THE CHOICE OF TECHNIQUE :

THE EXAMPLE OF COMPUTERISATION

P.S. Stoneman

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In his Presidential Address to the American Economic Association, Leontief[1] called for economists to perform,

'a very difficult and seldom very neat assessment and verification of assumptions in terms of observed facts'.

As part of a wider study into the spread of computer usage in the U.K.[2] it was possible to obtain data on the computerisation decision that enables one to go some way towards Leontief's objective with regard to the decision on technique choice.

In a dynamic economy the technique choice decision has three dimensions.

(a) Time: at what moment in time the decision is made to change or maintain the present technology.

(b) Composition: the technique that actually results from the choice decision.

(c) Level: the level at which the chosen technique is actually run.

The three dimensions combine to yield the determinants of the scale and composition of the desired capital stock at a moment in time. The decision on levels is essentially made once the firm has made its output decision, and for the purposes of this exercise it will be assumed that the firms output is determined and so the level decision need not be pursued any

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(1) W. Leontief, Theoretical Assumptions and Non-observed Facts, American Economic Review, March 1971, p. 2.

(2) P. Stoneman, On The Change in Techniques - a study of the spread of computer usage in the U.K., 1954-1970, Ph.D. Thesis submitted to the University of Cambridge Oct. 1973. I wish to thank Dr. R.M. Goodwin for his comments and help with that thesis and thus with the present paper. I also wish to thank Keith Cowling, Jeff Round and Norman Ireland, all of the University of Warwick, for comments on an earlier draft of this paper.

further[1]. In this situation the existing hypothesis on technique choice says that the decision can be characterised by two simple statements:[2]

(a) The technique desired is that which maximises an objective function in which profit is usually the only argument;

(b) Gross investment occurs in the technique resulting from selection procedures when (i) expansion is desired over what can be produced on the existing capital stock, or (ii) when the net present value of the existing technique is less than the net present value expected from the technique resulting from selection procedures at some given discount rate.

This theory suggests that the firm continually has in mind that technique which can maximise its objective function, and if production is to occur, will shift to that technique as soon as the present value comparison indicates. This therefore further implies a continual comparison of technologies.

The aim of this paper is to use some U.K. survey data on the computerisation decision to evaluate the realism of these assumptions and to suggest an alternative that is consistent with the survey data.

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(1) This assumption also rules out any difficulties resulting from non-constant returns to scale.

(2) These statements characterise the technique choice decision as discussed by W.E.G. Salter in Productivity and Technical Change, Second Edition, Cambridge University Press, 1969, pp. 48 - 65.

It is then shown that this interpretation is consistent with empirical results that have been derived with respect to different studies of the diffusion process.

The data available are survey data on the firm's decision to computerise. The first set of data is taken from two studies of computers in offices[1]. For the 1964 survey computer users were asked "to state why you decided to obtain the A.D.P.[2] equipment". In 1969 those users who had computerised in the previous two years were asked "why are you installing the A.D.P. equipment ?", and had to select from a number of possible replies. From all reasons given it was possible to separate out the prime reasons given for computerisation. The relevant data is presented in Table 1.

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(1) Ministry of Labour, Computers in Offices, Manpower Studies No. 4., HMSO, London 1965, and Department of Employment, Computers in Offices, 1972, Manpower Studies No. 12, HMSO, London 1972.

(2) Automatic Data Processing

Table 1:

Reasons for Installing a Computer

	All reasons		Prime reasons	
	No. affected		No. affected	
Reason	1964	1969	1964(1)	1969(2)
Quicker Processing	144	659	5	97
Savings in Data Processing Costs	137	347	23	83
Better Service to Management	115	747	25	325
Better quality results	110			
Replace worn out equipment(3)	66	415	26	197
Savings in Office Space	62		6	
Savings in Manpower	40	220	9	22
Better Service to Customers	29	437	3	75
Other	42	208	7	27
Sample size(4)	344	806		

(1) About one third of the 1964 sample specified a prime reason or gave only one reason. Savings in manpower related only to those cases where there were indications of difficulty in recruiting staff. Savings in manpower in order to save expenditure on salaries were classified as savings in costs. Similarly, saving in space relates only to those cases in which there had been difficulty in finding office accommodation. The study also finds that there had been no significant difference in the years up to 1964 in the reasons given for computerising.

