Lib sc. 9; 1972; PAPER V.

Research, Innovation, and Diffusion of Technology.

(Documentation problems. 9).

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[Technological change is a key-factor affecting the economic growth of a country. Technological change is stimulated by the knowledge generated by research and developmental activity. There is an appreciable time-lag between the generation of an idea by research and its incorporation into the mainstream of production of commodities and services. Based on published reports, the various factors affecting the diffusion of technology from one country to another, from one enterprise to another enterprise, and within a firm, are mentioned. Information dissemination systems at the national, regional, and institutional levels should be so designed as to facilitate the acceleration of the process of diffusion of technology between countries, between enterprises, and within an enterprise.]

1 Key Factor of Economic Growth: Technological Change

11 FACTORS OF GROWTH

It is now generally recognised that a good proportion of the socio-economic growth of a country depends on

1 Heavy investment in

11 education,

12 research and development,

13 production and distribution of technical know-how,

14 improved information dissemination and technology transfer facilities,

15 better organisation and management of research and industry; and

2 Use of improved materials, processes and equipment (36).

In other words, a good proportion of the investment is apportioned for the production and distribution of knowledge. Recently, Peter Drucker, the management specialist, pointed out that the United States of America spent on the production and distribution of information

25 per cent of the GNP in 1955;
33 per cent of the GNP in 1965; and
50 per cent of the GNP in 1970. (8).

12 Key-Factor

Studies indicate that technological change is a key-factor — if not the key-factor — contributing to economic growth. A technological change is an advance in knowledge as differentiated from a change in technique which is an alteration of the character of an equipment, product, or organisation.

13 Economic Growth and Technological Change

The need for maintaining a high rate of economic growth is a widely accepted concept. Countries with diverse socio-political systems and widely differing levels of economic development — for example, USA, UK, France, USSR, Yugoslavia, India and Japan — have set up targets for the rate of growth. Rough estimates have also been made of the impact of a country's rate of technological change on its rate of economic growth. For example, in USA,

1 Ninety per cent of the long term increase in output *per capita* resulted from technological change, increase in educational levels, and other factors not directly associated with the increase in labour and capital (17): and

2 Forty per cent of the total increase in income per person employed during the period 1929–57 was derived from advances in knowledge (18).

14 Technological Change and R and D Expenditure

A study was made of the Chemical, Petroleum and Steel Industries, using data regarding the number of significant inventions carried out by ten large firms in a few countries. Holding size of firm constant, the number of significant inventions has been found to be highly correlated, at least in the long run, with the amount spent on R and D. In the chemicals field, a proportional increase in the inventive output has also been observed. Studies further indicate that the rates of technogical change appear to be related to the rate of growth of cumulolated R and D expenditure of a country. Therefore, in most countries, an increasingly larger proportion of GNP is being allocated to R and D and to the acquisition of knowledge generated by R and D elsewhere.

A point to be noted is that "... the relationship between R and D expenditure and national economics is complex, and several countries have spent a great deal of money on R and D in recent years without achieving any spectacular economic growth."

15 Avoiding the Malthusian Trap

The economic, political, and social consequences of the imbalanced distribution of resources in relation to population pressure are quite serious. Yet, from the history of the past hundred years, one may infer that science and technology can provide the basis for new discoveries of new resources and substitutes, and together with proper management of available resources, the world can keep a step ahead of the "Malthusian trap".

16 TREND

With a view to keeping pace with the growing demands of society, the developing countries in particular are placing emphasis, among other things, on the following factors:

1 Producing a variety of commodities and services in increasingly larger quantities;

2 Developing the know-how — through its own R and D effort and on the basis of R and D work done elsewhere — to convert the unconsumable natural and near-natural raw materials into consumable commodities;

3 Maximum practical utilisation of new ideas generated by research and innovation anywhere;

4 Securing maximum productivity in research, in the application of the findings of research, and in the production of commodities and services; and

5 Promoting a research and industrial climate conducive to new discoveries, inventions and innovations.

17 PROTRACTED PROCESS OF ASSIMILATION

The mere production and accumulation of a large volume of know-how does not ensure its proper and full utilisation by industry. Being aware of the existence and the availability of know-how also does not ensure its proper and full utilisation. After research has created a piece of knowledge, there is usually a long incubation period before that knowledge gets assimilated in the stream of commodities and services. There is a long chain of events that usually links the idea generated by research with the commodity or services to which the idea may lead.

