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INTER-FARM RATES OF TECHNOLOGICAL DIFFUSION IN INDIAN AGRICULTURE*

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In Economics the process through which an innovation spreads from firm to firm has been largely neglected. The formal treatment of its workings has never gone beyond Schumpeter's simple assertion that once a firm introduces a successful innovation, a host of imitators appear on the scene. The problem why and how rapidly the use of an innovation spreads from one firm to another has always been relegated to the descriptive parts of the theory with almost complete neglect of its empirical verification.

In agricultural economics the importance of this study has long been recognized. For example, John D. Black in 1945 pointed out that "the process of innovation is particularly interesting to observe in agriculture, because of its gradualness."[1] Unfortunately, a clear overall treatment of technological change as a process in which an innovation is introduced and during which there is a reaction by the recipient farmers and ultimate rejection or acceptance of the new idea of the technique still largely remains unexplored.

The purpose of this paper is to answer the following questions. Once an innovation is introduced by one farmer, how soon do others in the farm sector adopt it? Why some farmers tend to be relatively quicker to introduce an innovation than others? More formally, what factors determine how rapidly they follow the innovator?

The plan of the paper is as follows. Section II takes up a formal analysis of the diffusion process of an innovation. In section III an attempt is made to fit logistic growth functions for three selected innovations to learn something about the ways in which the diffusion process is generated in Indian farm economy. It is the objective of section IV to measure and analyse the quantitative effects of various factors on a farm's speed of response to an innovation. Section V summarizes the results and provides some concluding remarks.

II

SOME GENERAL PRINCIPLES OF DIFFUSION OF AN INNOVATION[2]

Diffusion of an innovation will be understood here as a process in the course of which an innovation is adopted by those who had not already adopted it earlier.

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1. J. D. Black, "Factors Conditioning Innovation in Agriculture," *Mechanical Engineering*, Vol. 67, 1945, p. 180.

2. Throughout the paper farms are regarded as firms. New farm practices are referred to as agricultural innovations. They are innovations in that they are usually of fairly recent development and are new to the farm-user.

It refers to the spread of an innovation from its original sources among a group of potential users in a given region. The passage of time is therefore implicit in our definition of the concept.

The diffusion of an agricultural innovation thus refers to its inter-personal spread among farmers and the time lag between early and late acceptors of that innovation. The discussion in this section will therefore focus largely on whether the gradual adoption of a practice follows any time sequence and if so, what factors determine the time lag between its introduction and its commercial application. What follows in the succeeding sections is conversion of this into testable hypotheses and application of the appropriate tests.

How quickly is the diffusion process likely to go on depends on the speed of the farms' response to an innovation. To begin with it is assumed in this study that the supply of knowledge of an innovation or of the associated inputs is not the limiting factor and it is perfectly elastic.[3] The rate of development or diffusion path is then largely a demand variable. The demand adjustment function of the farmer on the other hand is basically a matter of distinguishing between willingness and ability of the farmer to accept an innovation. The willingness of the farmer to adopt broadly depends upon the farmer's knowledge or the technical know-how and his awareness of the economic attributes of the innovation. This is mainly the function of the education level, extension contact and motivation of the farm operator. The ability to adopt an innovation depends on two factors, *viz.*, the ability of the farmer to invest in new farm practices which involve additional outlay and the ability of the farmer to bear the risk in accepting that innovation. Thus, the factors which increase the farmer's propensity to innovate, are larger size of the farm business, ownership of the operational unit of land cultivated, larger asset position and more liquid assets.[4]

If we assume that the speed of farmers' response to an innovation is measured in the length of time the farm waits before introducing an innovation, we can very well postulate that other things held equal, the length of time the farm waits before introducing an innovation tends to be inversely related to its size, its asset and liquidity position, the education level of the farm operator and the rate of return to be realized from the change over. In the same vein it can also be hypothesized that there is a positive relation between the time lag involved before using an innovation and age of the farm operator and extent of tenancy. Implicitly these hypotheses show that farmers do not adopt an innovation straightaway but a considerable time elapses before all or even a majority accept it. The characteristic to be late rather than an early adopter of an innovation is a reflection of a complex of characteristics which make an individual to resist technological change. To sum up, all these propositions are based on the following general observations. First,