(2) Over 80% of the 1969 sample who replied gave only one reason

The data can be supplemented by some observations on why certain firms have not computerised. In a survey of computers in textiles[1] it was found that of the non users sampled, 19% had considered but rejected computerisation. The reasons given for rejection [some users giving more than one reason], are tabulated in Table 2.

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or specified a prime reason, with a small number specifying two prime reasons of equal importance. Reasons were classified as for 1964. There was a slight variation in the replies over different sized installations, notably some 40% of larger installations gave reduction of processing costs as their prime reason compared with 10% of all installations.

(3) The nature of the techniques replaced, considering that this data only refer to office computers, were a mixture of punched card machines, clerical labour and keyboard accounting machines. Outside the office area some special purpose logging and control equipment was replaced. These may be considered as the characteristics of the alternative techniques.

(4) The sample size is approximately the whole population of office computers costing over £20,000.

(1) National Computing Centre, Computers in Textiles, NCC Manchester, 1968.

Table 2:

Reasons for Rejecting Computers

Reason	Number
Insufficient Work	11
Too expensive	8
No technical staff	2
Delivery of results reputed to be too late	1
Computer not thought suitable	3
Other/Don't know	2
Sample size	19

In a study of the hotel and catering industry[1] a similar exercise was performed concerning the reason why certain tasks had not been computerised. The results are detailed in Table 3, with again some users giving more than one reason.

Table 3:

Reasons for Rejecting Computers

		Computers	
	All	Used	Not Used
Sample	95	24	71
Computerisation not considered	62	8	54
Computerisation considered but:-	33	16	17
(a) Insufficient work	13	3	10
(b) Too expensive	11	3	8
(c) No technical staff	1		1
(d) Intend to : no time yet	4	4	
(e) Other	11	2	9

(1) National Computing Centre & The National Economic Development Office, The Use of Computers - Hotel and Catering, NCC Manchester 1968.

Of the 'Other' category, only two of the sample preferred their present arrangement (the other reasons were speed, wait for own machine, or firm not large enough).

The final set of survey data is taken from a British Institute of Management survey of the current practice of technique evaluation when computers are installed[1]. Two samples of 360 and 270 respectively were asked what evaluation method was used to justify their investment in computers. Table 4 details the results although the response rate was very low, with some users using more than one method.

Table 4:

Current Practice with Respect to Evaluation Methods

	Sample 1	Sample 2
Evaluation Method	No. using	
Discounted Cash Flow	24	12
Payback	14	4
Book Return	2	5
Other	16	26
Sample size	71	49

II

Before proceeding to draw any implications from the data in section 1, it is necessary to discuss first the applicability of this survey data.

(1) This survey is reported in National Computing Centre, Economic Evaluation of Computer Based Systems, Vol. 1, NCC, Manchester 1971.

The coverage of the Computers in Offices data has already been mentioned and the questions asked have been detailed. The problem with this data apart from referring only to office computers (although these represent 67% of all machines installed)[1] is the extent to which data collected after the technique choice decision has been made can throw light on behaviour prior to the choice of techniques. Technique choice must depend on expected costs and benefits but the use of survey data to investigate expectations when the data is collected after the decision has been made, leaves open the question of the extent to which replicants attribute expectation to realised fact. To the extent that this leads to replicants trying to imply rationality in their decision making the data will be biased against our interpretation of it below.

This criticism also applies to the other three sets of data. The data on the textile industry was collected from a random sample of 140 firms from a population of 3,600 firms with 39 known computer users added. In the industry only 4% of the companies own computers and 12% make some use often, although most users are in the consumer or growth areas of the industry. The Hotel and Catering study used a sample of 127 with 95 replies. Neither of these industries are considered as in any way typical of other industries but it is felt that if one can find any data on why a task has not been performed one is very fortunate, for it enables one to overcome some of the bias that results from studies including only those members of the population who have performed the task.

