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The Diffusion of New Processes

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Technological advance is the most important source of the increase of productivity in the broadest sense: of the utilisation of all factors of input. It not only raises the production of a given input of labour or materials, and adds to the yield of the capital employed, but can also result in new products which help to satisfy the ever-increasing requirements of society.

Attempted Empirical Study

Six economic research institutes in Europe¹ made an attempt to study the extent of the diffusions of new technology on an empirical basis. They were aware of many statistical difficulties. Nevertheless it was believed that a joint study of allied problems would be rewarding, for a number of reasons. First, information would be collected in an area which had hitherto remained almost wholly unmapped. Secondly, the study would reveal differences which exist in the rate of diffusion in the countries in question, and possibly also point to the causes of these divergencies². Thirdly, in the course of the investigation it will be possible to identify those factors which determine—promote or deter—the application of new technologies.

This report briefly describes some of the interim results of the inquiry; full details, though still on an interim basis, were given elsewhere³.

Selected Processes

It was clear from the beginning that "new technologies" is an extremely wide field which had to be

¹ Austria: Österreichisches Institut für Wirtschaftsforschung, Vienna; France: Bureau d'Information et de Prévision Economiques, Paris; Germany: IFO Institut für Wirtschaftsforschung, München; Italy: Istituto Nazionale per lo Studio della Congiuntura, Rome; Sweden: Industriens Utredningsinstitut, Stockholm; and United Kingdom: National Institute of Economic and Social Research, London.

² Various previous studies attributed that part of the various countries' economic growth, which remained as a residual after due allowance for changing labour and capital input, to factors such as education, technology, management, etc. This study aims at trying to quantify the factor 'technology' directly, and not as a residual. Because of its partial coverage, even if the outcome of the research is satisfactory, the answer cannot avoid being incomplete, restricted to a narrow area.

³ National Institute Economic Review, No. 48, May 1969, where detailed descriptions of the processes listed can also be found.

delimited. New processes were chosen (as against new products, of which somewhat more is known) as the main area of study and the following ten processes were selected for investigation: basic oxygen processes in steelmaking (OXY); continuous casting of steel (CC); special presses in papermaking (SP); numerical control on metal-working machine tools (NC); shuttleless looms in the weaving of cotton and man-made fibres (SL); tunnel kilns in brickmaking (TK); new methods of steelplate marking and cutting in shipbuilding (SCM); float glass (FG); automatic transfer lines in the manufacture of engines for passenger cars (ATL); and the treatment of malt with Gibberellic Acid in malting-brewing (GA).

In the course of the inquiry the following information was collected, as far as possible on an internationally comparable basis: the date of the first application in the country; the diffusion of the new technique since the first application (measured, where possible, in three ways: the number of users, the share of new equipment in the total productive outfit, and the proportion of output produced by the new technique); companies' views concerning the advantages (and disadvantages) of the new, as compared with the conventional, technique; and any factors favouring or

Table 1
Diffusion Achieved by 1966/68

	Austria	France	Germany	Italy	Sweden	UK
OXY: A (1967)	67	17	32	27	33	28
CC: A (1966)	1.2	0.6	2.4	2.0	2.2	1.6
SP: A (1968)	12	xx	15	4	52	24
NC: B (1966)	x	0.81	0.35	0.36	x	0.88
SL: C (1968)	(5.0)	(8.5)	9.5	3.0	2.4	8.0
FG: A (1966)	—	7	6	6	—	25
TK: C (1966)	58	31	48	45	59	12
SCM: C (1966)	—	68	66	48	80	36
ATL: C (1968)	—	x	81	39	97	52
GA: A (1968)	—	x	—	—	48	70

Key: A = percentage of national output; B = number per 1000 machine tools (including aircraft industry); C = percentage of respondents' total output.

x Insufficient data. xx Between 20 and 30 p.c.

hindering the introduction or the spread of the new method.

Diffusion of New Techniques . . .

The diffusion, or penetration, of the new techniques, as achieved by 1966-68, is shown in Table 1 for the countries covered.

There are considerable differences by countries in the diffusion achieved. This is the combined result of the year of introduction in each country and of the speed of the following diffusion. The innovation in the first country was followed by different time lags in the other countries. Both the first adoption and the time lags are demonstrated in Table 2. Here the year of introduction is given; this refers to the country where the time lag is zero and the lags shown for the other countries have been related to that year.