3. It is assumed throughout the paper that the "availability" problem is given and approximately uniform to all the farmers. "Clearly though it would be physically impossible for a large percentage of farm operators to have innovation in sufficient quantities, it seems likely, however, that this operated more as a potential than an actual limitation upon the will of the operator and that rapidity of adoption approximated the rate at which farmers decided favourably upon the new technique." B. Ryan, "A Study in Technological Diffusion," *Rural Sociology*, Vol. 13, 1948, p. 273. Similar view is expressed by Zvi Griliches in "Hybrid Corn—An Exploration of the Economics of Technological Change," *Econometrics*, Vol. 25, October, 1957, p. 516.

4. The willingness and ability of the farmers to adopt and the factors which determine them are discussed in detail in the dissertation under preparation by the author.

the costs and risks involved in being the first to use a new technique are likely to loom much larger for small farms than for big ones. Because of their larger financial resources the larger farms can play the role of a pioneer more cheaply and with less risk than smaller ones. Second, larger farms are likely to encompass a wider range of operating conditions and maintain closer ties with the communication agencies and therefore are likely to have a better chance of containing those conditions for which the innovation is applicable at first. Third, the larger the stimulus the faster reaction to it. If the returns the farm obtains from the innovation are very high, the expected returns are likely to be high enough to make the gamble involved in introducing the innovation seem worthwhile at the outset. If they are not so high, the farm will wait until the risks are reduced to the point where the investment seems warranted. Fourth, the elderly and illiterate farmers are less prone to change their methods and practices. It is often asserted that younger and more literate farm operators being less bound by traditional ways, are more likely than older ones to introduce the technological change relatively quickly.[5]

III

THE CURVE AND PROCESS OF DIFFUSION

Essentially this section will consist of constructing diffusion curves to the data collected in a survey of 270 farmers.[6] The innovations selected for the study are improved seeds, the application of chemical fertilizers and of the Japanese method of paddy cultivation. These innovations were chosen because of their fairly recent introduction and outstanding importance for increasing productivity. Also it is likely that farm operators would be able to recall the factors which were believed to facilitate the process by which they adopted these practices.

From Table I it is clear that there were substantial differences among the farms in the rate of diffusion. Although 9 years were required on the average to adopt improved seeds, some farms took 3 years and others 16 years. The same pattern of diffusion is visible in case of chemical fertilizers and Japanese method of paddy cultivation; though it varies largely in the time lag taken for adoption. If the basic problem in planning is to narrow the time lag between the appearance of technological changes and their adoption and widespread use, we have a problem of learning something about the manner in which the diffusion process is generated and explaining tentatively what are the factors by which that manner of diffusion is shaped.

Since time and the number of adopters at a given time are continuous and easily quantifiable variables, it provides us basis for charting of diffusion curves and thus making possible the development of theoretical models of the diffusion process.

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5. P. Hildebrand and E. Parsenheimer, "Socio-Economic Characteristics of Innovators," *Journal of Farm Economics*, Vol. XL, May, 1958.

6. The required data were collected in two villages of South Kanara district in Mysore State, namely Haleyangadi and Mundkoor in 1965. All the farmers of the two villages were covered for the collection of information by survey method.