The study of current practice with regard to evaluation methods had a very low response rate as detailed. The question asked was, 'What method of evaluation do you use?' and the list of alternatives presented. The first sample was taken from the National Computer Centre list of users, the second from its membership list. The first sample was biased

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(1) Computers in Offices 1972, op cit, p. 11

towards the engineering industry (23 replies) with 13 from coal, petroleum and chemicals and 10 from other manufacturing . Thirty replicants had their first machine, 28 their second and 10 their fourth. The average data processing costs of this first sample were £252,000 per annum. The main bias that could come from this sample again relates to the degree to which managers should attempt to imply rationality in their replies. The low response rate may be because those who do not evaluate their computer systems felt unable to reply to the questionnaire. Both biases would strenghten the conclusions drawn below.

It is therefore suggested that if we could have unbiased data then the evidence for the conclusions drawn below would be stronger.

III

To begin the analysis we can start by detailing the benefits of computer use. From Table 1 we can say that it would seem that users expected to achieve from their computer systems savings in cost in general, or manpower and office space in particular, and/or improvement in service to customers, and/or improvements in the quality and quantity of management information.

Given these benefits we can begin an analysis of the technique choice decision by looking at the evaluation process. First some comments on the data are relevant. The DCF rates when quoted varied from 10% net to 30% gross, although no indication was given of net or gross of what or what prices were used in the evaluation. The payback rates varied between 10% and 100%. This would tend to imply that "payback" means some measure of the average annual net or gross return on the investment. It is not to be taken as the payoff criterion. (1) The companies in Sample 1 who used other methods nearly all used adaptations of the payback method. Ten companies in this sample used two or more methods.

(1) 'Payback' is taken to mean the annual net or gross return on historic cost.

Consider then the data in Sample 1. It would seem, if the effects of double counting are removed, that 46 out of the sample of 71 use some evaluation method. This implies that 25% of the sample do not evaluate their systems. In the second sample a similar statement is not possible as we do not have data on double counting. However, in another question in the survey companies were asked whether they evaluated their computer systems with the same criteria used for other investments. The positive replies totalled 38 in the first sample and 25 in the second. It seems implausible that 47% in the first and 49% in the second sample should use different evaluation techniques for this one investment, thus in the 47% or 49% there must be an element of users who never evaluated their systems and thus could not answer positively. The most relevant point that we can draw at this stage is simple but basic. The DCF and payback criteria imply the principle of meeting targets not of obtaining a maximum return. If one considers the above data and also realises that government and nationalised industries use the DCF methods(1) then one can conclude that the majority of computerisation projects that are evaluated are done so using satisficing rather than optimising techniques (at least in the short run).

Thus a point has been reached where one can reject any theory of technique choice that depends on maximisation, for it has been shown that in many cases no evaluation takes place, and in the cases where it does take place the methods used are of a satisficing and not optimising (or maximising) nature.

Even if this is rejected is it still possible to maintain the hypothesis that firms have in mind a certain technique that they will use as soon as the time is right? Thus one must ask can a concept of the continuous re-evaluation of technology be supported, such that the costs and benefits of the existing technique are continuously being compared to those of a 'preferred' activity ?

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(1) See below.

Consider the replies in Table 3. As one can see, from a sample of 95, 71 did not use computers and of this 71, 54 had never even considered computer usage. In the study of computers in textiles, 12% of the firms made some use of computers and of the other 88% only 19% had considered and rejected them. This leaves approximately two thirds of the sample that had never considered computer usage. Realising that 20% of the sample considered them the technique to use, if 2/3rds. of the sample have never considered their use, then an hypothesis that implies the continual comparison of techniques cannot be supported. There must therefore be other forces at work leading to the re-evaluation of the firm's technique. This does not mean however that continuous comparisons of techniques never occur, for in fact the Civil Service Department insist that this is how they operate.

