and production of wheat after the effects due to level of prices of other crops (y) have been removed from the price of wheat (u) alone. This differs from partial correlation in that the effects due to the eliminated variable are removed only from the dependent variable. It is usually called 'part correlation' and its value in the present case is $_{u \cdot x}r_y = -0\cdot46$. This may therefore be looked upon as the measure of correlation between the production of wheat and its absolute price *i.e.* the price which is free from the effects of fluctuating level of prices of other crops.

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⁶ The individual correlations are $r_{ux} = -0\cdot59$, $r_{uy} = +0\cdot84$, and $r_{xy} = -0\cdot46$, with $\bar{y} = 1\cdot74$ and $\sigma_y = 14\ 15$.

For the reason already stated in footnote 4, the multiple correlation coefficient also requires adjustment for the number of observations and the number of variables used in the sample study. The effect of adjustment is very small in the present case, the adjusted value of R being $0\cdot66$ with the corrected value of the standard error $s = 8\cdot6$.

⁷ *Maund* is the weight in terms of which prices are usually quoted in India. It is equivalent to 82·284 lbs.

Fig. 1. Prices Estimated by Equation (1)

Fig. 2. Prices Estimated by Equation (2)
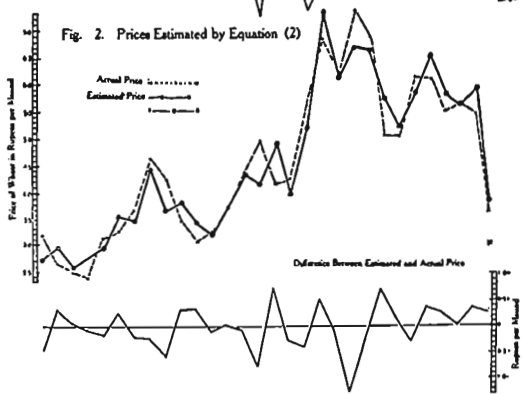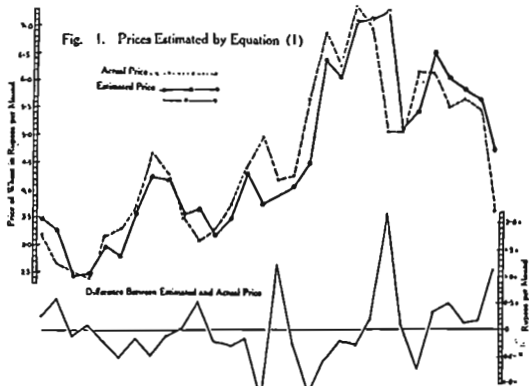
Actual and Estimated Price of Wheat in the United Provinces·

Conclusion.

We may now state the main conclusions which follow from this preliminary study in non-technical language.

(1) There is a significant relationship between the price of wheat at the Cawnpore market and the size of the wheat crop in the United Provinces.

(2) When the general level of prices of other crops remains constant, an increase (or decrease) of one per cent. in the production of the wheat crop in the United Provinces is associated with a fall (or rise) of 0·2 per cent. in its price at the Cawnpore market. In other words, a variation of 10 per cent. in production is likely to cause a change of about 2 per cent. in its price at the Cawnpore market.

(3) When the production of the crop remains constant, a change of one per cent. in the general level of prices of other crops is associated with a similar change of 0·84 per cent. in the price of wheat at the Cawnpore market. In other words, production remaining constant, the price of wheat increases or falls by 8·4 per cent. when there is a rise or fall of 10 per cent. in the level of prices of other crops.

In conclusion, I would like to acknowledge the help I have received from my fellow workers of the Statistical Laboratory, Presidency College, Calcutta.

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