TABLE I—DISTRIBUTION OF THE ADOPTERS ACCORDING TO TIME INTERVAL BETWEEN "ORIGIN" OF THE INNOVATION AND DATE OF ADOPTION

Time interval	Improved seeds		Chemical fertilizers		Japanese method of paddy cultivation	
	No.	Per cent	No.	Per cent	No.	Per cent
0 — 2	11	6	5	4	25	31
3 — 4	10	5	11	9	21	26
5 — 7	27	13	37	28	26	32
8 — 10	61	30	60	46	8	10
11 — 13	59	29	14	11	1	1
14 — 16	26	13	3	2	—	—
17 and above	7	4	—	—	—	—
Total	201	100	130	100	81	100

The logistic curve is adopted as a more satisfactory measure of diffusion path.[7] The mathematical expression of this curve is defined by $P = \frac{1}{1 + e^{-(a+bt)}}$, where P is the proportion of the farmers adopting a particular innovation, t the time variable, b the rate of diffusion coefficient and a the constant of integration which positions the curve on the time scale.[8]

There are several methods of estimating the parameters of the logistic.[9] The method chosen here involves the transformation of the logistic into an equation linear in a and b. The linear transformation of the equation is $\log\left(\frac{P}{1-P}\right) = a + bt$. From this the parameters are estimated directly by least squares.

The results of these calculations are presented in Tables II and III. Figure 1 shows the percentage of the farmers who have introduced each of the innovations at various points in time.

Several features of the curve are of interest for the proper appraisal of diffusion process.[10] In the equation P represents the growing diffusion process among the farmers and t represents the time. The rate of change of P with respect to t, that is the increase in the percentage of the farmers per unit of time is given by

$$\frac{dP}{dt} = bP(1-P).$$

7. The argument for the logistic is given by R. Pearl: Studies in Human Biology, Baltimore, 1924, pp. 558-583 and more recently by Zvi Griliches, *Op. cit.*, and Edwin Mansfield, "Technical Change and the Rate of Imitation," *Econometrica*, Vol. 29, No. 4, October, 1961, p. 741. The general conclusion is that the percentage of farms having introduced an innovation if plotted against time should approximate a logistic function.

8. The mathematical derivation of this model is discussed in detail in the dissertation under preparation by the author. I am grateful to Prof. A. Rudra and Dr. V. R. Panchamukhi for the helpful comments in this connection when this paper was presented in the staff seminar of the Department of Economics, University of Bombay.

9. See Pearl : *Op. cit.*, and G. Tintner : Econometrics, John Wiley & Sons, 1952, pp. 208-211 and Zvi Griliches, *Op. cit.*

10. For a more detailed description of the logistic and its mathematical properties see Pearl: *Op. cit.*

P is always non-negative and less than 1. Thus the complete curve falls between the X axis and a line parallel at a distance 1 above it, and thus approximating an S-shaped growth curve. This growth curve depicts that the rate of diffusion is proportional to two things, *viz.*, (a) the absolute growth already achieved, and (b) to the distance from the ceiling.[11] Thus for a proper appraisal of diffusion process, we should phrase our questions in terms of the beginning of the movement (lower limiting asymptote of diffusion curve =0), its relative speed (slope of the curve) and its destination (both upper limiting asymptote and ceiling point of diffusion curve).

TABLE II—CUMULATIVE OBSERVED AND EXPECTED PERCENTAGES OF FARMERS ADOPTING AN INNOVATION YEAR BY YEAR WITH LOGISTIC CURVE FITTED TO OBSERVED DATA FOR THREE INNOVATIONS