> The aim of the Civil Service Department has been to encourage Departments to have computers constantly in mind when considering how to do their work. Management service units (including O & M and Operational Research Sections) both in the Civil Service Department and in other departments are always on the alert for new ways of exploiting the computer in the interests of efficiency and economy, in all fields of government activity. O & M and A.D.P. assignment officers are trained to look for and bring to notice possible areas of computer application.(1)

Enough evidence has been presented to show that this cannot be the case in all applications. It has become obvious that a different theoretical framework is required if the above data is to be interpreted consistently. This framework must be able to predict that techniques will not be reconsidered continuously but will only at times be re-evaluated. It must also allow for the evaluation procedures to depend on satisficing rather than maximising with different evaluation methods in different firms and no evaluation at all in others. The framework

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(1) Memorandum by the Civil Service Dept. to the Select Committee on Science and Technology Sub-Committee D., reprinted in Select Committee on Science and Technology, U.K. Computer Industry, Vol. 1. H.C. 137 (Session 1969-70), HMSO 1970

which, it is felt, can best accommodate these influences is the behavioural theory. The version of the theory presented by Cyert and March[1] will be used below.

The theory argues that decision making in the firm can be analysed in terms of the variables that affect an organisation's goals, expectations, and choice. The firm has certain goals to be achieved in a period. These goals would refer to level of production, sales, profit and market share. The level at which goals are set depends on the past performance of the organisation and the performance of comparable institutions. If the organisation cannot meet its goals there is a stimulus to change. Such a stimulus may also come from a member of the organisation seeking a problem for which a pet project is a solution. The problem stimulates search behaviour for a solution, this search being initially localised and only spreading if no local solution is available.

The results of the search behaviour are evaluated in a simple manner, the evaluation also being biased by the aspirations of the evaluator. Uncertainty is avoided by working in terms of the short run, feasibility in terms of finance being available is a major consideration. The choice of solution is in terms of satisficing rather than optimising, with non marketed benefits being considered as constraints, so as to avoid uncertainty.

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(1) R.M. Cyert and J.G. March, A Behavioural Theory of the Firm, Englewood Cliffs, N.J., Prentice Hall, 1963. A summary of the theory is provided in pages 114 - 127.

Thus, with a bias towards the present context, the theory says that prior to a change in technique a problem is required, or an expected problem or a pet solution seeking a problem. The problem stimulates a search for a solution which must satisfy certain standard rules to be accepted and if it does not search will continue. Once the decision is made to implement the solution a further problem must arise before another solution will be considered.

The application of this framework to the data on the computerisation decision must begin with some discussion of the nature of the problem stimuli that have been apparent. From Table 1. an initial important observation is that among the reasons given for installing computers certain categories can be identified that imply that computerisation resulted from the inoperability of the existing technique. These reasons are listed as the replacement of worn out equipment, savings in office space and savings in manpower and difficulty in recruiting staff. It may well be that office and staff considerations are just indicators that the firm is not willing to operate its old technique at higher prices, but they still indicate that the firm is being forced to reconsider its technique.

Depending on the degree of overlap anything between 51% and 78% in 1969, or 19% and 48% in 1964, of installations were the result of the inability of the old method to continue to operate. Turning to prime reasons the pattern in Table 5 emerges.

Table 5:

% of Installations Giving Each Prime reason for Installing Computers

Reason	1964	1969
Replacement of worn out equipment	8%	24%
Difficulty in recruiting staff	2.5%	3%
Savings in Office space	1.5%	-

In 1964 the replacement of worn out equipment is the largest single category of reasons given, only 1/3rd. of the sample giving a prime reason (it was not asked for specifically in the questionnaire). When one considers that in many cases the change was from clerical labour the relative importance of replacement increases. Taking the two totals, in 1964 12% and in 1969 27% of machines were installed primarily because the old technique was no longer operable. If one considers prime reasons as a percentage of all prime reasons given then this sector increases to 40%. It is interesting to note that similar forces are at work in forming the decision to change computers to the latest type. The following statement illustrates this point(1).