Table 2

Time Lag of Each Country behind Pioneer Country

	Date (and country) of first introduction	Austria	France	Ger- many	Italy	Sweden	UK
OXY	1952 (A)	0	4	5	12	4	8
CC	1952 (A)	0	8	2	6	11	8
SP	1963 (S)	3	2	2	2	0	1
NC	1955 (UK)	8	2	7	5	3	0
SL	1953-4 (F)	7	0	1	6	3	4
FG	1958 (UK)	—	8	8	7	—	0
TK (a)	1948 (S) (a)	9	1	11	3	0	0
SCM	1950 (S)	—	10	3	12	0	0
ATL	1947 (F-UK)	—	0	7	3	8	0
GA	1959 (S-UK)	—	7	—	—	0	0
Mean		4.5	4.2	5.1	6.2	3.2	2.3

* Omitted as extreme.

(a) The extreme value (1902) for the UK has been omitted.

. . . as a Result of Management Decisions

Both the first and the later adoptions in each of the countries were the result of decisions of company managements. In some cases the technicalities of the new process, the differences in the size of the market or in the importance of the industry, or some other factor help to explain why a company in country A was the innovator, or why the other countries followed in the order they did.

Thus, the proportion of scrap used in steelmaking seems to explain the order in which the other five countries followed the pioneering country, Austria, since one of the conditions of oxygen steelmaking is the availability of liquid hot metal. Similarly, the share of solid fuel provides some explanation for the order of the adoption of tunnel kilns in brickmaking since liquid and gaseous fuels are much better suited to this type of kiln⁴. In other cases market conditions go some way to explain why a particular country was the innovator and why others followed it in a specific order; the

⁴ In most cases mentioned here the relationship was established by regression analysis and this statistical method was used for assessing the reliability of the relationship.

size of the market provides such tentative guides in the cases of automatic transfer lines in the car industry and of new steel-cutting methods in shipbuilding. The overwhelming importance of paper-making in Sweden, as compared to the part played by this industry in the economies of other countries, may be the key to Sweden's leadership in the adoption of the new special press technique. The aircraft industry in the United Kingdom might have played a similar part in promoting the early adoption of NC machine tools.

Speed of Diffusion

In other cases no such evidence could be found. This is not surprising, considering the large number of factors affecting management decisions. Similarly, for the time being we do not have sufficient data to specify the factors affecting the speed of diffusion. This can be measured in different ways; the measure applied here is the number of years taken in each country to reach "z" per cent of an industry's output produced by means of each new technique. The level of "z" varies between techniques since these are of different vintage and at different stages of development; it is shown in the first column of Table 3. Information on this measure of diffusion is available for seven of the ten techniques only (and the data could not be assessed for each country).

Table 3

Years Required for Each Country to Produce z per cent of an Industry's Output with the New Techniques

	z p.c.	Austria	France	Ger- many	Italy	Sweden	UK
OXY	20	2	12	8	2	9	5
CC	1	10	—	9	7	3	6
SP	10	2	2	2	—	2	3
SL	2	—	—	6	3	9	6
TK	10	4	12	2	10	8	0*
ATL	30	—	—	1	15	2	10
GA	50	—	—	—	—	3	4

* Omitted as extreme.

Scatter diagrams were prepared for each of these techniques with speed of diffusion plotted against the introduction time-lag (with the exception of GA where there was no time-lag between the two using countries). For SP the speed of diffusion seems to be independent of the time-lag, or the technique may be too recent and the speed cannot yet be measured sufficiently. For each of the remaining five processes the scatters indicate a negative correlation between speed of diffusion and time-lag. For each one of them the number of observation is rather small and hence the data for the five techniques—OXY, CC, TK, SL, and ATL—were pooled and the speed of diffusion was regressed on the time-lag. This aggregate approach, together with the results of the regressions for all the five processes and the aggregate, are also shown in the chart and the following notes.

The analysis of these five processes suggests that in these cases there is a fairly marked negative relationship between the speed of diffusion and the time-lag of introduction: pioneer countries tend to have slower speeds of diffusion.

This finding is consistent with the hypothesis that the pioneer faces all sorts of teething troubles, new problems associated with the new technique; these are likely to be gradually solved by the time others adopt it. It is therefore not necessarily desirable to be the first to introduce a new technique. There are of course many other aspects of this problem. It must also be borne in mind that the above statement is suggestive but not definitive; it offers not more than partial explanation of the differences between countries.