$$P = \frac{1}{1 + e^{-(a+bt)}}$$

Year	Improved seeds		Chemical fertilizers		Japanese method of paddy cultivation	
	Observed	Expected	Observed	Expected	Observed	Expected
1946	3.48	3.95				
1947	5.47	5.62				
1948	7.96	7.94				
1949	10.45	11.12				
1950	14.43	15.31				
1951	17.91	20.75	2.31	3.11		
1952	23.88	27.47	3.85	5.07		
1953	31.84	35.46	6.93	8.16		
1954	41.79	44.25	12.32	12.90	22.22	30.40
1955	54.23	53.48	20.01	19.76	30.86	39.37
1956	65.18	62.50	29.24	29.16	41.98	49.26
1957	74.63	70.42	40.78	40.49	56.79	59.17
1958	83.59	77.52	56.93	53.19	74.07	68.49
1959	90.06	83.33	71.54	65.36	82.72	76.34
1960	93.54	87.72	86.15	75.76	88.89	82.65
1961	96.52	91.74	93.84	84.03	91.36	87.72
1962	98.51	93.46	96.15	90.09	96.50	91.74
1963	100.00	95.24	97.69	93.46	98.77	94.34
1964			100.00	96.15	100.00	96.15
	$t_{1945}=0$		$t_{1950}=0$		$t_{1953}=0$	
	N=201		N=130		N=81	

11. "In a spatially limited universe the amount of increase which occurs in any particular unit of time at any point of the single cycle of growth is proportional to two things, (*a*) the absolute size already obtained at the beginning of the unit interval under consideration, and (*b*) the amount still unused or unexpended in the given universe or (area) of actual and potential resources for the support of growth." *Vide* Pearl : *Op. cit.*

TABLE III—ESTIMATES OF PARAMETERS OF LOGISTIC CURVE FITTED TO OBSERVED DATA FOR THREE INNOVATIONS ON THE BASIS OF LEAST SQUARE METHODS

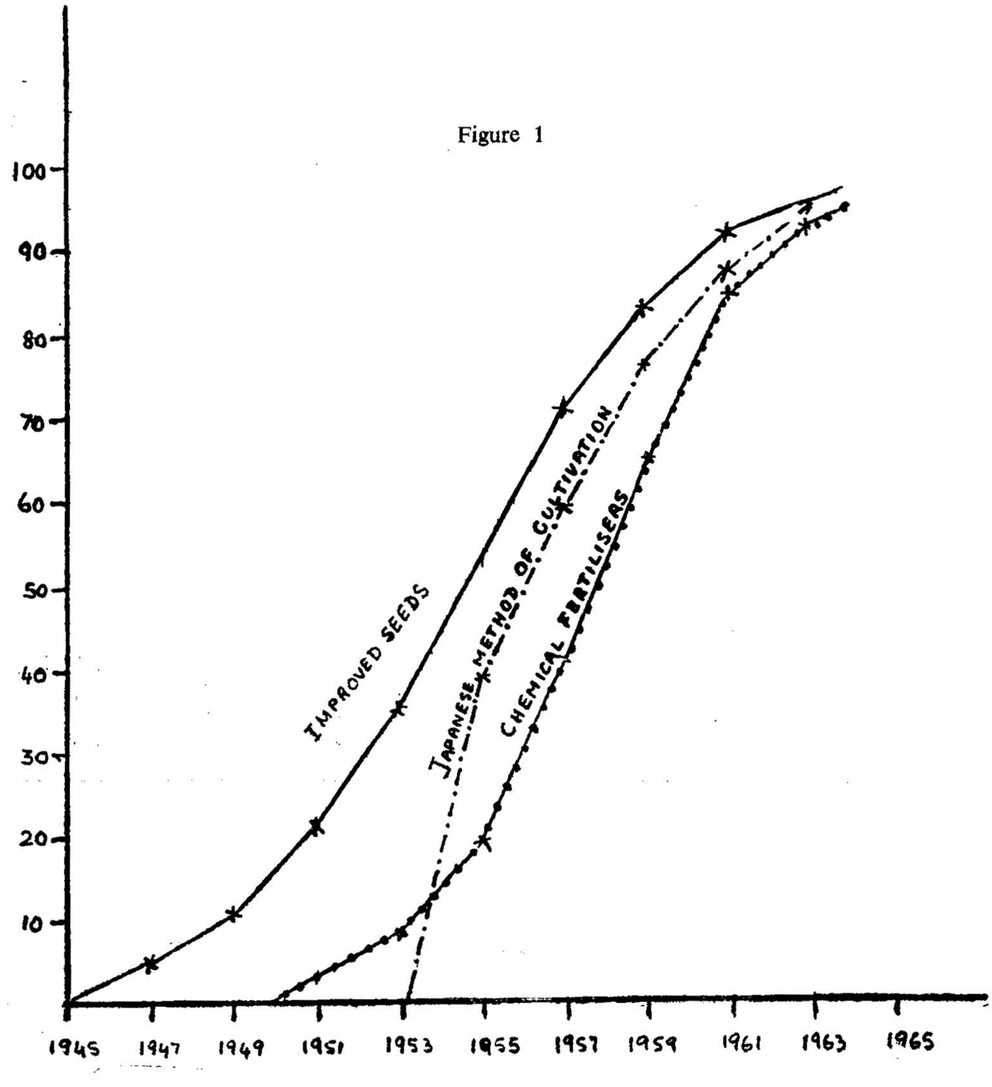
Innovations	a	b	Goodness of Fit X^2 (Chi-Square)
1. Improved seeds	—3.19	+0.37	4.09* (33.41)
2. Chemical fertilizers ..	—3.44	+0.51	4.64* (27.69)
3. Japanese method of paddy cultivation	—0.83	+0.40	7.42* (23.21)