18 TOTAL PICTURE

In order to get a proper perspective of the long chain of events, it is necessary to examine it against the background of the total socio-economic system. For, in a dynamic system with interacting components, a change in the value of any one of the attributes of any one of the components car produce change in the values of the attributes of the other components and even in the system as a whole. Research, Industry, and Documentation systems are components of the socio-economic system. Research produces ideas that can lead to socio-economic change. The entrepreneur uses the ideas to bring about technological change and produce the goods and services the society needs. The Documentation systems help to disseminate ideas, ostensibly to accelerate the technological change by establishing and timulating communication between research and industry. The close interrelation between invention, innovation and economy is well summarised by Myers, Director of the National Planning Association, R and D Utilisation project. On the basis of a study of five hundred innovations, he concluded: "Perhaps the best way to stimulate an innovation is to stimulate the economy as a whole . . . About one half of the innovations came about in direct response to market factors. A rapidly growing economy obviously expands the market for innovations and encourages business investment in new idea" (27).

19 Scope of the Paper

In the succeeding sections of this paper, some of the problems in the diffusion of technology are considered. It will be helpful for those engaged in research and those engaged in the design, operation, and development of document finding systems to recognise and appreciate the time lag between the generation of an idea by research and its incorporation into the stream of production of commodities and services and of the causes for the lag.

2 From Idea to Adoption

21 Chart of Steps

Table 1 (p 423) mentions the steps in the succession of links between research, innovation, and incorporation of findings of research into the production system (13).

22 Research as Starting Point

In Sec 14–18 we have indicated that research is the source of new ideas which, in turn, can produce technological change stimulating the progress of society. Therefore, one of the main functions of R and D facility to industry is to solve problems and to generate new ideas helpful in the operation and advancesment of the industry. For instance, a survey of business plans for new plant and equipment carried out about a decade ago provided the following information (20).

Table 1. Idea-to-Adoption Continuum

		Objective	Criteria	Leads to
1	Research	.. To advance knowledge : New ideas	Validity: (1) Hypotheses tested; (2) Generalisability	Basis for invention
2	Development			
21	Invention	.. To innovate. Provide new solution to an operating problem(s)	(1) Appropriateness or suitability (2) Estimated viability (3) Relative contribution (impact)	Invention
22	Design	.. To engineer: Systematise and arrangements of the solution To prepare a design or innovation package for institutional use	(1) Institutional feasibility (2) Generalisability (3) Performance (4) Spin off	Design package
3	Diffusion			
31	Dissemination	.. To inform: Create wide-spread awareness of the invention among practitioners and potential users	(1) Intelligibility (2) Fidelity (3) Pervasiveness (4) Impact	Awareness about the invention

Table. 1, Idea-to-Adoption Continuum (*Contd.*)

		Objective	Criteria	Leads to
32	Demonstration	To build conviction: Provide opportunity to examine and assess the qualities of the invention	(1) Credibility (2) Convenience (3) Evidential assessment (Alternative professional consideration)	Building conviction about the invention
4 41	Adoption Trial	Technology transfer. Assess the suitability, Value, etc, of the invention in a particular environment	(1) Adaptability (2) Feasibility	Building familiarity with the invention Establishing contextual suitability of invention
42	Installation	To fit the characteristics of the invention to the characteristics of the adopting environment	(1) Effectiveness (2) Efficiency	Adaptation of invention to a particular context
43	Institutionalisation	To incorporate invention as an integral component of the system	(1) Servicing (2) Evaluation (3) Support	Integrating the invention into the ongoing program Sensing new problems and needs
5	New cycle of Research, Development, Diffusion and Adoption			

Table 2: Objective of R and D

SN	Objective of R and D	% of reporting
1	Develop new products	47
2	Improve existing products	40
3	Develop new process	13

The role of R and D for development of new products was particularly emphasised in the industries dealing with electrical equipment, chemicals, and fabricated metal, while the improvement of existing products was emphasised in those dealing with rubber and petroleum.

23 Research and Innovation

The table in Sec 21 indicates that new knowledge generated through research by itself may not directly contribute to technological change and economic growth. It is only when the idea or invention is assimilated fairly widely into the production system of a country that technological change and economic growth can result.