' There is a market force that is illogical in the extreme and uncommercial. The market force is the desires and wishes of those very scarce people, the programmers. If a new, up to date, modern machine which requires a vast investment in new programmes, new techniques, and so on, is brought out it will be very difficult to recruit and retain programmers to work on older style machines. We have already seen this problem in the move from second to third generation in investment and retraining and having to move up to the more modern machines because of the programmers desires.'

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(1) Evidence of Computeraid to the Select Committee on Science and Technology Sub-Committee D., op. cit., p. 263.

These problems of obsolescence and obtaining inputs are taken as indicators of difficulty in achieving the production goal. However, there is little evidence that the other goals with which the firms have been attributed have any influence. If one looks again at Table 1, the fact that firms list a number of benefits that they wish to obtain from conputers indicates that different firms put different valuation on each of the benefits. One way to explain this is to say that the different valuations depend on the need that the firms have for improvements in specific areas, i.e. the problems that are being met in the achievement of different goals. Thus for example if a firm installs a computer and expects benefits of reduced cost and a better service to customers, the fact that they list the better service as the prime reason for the installation suggests that the organisation was in need of sales improvement rather than cost reduction. Another firm might also generate cost reductions and better service but list the cost reduction as the prime reason. It would seem that this firm would be seeking profit increases. In other words it would appear that nearly all firms can gain the same benefits from computers, but the fact that they order the relative importance of the benefits differently suggests that they are trying to find solutions to different goal achievement problems.

It has only been possible in this one category, however, to identify any specific benefit as solely attributable to the need for improvement in the achievement of any specific goal. Take for example a firm having problems achieving its profit goal. To generate greater profits the firm may either reduce data processing costs, provide better service to customers, or improve efficiency by a better service to management by installing a computer. However,

another firm installing a machine to increase sales could quote exactly the same desired benefits. Thus one to one links do not exist.

To draw some conclusions from this section, it would seem that once one removes the concept of the continuous re-evaluation of techniques it becomes necessary to provide a rationalisation of why techniques are re-evaluated. This theory indicates that stimuli come through the problems that the organisation meets, or is expected to meet, in the attainment of its goals. Some evidence has been provided to illustrate that the production goal can be reflected in the data, although the evidence to support the other goal achievement problems is circumstantial.

The next stage in the theory states that a problem stimulates search and evaluation. Enough evidence has already been provided to suggest that satisficing rather than optimising takes place but one may be able to find that the evidence and the theory correspond in more cases.

In those cases where search behaviour is necessary the theory states that search is initially localised and also limited. The fact that satisficing rather than optimising takes place supports the limitation contention. To support the localised nature of search one can argue that the more of an organisation's competitors that are using computers the more it is likely to use them itself. This is definitely reflected in the wider study. However, there is some further data that can be used. In the hotel and catering study (data in Table 3) the sample were asked why they had not applied computers to specific tasks - of the users 67% said they had

considered it but 75% of non users had not considered computer usage. This would tend to indicate that the contact with the computer promoted consideration of it i.e. localised search. Some further evidence to support this contention can be derived by looking at the relationship between the tasks to which computers are applied and the number of years since a computer was first acquired. In Table 6 some data on the use of advanced techniques and the period of ownership is presented (1).

Table 6:

Computer Use and Period of Ownership

Average number of advanced techniques per organisation		Years since first installation 1	1 - 3	3 - 5	5 - 8	8 +
(a)	In use	0.6	0.6	0.8	1.1	2.1
(b)	Planned	2.1	1.9	2.4	3.3	4.6

The data implies that experience generates further computer usage in a similar manner to numbers installed influencing search procedure.