$$P = \frac{1}{1+e^{-(a+bt)}}; \quad \log \frac{P}{1-P} = (a+bt).$$

Figures in brackets represent the table value of X^2 at 0.01 probability.

* Logistic curve gives a good fit as the divergence between expected values and observed values is not significant at 1 per cent level.

Figure 1



From the figure it is clear that the rate of diffusion has not been constant over time. It varies widely in different practices. For example, in case of improved seeds at first the diffusion path grows slowly but constantly increases to a certain point where the rate of growth reaches a maximum. This point of maximum rate of growth is the point of infection of the diffusion growth curve. After that point is passed the rate of growth becomes progressively slower till finally the curve stretches along nearly horizontally in close approach to the upper asymptote. The same thing is true in case of other innovations though the slope and pattern of diffusion curve is different in different practices.

Two conclusions regarding the diffusion process emerge from Figure 1. Firstly, the diffusion of an innovation in Indian agriculture is generally a rather slow process. Measured from the date of the first successful commercial application it took 20 years for all the potential users to accept improved seeds. Even in case of chemical fertilizers and Japanese method of paddy cultivation, it took more than a decade.

Secondly, the rate of diffusion varies widely from one innovation to another. Although it sometimes took decades for farmers to accept a new farm practice, in other cases they followed the innovator very quickly. For example, it took about 10 years for half of the farms to accept improved seeds and in case of chemical fertilizers it took 7 years, but it took only 3 years in case of Japanese method of paddy cultivation.

IV

FACTORS DETERMINING THE FARMER'S SPEED OF RESPONSE TO AN INNOVATION

The diffusion curves in the previous section have given us only an empirical statement of the nature of the changes that have occurred in the past. It provides merely a summary device to show whether the gradual diffusion of an innovation follows any time pattern. It has not explained why some farms were so slow to accept an innovation and others so quick and what factors seem to govern the rate of diffusion. This section provides some tentative answer to these questions.

To begin with, we translate the proposition mentioned in section II into the following more specific model :[12]

$$dij = Qi. \; Sij^{a_1}. \; Tij^{a_2}. \; Cij^{a_3}. \; Lij^{a_4}. \; Aij^{a_5}. \; Eij^{a_6}. \; Rij^{a_7}. \; \overset{e}{E}ij.$$

In the model, dij is the measure of the farm's response in the number of years the jth farm waits before beginning to use the ith innovation; Sij is its size ; Tij represents the extent of tenancy; Cij is magnitude of the farm's wealth position; Lij is its liquidity; Aij is the age of the farm operator and Eij is the measure of education level of the farm operator; Rij is a measure of the rate of return for its investment in the innovation. Qi is a scale factor which differs from innovation to innovation and eij is a random error term. a_1, a_2, a_3,...are parameters which according to our proposition are negative except in case of a_2 and a_5.