Even among the relatively few processes investigated there are two which indeed point to the opposite direction — that is, the pioneer's diffusion speed was the fastest; it is true however that special circumstances affected both cases. SP probably spread faster in Sweden than elsewhere because the importance of the paper industry exceeds the part played by this industry in any of the other countries; whereas the case of float glass is unique in view of the pioneer's world licence, of the very special structure of this industry, and also considering the important fact

that in this case most of the teething troubles were probably ironed out by the inventor company before commercial introduction.

Special Factors of Importance

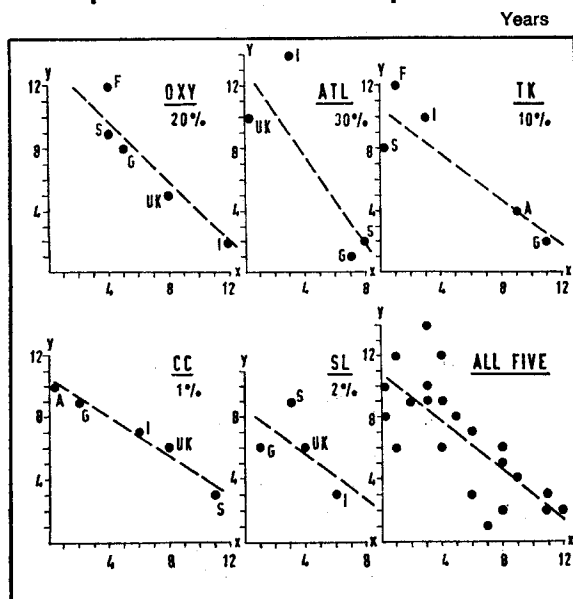
Finally, and this may be the main moral of the study, there are a very large number of special factors of different importance which have to be taken into consideration when comparing diffusion rates between countries (and these may affect any such comparison between companies too). It is very hazardous, and hence probably not justified to make such comparisons without analysing all aspects of the situation as existing in the various countries and allowing for their possible impact on the introduction or on the speed of diffusion of any innovation.

It may be convenient to mention briefly those factors which, in the light of this pilot study, appear to have had the most significant influence on the diffusion of each of the techniques investigated. A selection of this type is naturally subjective, since the spread of new techniques is the outcome of a large number of different, often conflicting, influences. The three most important among them are probably the advantage of the new, as compared with the existing "traditional", process in terms of overall profitability; the attitude of management to the adoption of new technique, and the access to capital. In the course of the study certain other specific factors emerged as having had a leading impact on the decision-makers; these, superimposed on the above three general factors, resulted in the dates of adoption and in the speed of diffusion as reported. The diffusion of each of the new techniques was of course also influenced by a long list of supplementary factors but in general the importance of each of the latter appeared, in the cases studied, as relatively minor compared with those mentioned below.

Role of Management's Attitude

The study provides no definitive evidence for saying that large companies have always been in the forefront of technical progress in the sense of being leaders in innovation and the adoption of new techniques. It is of course admitted that their often leading role in research and development, their generally more sophisticated managerial set-up, and their easier access to new capital are likely to give them a lead over smaller firms: within the framework of these ten case studies we have indeed found some which point to the outstanding part played by large companies. But these studies have equally produced cases with a contrary result, illustrating the pioneering spirit in smaller and medium-sized companies. Whether large company or small, the least tangible factor is however likely to have the greatest impact on the application of any new technique — the attitude of management.

The relation between time-lag of introduction and speed of diffusion of five processes



Source: Tables 2 and 3.

Key: x = number of years since introduction of technique into first country;
y = number of years required to reach first 'z' per cent.
A = Austria; F = France; G = West Germany; I = Italy;
S = Sweden; UK = United Kingdom.

The regression equations are:
for OXY: $y = 14.14 - 1.051x$; $R^2 = 0.886$; $s = \pm 0.217$,
for CC: $y = 10.27 - 0.606x$; $R^2 = 0.970$; $s = \pm 0.062$,
for TK: $y = 10.81 - 0.752x$; $R^2 = 0.796$; $s = \pm 0.220$,
for ATL: $y = 13.37 - 1.415x$; $R^2 = 0.612$; $s = \pm 0.796$,
for SL: $y = 8.420 - 0.692x$; $R^2 = 0.346$; $s = \pm 0.673$,
for the aggregate of the above five processes:
 $y = 10.766 - 0.764x$; $R^2 = 0.560$; $s = \pm 0.148$.