24 Innovation

One of the key factors of technological change is innovation. Innovation is the totality of scientific and technological effort culminating into a product or service. In market economy terms innovation is defined as the commercial exploitation of technical knowledge in order to

1 Win new markets, or

2 Hold existing markets against competition, by

 1 Reducing the cost of production of existing goods, or

 2 Introducing more efficient goods and services than the existing ones, or

 3 Introducing new goods and services.

In the terminology of planned economy innovation involves the intentional introduction of ideas of science and technology into the production system in order to

1 Improve labour conditions; and

2 Speed up the general rate of economic growth adequate to meeting the growing demands of society (15).

25 Part of Innovation Process

Research and development constitute only a part of the total innovation process. In fact, economically speaking R and D expenditure is an overhead expenditure until the results are commercially exploited. Table 3 presents a general picture of the distribution of cost in successful innovation (6).

Table 3: Distribution of Cost

SN	Stage	% of total cost
1	R and D. basic invention	5–10
2	Engineering and design	10–20
3	Manufacturing engineering	40–50
4	Manufacturing start up	5–15
5	Marketing start up	10–15

It is obvious then that the benefits of technological change can be generally achieved only at the cost of heavy investments in education, in R and D, capital equipment, and marketing.

26 Enriching the Innovation Potential

In actual practice, innovation may arise not only from R and D, but from operational improvements introduced by a "productivity conscious staff and management personnel". A large number of minor improvements may be more important than a small number of breakthroughs.

Enriching the innovation potential requires:

1 Developing an environment helpful in promoting innovation in the whole chain of industrial activity — research, development, production, marketing, and post-sales service, feedback, and repetition of the cycle;

2 Selecting the appropriate advanced technology;

3 Applying the advanced technology before it becomes obsolete;

4 Bearing in mind that there may be competitors using similar or even more advanced technology; and

5 Developing a management structure conducive to maximising the chances of making gainful decisions in planning, organising, and controlling at all levels.

A successful innovation will have a significant impact on the rate of growth of the innovating firm. The impact is greater for a small firm than for a large one.

27 Buying and Borrowing Technology from Abroad

In the early stages of its development a country might find it more economical and helpful to borrow technical know-how from whatever sources available, including foreign countries. A good part of the local effort will be concentrated on innovation to adapt the imported technology to local conditions, available resources, social institutions and expertise. As development proceeds dependence on borrowed technology will be progressively reduced by investing an increasing percentage of the GNP on indigenous R and D. At all stages imported technology and local research effort should be effectively blended so as to be complementary to rather than competing with, each other. In this view it would be considered wasteful to use the limited resources in duplicating effort and reinventing know-how that can be more economically had from published documents, through licensing, etc. Reliance on the products of one's own R and D effort alone is neither necessary nor normally practicable.

28 Technical Know-how: Marketable Commodity

Every country has an interest in the dissemination of technical know-how. Arrangements for this purpose are becoming the subject of discussion at the national and international levels. It is beneficial to the donor as well as to the recipient. In fact technical know-how is now a standard commodity in the international market. The results of research are available internationally through published documents, private communication between specialists, and through conferences, seminars and similar meetings of specialists. Technical know-how may be disseminated through several channels — such as, movement of people, technical cooperation programmes, joint ventures, licenses, patent agreements, foreign investments and the purchase of capital equipment and machinery.

281 *Technological Balance of Payment*

The international exchange of know-how can be shown by a technological balance of payments. Therein we may compare a country's payments to other countries for technical know-how, licence, and patents received with its receipts for "selling" such items. Table 4 presents some data for 1964 on such transactions. The data excludes the transactions between socialist countries and between those countries and developing countries (16).