12. Edwin Mansfield, "The Speed of Response of Firms to New Techniques, "*Quarterly Journal of Economics*, Vol. 77, 1963, p. 290.

Before discussing the results of the appropriate tests, we must describe how different variables are measured. dij is obtained as a difference between the date when jth farm began to use ith innovation and the date when the first farm began to use it. Size of the farm business is measured in terms of acres of the operational unit of land. Tij is computed as a percentage of the area under tenancy. Cij represents value of the fixed capital excluding land. Cash income that the farm obtains during the year from all the sources other than farm business are included in Lij.[13] Aij and Eij are in years. To estimate the rate of return of each innovation data were obtained for both yield per acre before adoption and after adoption of a particular innovation. The percentage of change in yield per acre is estimated to obtain Rij.

The method of least squares is used to estimate the parameters of the model. The logarithmic form of the function is as follows :

$$\text{Log dij} = a_0 + a_1 \log \text{Sij} + a_2 \log \text{Tij} + a_3 \log \text{Cij} + a_4 \log \text{Lij} + a_5 \log \text{Aij} + a_6 \log \text{Eij} + a_7 \log \text{Rij} + \text{eij}.$$

The main results of regression analysis of these variables are summarised in Table IV.

The estimates in Table IV depict considerable support for our hypotheses. These estimates indicate the elasticity of delay with respect to various independent variables. The elasticity coefficients show considerable amount of variation from innovation to innovation. The estimates of a_1, and a_2 are quite consistent with the hypotheses presented above. In each innovation these estimates have the expected signs although they are often statistically not significant. Inconsistency observed in the results with respect to our other hypotheses can be explained by the attributes and direction of various innovations. For example, the rate of return has considerable influence on dij in case of chemical fertilizers and Japanese method of paddy cultivation. The reverse is true in case of improved seeds. With regard to liquidity one might expect that more liquid farms would be better able to finance the investment in the innovation and that consequently they might be quicker than less liquid farms to use it. This is evident in the estimates of effects of Lij on dij in case of improved seeds and chemical fertilizers. The effect of Lij on dij is not discernible in case of Japanese method of paddy cultivation which by and large does not need substantial capital investment. Education seems to have less influence on the farm's speed of response among all the innovations. Strangely education has statistically significant influence in "wrong" direction on farm's speed of response to improved seeds. With regard to the effect of age of the farm operator on the farm's speed of response, it is interesting to note that Aij is shown to have some influence on the elasticity of delay in case of improved seeds although it has not shown any effect in case of other two farm practices. Wealth position of the farm operator is shown to be an important factor which discerns substantial influence on dij in case of Japanese method of paddy cultivation and chemical fertilizers. With regard to improved seeds, wealth position is not an inhibiting factor on the farm's speed of response.

13. Liquidity position of the farmer in this paper means only his cash income other than from farm business. The concept is used in a limited sense.