What is it possible to say on evaluation procedures ? Earlier discussion has already supported the satisficing proposition, but Table 4 also implies that simple standard operating rules are used for evaluation, e.g. mainly payback rates and discounted cash flow. The importance of the use of payback rates is that it is a procedure that is essentially dependent on current prices and thus avoids prediction of the future as the theory would suggest. The theory also suggests that non-marketed benefits

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(1) The source for the data is National Computing Centre, Analysis of Computer Usage in the U.K., 1971, NCC, Manchester, 1972.

are treated as constraints. The data on technique selection gives no indication of how intangibles such as better service are valued, or even if they are valued. However, the Civil Service Department state that[1],

'Currently, A.D.P. projects are appraised by the discounted cash flow technique using a test discount rate of 10% (formerly 8%). They are normally required to show a substantial surplus, but cost is not the only criterion. Projects which do not show a positive present value are approved if it can be shown that sufficient additional direct savings or operating advantage can be achieved or if there will be unquantifiable benefits which justify the cost'.

This suggests that unquantifiable benefits are considered separately and treated as parameters. It may well be the case that private organisations behave in the same way.

Some support for the theory can be gained from Tables 2 and 3 on why computers are rejected. The two main reasons for rejection are indivisibilities and expense. The interpretation of 'too expensive' can be twofold, either the computer would not pass evaluation procedures, or what appears more likely, the cost of computerisation is too great to be met from the organisation's resources - what the theory calls feasibility. It is significant that Mansfield[2] finds that the probability that a firm will introduce a new technique is a decreasing function of the size of the investment required.

The final point of the theory on which some comments can be made is the bias in evaluation procedures. These biases can arise

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(1) Memorandum by the Civil Service Dept. to the Select Committee on Science & Technology Sub-Committee D. op. cit..

(2) E. Mansfield, Industrial Research & Technological Innovation, Longmans, Green & Co. Ltd. London 1968, p. 153.

from the views of the evaluators. The BIM[1] survey tabulates the distribution of responsibility for computer evaluation as in Table 7.

Table 7:

Computer Evaluators

Group	Sample 1	2
Financial Staff	32	15
D.P. Staff	52	39
Consultants	8	3
Others	7	18

Of the financial staff category in Sample 1, 22 were helped by data processing staff. The first indication that bias occurs in evaluation is provided by the results of the McKinsey report[2], where it was found that of the 18 less successful applications of computers only 3 involved operating managers in the specifications of benefits whereas of the 18 more successful users 11 did so. However some more direct evidence of the influence of personalities can be found. In Table 8 the use and planned use of advanced techniques in computers relative to the status of the computer department is detailed.[3]

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(1) National Computing Centre, op. cit..

(2) McKinsey & Co. Ltd., The 1968 McKinsey Report on Computer Utilization, 1968, pp. 1 - 38. Reproduced in Management Information Systems, ed. T.W. McRae, Penguin Modern Management Readings, Penguin, 1971, pp. 94 - 122.

(3) National Computing Centre, Analysis of Computer Usage, op. cit., p. 42.

Table 8:

The Use of Advanced Techniques

Technique	Computer Department Status							
	Autonomous		In A/C Dept.		In Man.Services		Other	
	% applying							
	1971	1974	1971	1974	1971	1974	1971	1974
Mathematical Models	18	53	11	48	35	73	46	43
Management Information Systems	21	39	18	20	30	65	14	50
Teletype Terminals	13	33	8	35	27	56	25	46
On Line	10	36	6	25	15	51	25	46
Graphics	7	35	4	19	16	47	25	21
Other Terminals	8	27	4	15	10	36	6	21
VDUs	5	22	2	7	7	31	3	36
Real Time	3	14	1	7	7	27	11	32
Microfilm	2	11	2	7	2	21	3	7

The relevant point about these figures is that the machines that are under the control of the accounting department are being used much less adventurously than those in other departments. This impression is also carried over into the plans for 1974. It would seem therefore that the concept of organisational bias is reflected in computer use.