Table 4: Technological Balance of Payment (1964)

Country	% of world total		
	Receipt	Payment	Balance
USA ..	57	12	+45
UK ..	12	11	+ 1
Germany (FR) ..	6	14	− 8
France ..	5	11	− 6
Other countries of W Europe	18	25	− 7
Japan ..	1	13	−12
Other developed countries ..	1	6	− 5
Developing countries ..	1	8	− 7

291 Assimilation of Technolgoy is Costly

It may be seen that even developed countries borrow technology from abroad. But to be able to utilise it profitably and generate newer technology for "sale" in the international market, it needs a suitable R and D facility to adapt, innovate, and absorb the knowledge into the system. This again can be expensive. For sophisticated technology is often made available in the form of costly equipment and specialist personnel. Basic knowledge about the technology may be acquired through training abroad, published documents, technical information centres, licencing agreements, etc, but technology transfer does not easily take place in this way. In addition to developing the necessary skills and abilities for using the technology, there needs to be good management, organisation of production and marketing facility. A constant stream of innovation has to be stimulated and maximum productivity should be aimed at. The structure of economy, availability of local expertise in adequate measure, and the pattern of organisation and management of R and D and of industry and the distribution of scientists and technologists in research and industry affect the productive utilisation of ideas. In general, the wider the disparity in economic and technical levels between the cooperating countries, the less successful the transfer and adoption of technology is likely to be.

3 Inter-Country Diffusion of Technology

31 Factors Affecting Diffusion

The socio-economic structure of a country should facilitate the free and rapid diffusion of new technology. The rate of diffusion is an important factor. For instance, in process industries, it would determine the rate of increase of productivity in response to the new process. Several factors affect the diffusion rate. While several potential users may learn about a new technology, they may not all be able to predict accurately about its future impact on the industry. There may be need for a considerable investment in R and D for redesigning and adopting the process before it can be profitably assimilated into the production system. Reallocation of resources may be necessary. New skill and expertise may have to be acquired or developed. A major technological change may involve serious problems of personnel adjustment to new work, and consumer orientation to new products. Differences in social structure and social practices of communities can affect the diffusion process in the target system. Using Roger's framework, a diffusion of innovation may be stated as: "The process of adoption or rejection, over time, of some specific idea or practice, by individuals, groups, or other target systems, connected to specific channels of communication which may be complementary to social structures, and to a given system of values and cultures (34).

The complicated feature of the diffusion process is evident from this definition. Mansfield selects four major factors which appear to govern the rate at which an innovation reaches an equillbrium level of use. These are:

1 The extent of economic advantage of the innovation over existing methods or products;

2 The extent of uncertainty associated with using the innovation when it first appears;

3 The extent of the commitment required to try out the innovation; and

4 The rate of reduction of the initial uncertainty regarding the performance of the innovations (19).

The availability of information on each of these factors can accelerate arriving at a decision about the adoption of a technology by a target system.

32 Differences Among Farmers

Mansfield (23) points out differences among individual farmers in the rate of adoption of a new agricultural technique. The farmers were classified as

1 Innovators (first 2·5 per cent to adopt a new process);
2 Early adoptors (next 13·5 per cent);
3 Early majority (next 34·0 per cent);
4 Late majority (next 34·0 per cent); and
5 Final adopters (last 16·0 per cent).

Among these adoptor categories, differences were found in regard to attitudes, values, social status, abilities, group membership, and farm business characteristics. The innovators were found to be more cosmopolitan, seek out new ideas and information, venturesome, reach decisions quicker, better educated, and more affiliations and friends outside their group. They tended to have larger farms, more specialised enterprise, and greater farm ownership. The prevailing culture of the community also influenced the diffusion of innovation.

33 A Study of Inter-Country Diffusion

Although several factors complicate the picture of diffusion of technology, it would be useful to take note of some features, such as time-lag between invention and innovation.

Ray (33) has reported on the inter-country diffusion of the following new processes:

1 Basic oxygen process in steel making (Oxygen);

2 Continuous casting of steel (Casting);

3 Special press in paper making (Press);

4 Numerical control of metal working machine tools (NC);

5 Shuttleless looms in the weaving cotton and man-made fibres (Loom);

6 Tunnel kiln in brick making (Kiln);

7 Steel plate marking and cutting in ship building (Steel marking);

8 Float Glass (Glass);

9 Automatic transfer lines in the manufacture of engines for passenger cars (Transfer line); and

10 Treatment of malt with gibberellic acid in malt brewing (Malting).

Information was gathered on:

1 The date of first application in a country;

2 The diffusion since the first application (in terms of the number of users, share of new equipment/process in the total productive output, and the proportion of the output produced by the new technique); and

3 The firm's views of the advantage and disadvantage of the new technique compared with the technique in use, and the factors favouring or hindering the introduction and spread of the new technique.

Ray's data regarding the time-lag of each of a few countries behind the pioneering country are presented in Table 5.