TABLE IV—REGRESSION COEFFICIENTS, STANDARD ERRORS AND MULTIPLE COEFFICIENTS OF DETERMINATION

Innovations	Constant	Regression coefficients							Coefficient of determination	No. of observations
	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	$\bar{R}^2$	
1	2	3	4	5	6	7	8	9	10	11
Improved seeds ..	1.3662	— 0.2780	+ 0.0462	+ 0.0692	— 0.1873*	+ 0.6262*	+ 0.3765*	+ 0.0744	0.0743*	201
	(1.6823)	(0.1913)	(0.1172)	(0.1623)	(0.0791)	(0.2936)	(0.1497)	(0.1008)	(2.2141)	
t	0.8121	— 1.4533	+ 0.3939	+ 0.4263	— 2.3691	+ 2.1124	+ 2.5151	+ 0.7383		
Chemical fertilisers ..	5.0012*	— 0.1462	+ 0.0527*	— 0.1829*	— 0.0134	— 0.0502	— 0.0338	— 0.3278*	0.5233*	130
	(0.6928)	(0.0779)	(0.0195)	(0.0625)	(0.0239)	(0.1422)	(0.0555)	(0.0927)	(19.1288)	
t	7.2187	— 1.8755	+ 2.7034	— 2.9289	— 0.5616	— 0.3529	— 0.6081	— 3.5379		
Japanese method of paddy cultivation	6.0293*	— 0.0346	+ 0.0347*	— 0.1131*	+ 0.0105	+ 0.0019	— 0.0252	— 1.1928*	0.8053*	81
	(0.5781)	(0.0628)	(0.0160)	(0.0442)	(0.0153)	(0.1133)	(0.0412)	(0.1192)	(43.1322)	
t ..	10.4295	— 0.5505	+ 2.1693	— 2.5570	+ 0.6844	+ 0.0166	— 0.6103	— 9.9718		

* Statistically significant at 5 per cent level.

Note : Figures in brackets in columns 2 to 8 are standard errors. In column 10 figures in brackets are estimated value of F.

As one would expect there seems to be considerable variations among innovations in the estimated elasticity of delay with respect to various causal factors. For example, the estimated elasticity of delay with respect to size of farm ranges from—0.04 to—0.28. The effect of Rij on dij is shown to be very high both in case of chemical fertilizers and Japanese method of paddy cultivation. Statistically significant elasticity of delay with respect to extent of tenancy and wealth position of the farm is also shown in case of both the innovations.

V

SUMMARY AND CONCLUSIONS

The present study is obviously too brief to go thoroughly into the question of diffusion function of an innovation, but will perhaps suffice to set out more sharply the real character of a few of the outstanding issues in the light of easily verifiable facts and figures. The study succinctly indicates that diffusion of an innovation in Indian agriculture is a slow process. As expected there is first a slow, gradual adoption, then a more rapid rate of adoption and finally a levelling off in the rate of adoption. The rate of diffusion tended to be faster for innovations that were more profitable. The results also strengthen our suppositions that the variations in the farm's speed of response to an innovation can be explained by the differences in size of land holding, tenurial status of the farm operator, profitability of the innovation and the farm's liquidity. Holding these factors constant, there is no significant tendency for the length of time the farm waits to be inversely related to the education level of its operator or directly related to the age of the farm operator. Although these factors might seem to be statistically important their effects are often in the "wrong" direction.

The study will provide also some basis for predicting whether one farm will be quicker than another to use particular innovation. The farmers who cultivate larger land holdings and who are also owners of the farms and have larger fixed capital with adequate liquidity are the early adopters of an innovation. The logical implication of the study is that rapid technological change can be generated only if the structure of the farm and its ownership are altered to bring about a greater identity between different factors such as land, fixed capital and the liquidity of the farm.

In evaluating these results the limitations of the data, methods and scope of investigation must be taken into account. The data we could obtain are limited in quality and reliability. For example, much of the data regarding he date of the adoption of an innovation are probably fairly rough. Similarly, the estimates of the rate of return are only rough. In view of these and other imperfections of the survey data, these results are quite preliminary and tentative. Having cursed the dark loudly and openly, our purpose here is to stimulate discussion of the problem and to light a few candles limited though their power may be. To understand how economic growth is generated, we must know more about the way innovations occur and how they become generally accepted. "It is not enough that knowledge should grow, it should also be diffused and applied in practice."[14] If the basic problem in planning is to narrow the time lag between the appearance of technological changes and their adoption and their widespread use, we need to know much more about these and other aspects of technological change.

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14. W. Arthur Lewis : The Theory of Economic Growth, London, 1956, pp. 177 and 191.