The conclusions of this section thus state that the timing of the technique choice decision is determined for the firm by the interaction of its goal formation and goal achievement characteristics, leading to problems and the search for solutions. The actual composition of the technique choice decision depends on the nature of the search and evaluation procedures which have been shown to be simple minded and biased. The search procedures are influenced by the number of machines installed in comparable organisations, and if new tasks are being considered, whether a machine is already installed. The evaluation procedures are also simple minded, satisficing rather than optimising is the rule, non-quantifiable benefits are considered as parameters, feasibility is important, and short run considerations dominate. Moreover it has been illustrated that the conception of the costs and benefits is biased by the views of the evaluator.

IV

The final stage of this analysis is to show the extent to which the results derived above are consistent with the results on technique choice that have been derived from the study of diffusion processes. These can be listed[1].

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(1) These results are derived from two sources; E. Mansfield, op. cit.; C. Kennedy and A.P. Thirlwall, Technical Progress - A Survey, Economic Journal, March, 1972, pp. 11 - 72.

(a) As the number of firms in an industry using an innovation increases the probability of non user innovating increases.

(b) The rate of diffusion tends to be higher for more profitable innovations and those requiring small investments. There is also some evidence that less concentrated industries diffuse innovations quicker.

(c) Differences between firms in the rate of diffusion can be attributed to the profit they derive from the new technique, differences in size, liquidity, and the date when they first used the new technique.

(d) There are indications that the rate of imitation is higher if not very durable equipment is being replaced and if the firms output is growing rapidly.

(e) The majority of the studies of diffusion have found that the percentage of the total potential usage of a new technique as a function of time can be best approximated by an S shaped curve.

The first result on the effect of the lagged stock was covered above. The second result refers to faster diffusion for an innovation which is very profitable and requires a smaller investment relative to a less profitable and more expensive innovation. The explanation given by Mansfield[1] for these results corresponds to the present discussion of the evaluation process - more profitable innovations can pass evaluation tests more easily and smaller investment pass 'feasibility' tests more

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(1) E. Mansfield, op. cit., p. 138.

readily. Also included in the second result is a slight indication that diffusion rates are faster in less concentrated industries. This conclusion has been much disputed and will not be pursued.

The third set of results indicate that firms for whom the innovation is most profitable, are most liquid and first used the new technique, diffuse it faster over all possible applications in the firm. It would also appear that small firms are at least as fast as large firms to diffuse once they have begun to use the technique. The liquidity variable could reflect 'feasibility', the profitability variable reflect on evaluation procedures, and the date of first use has already been shown above to have influence, where it was rationalised as another aspect of the information variable. Little can be said on firm size, except that indivisibilities exist, and that large firms may have less problem with feasibility, which might imply faster diffusion for larger firms instead of the opposite.

Fourth, it might also be that a firm's growth rate and the durability of its previous equipment could have influence. The durability argument fits in well with the above analysis where it was shown that obsolescence promoted the re-evaluation of technology. Thus the less durable is equipment the earlier is the stimulus to re-evaluate technology. The effect of the firm's growth rate can be rationalised on a number of levels, but the clearest explanation is that the faster growing firm will meet more problems than the slower growing one, e.g. management control problems,(1) labour supply and office space problems, etc.

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(1) See for example, O.E. Williamson, Hierarchical Control and Optimum Firm Size, Journal of Political Economy, April 1967, pp. 123 - 138.

Finally there is the existence of the S-shaped diffusion curves. It can be argued that with the influence of the information variable, this results from the fact that as time proceeds the amount still to be converted to the new technique is falling as the installations increase, but the chance of changing technique increases. These two pressures result in the S-shaped curves. There is nothing in the theory under discussion that would invalidate this.

To conclude we can say that the data presented will not support the original hypothesis put forward on the timing and composition of the technique choice decision. An alternative is proposed that is consistent with the data presented[1] and can also be used to support conclusions on technique choice derived from the use of non survey data.

P. Stoneman

University of Warwick

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(1) It should be stated however that an attempt to apply this theory to data on the number of computers in use and thus test it on the computer diffusion data, ran into severe difficulties because of the general problem of applying behavioural theory to industry and time series data.