Table 5: Time-lag Differential Between Selected Countries.

SN	Process/ Technique	Year of introduction	Pioneer country	N of years of lag after pioneer country					
				Austria	France	Germany	Italy	Sweden	UK
1	Oxygen ..	1952	Austria	0	4	5	12	4	8
2	Casting ..	1952	Austria	0	8	2	6	11	8
3	Press ..	1963	Sweden	3	2	2	2	0	1
4	NC ..	1955	UK	8	2	7	5	3	0
5	Loom ..	1953-54	France	7	0	1	6	3	4
6	Kiln ..	1948	Sweden	9	1	11	3	0	0*
7	Steel marking ..	1950	Sweden	..	10	3	12	..	0
8	Glass ..	1958	UK	..	8	8	7	..	0
9	Transfer line ..	1947	France-UK	..	0	7	3	8	0
10	Malting ..	1959	Sweden-UK	..	7	..	..	0	0
	MEAN ..			4·5	4·2	5·1	6·2	3·2	2·3

* The extreme value (1902) for UK omitted.

Ranked according to increasing mean time-lag, the countries fall in the following sequence: UK (2·3); Sweden (3·2); France (4·2); Austria (4·5); Germany (5·1); and Italy (6·2). Whether the differences in time-lag between the countries are statistically significant is to be verified with more data.

4 Inter-Enterprise Diffusion of Technology

In another investigation in USA (25), the diffusion rate of twelve innovations from one enterprise to another in four industries have been studied. The innovations studied were:

1 Bituminous Coal Industry
- (*a*) Shuttle car
- (*b*) Trackless mobile loader
- (*c*) Continuous mining machine

2 Iron and Steel Industry
- (*a*) By-product coke oven
- (*b*) Continuous wide strip mill
- (*c*) Continuous annealing line for tin plate

3 Brewing Industry
- (*a*) Pallet loading machine
- (*b*) Tin container
- (*c*) High speed bottle filler

4 Railway
- (*a*) Diesel locomotive
- (*b*) Centralised traffic control
- (*c*) Car retarders

Some inferences from the study were:

1 Diffusion of a new technique is generally a slow process. From the date of the first successful commercial application, it took about twenty years or more for all the major firms in USA to install centralised traffic control, car retarders, by-product coke oven, and continuous annealing. The period was about ten years in the case of pallet-loading, tin container, and continuous mining machine;

2 The rate of initiation varied widely (0·9 to 15 years);

3 There was also a wide variation in the initiation rate of diffusion (average 9 years).

5 Rate of Diffusion

51 Time-lag from Invention to Innovation

Surveys indicate that the time lag between invention and innovation varies to a considerable extent and depends on several factors. Some inventions mark a major departure from the existing technique while others may be of a routine kind. Change of taste, attitude, technology and factor pricing may be involved in some cases before there can be a profitable utilisation of an invention. Table 6 presents data about the estimated time interval between some inventions and corresponding innovation (9).

Table 6: Estimated Time lag Between Invention and Innovation

SN	Invention	Interval (years)
1	Cotton picker	53
2	Spinning jenny	5
3	Spinning machine (water frame)	6
4	Spinning mule	4
5	Power steering	6
6	Steam engine (Watt)	11
7	Steam engine (Newcomen)	6
8	Jet engine	14
9	Turbojet	10
10	Fluorescent lamp	79
11	Wireless telephone	8
12	Wireless telegraph	8
13	Triode vacuum tube	7
14	Radio (Oscillator)	8
15	Gyrocompass	56
16	Self-winding watch	6
17	Xerography	13
18	Ball point pen	6
19	Zipper	27
20	Safety razor	9
21	Long playing record	3
22	Magnetic recording	5
23	Shell moulding	3
24	Titanium reduction	7
25	Electrical precipitation	25
	Petroleum production	
26	Distillation of hydrocarbons with heat and pressure	24
27	Distillation of gas oil with heat and pressure	3
28	Continuous crakcing (Hommes and Manley)	11
29	Continuous cracking (Dubbs)	13
30	Clean circulation	3
31	Tube and tank process	13
32	Cross process	5
33	Houdry catalytic cracking	9
34	Fluid catalytic pellet	13
35	Gas lift for catalyst cracking	13
36	Moving bed catalytic cracking	8
37	DDT	3
38	Streptomycin	5
39	Freon refrigerent	1
40	Hardening of fat	8
41	Plexiglass, lucite	3
42	Nylon	11
43	Terylene	12
44	Crease resistant fabric	14

Some of the findings of the study were:

1 Average time lag:

11 The average time-lag was about 11 years in the petroleum industry.

12 The average time-lag was about 14 years in other industries.

2 Field of Innovation:

21 Mechanical innovations required the shortest time intervals, with chemical and pharmaceutical innovations taking a longer time in that sequence.

22 Electronic innovations involved the longest time-lag.

3 Innovator:

31 The interval was shorter if the inventor himself attempted to innovate than when he merely disclosed the new concept and left it to others to innovate.

52 Acceleration of Diffusion

Killingsworth, Lynn and others (22) claim considerable acceleration of the rate of diffusion between the early part of this century and the inter-war period, with a slight acceleration after 1945. The reasons for the acceleration of diffusion are:

1 Development of a variety and improved channels of communication of information;

2 Development of more sophisticated methods for determining the time at which equipment should be replaced; and

3 Greater receptivity to newer ideas and techniques.

521 *Reduced Time-lag in Application of Discovery*

Table 7 presents data about the time-lapse between formulation of a principle and its use for the development of a device, over the period 1700 to 1960.

Table 7. Discovery-to-Device Time-lag.

SN	Invention	Year of		Time-lag
		Discovery of principle	Development of device or use	
1	Internal combustion engine	1710	1892	182
2	Photography	1727	1839	112
3	Aerial flight	1809	1903	94
4	Telephone	1823	1876	53
5	Radar	1889	1935	48
6	Gamma ray	1896	1939	43
7	Atomic power release	1932	1945	13
8	Transistor	1940	1948	8
9	Laser	1958	1960	2

522 *Reduced Time-lag Between Innovations in an Industry*

Table 8 presents data about time-lapse between successive innovations in the field of marine engineering (10).

Table 8: Innovations in Marine Engineering

SN	Invention	First plan	Commercial success	Time-lag
1	Geared turbine ..	1629	1911	282
2	Steam boat ..	1661	1808	147
3	Propeller ..	1746	1836	90
4	Ironship ..	1777	1829	52
5	Fixed contra-propeller	1864	1910	46
6	Diesel engine ..	1882	1903	21
7	Rotorship ..	1923	1926	3

523 *Commercial development*

A survey of the products on sale by different manufacturing firms in USA in 1960, indicated that 10 per cent of the sales were of products developed during the immediately preceding five years.

Lynn, in a study of twenty major innovations during the period 1885 to 1950, has estimated.

1 The incubation period — that is, the average number of years elapsing from the time of the basic discovery or invention and the establishment of its technical feasibility to the beginning of its commercial development; and

2 The commercial development period — that is, the average number of years elapsing from the beginning of the commercial development of a product/process to its introduction as a commercial product/process (21).

Data from Lynn's study are presented in Table 9.

Table 9. Average Rate of Development of Selected Technological Innovations

Particulars	Average time intervals (years)		
	Incubation period	Commercial development	Total
1 Time period			
11 Early twentieth Century 1885–1919	30	7	37
12 Post World War I (1920–44)	16	8	24
13 Post World War II (1945–64)	9	5	14
2 Type of market application			
21 Consumer	13	7	20
22 Industrial	28	6	34
3 Source of Development			
31 Private Industry	24	7	31
32 Federal government	12	7	19

53 Inference from the Findings of Studies

1 The time-lapse between invention and the innovations based on it has been decreasing over time;

2 The time-lapse is much shorter for consumer products than for industrial products; and

3 The time-lapse is shorter for innovations developed using government funds than those using private funds.

6 Sources and Media of Transfer of Innovation

61 Pure Research and Technology

Studies have disclosed differences in the modes and media of diffusion of knowledge generated from pure research and that generated by technology (29–32). The following are some of the findings:

1 New information becomes known to a scientist's peers in the world scientific community much earlier than to other groups, well in advance of any formal written publication;

2 In technology, including the application of science and engineering, creative efforts are primarily concerned with the integration of previously existing knowledge to produce usable commodities and services including, for example, systems, devices, processes, methods and materials;

3 Pure research and phenomenon-oriented research are concerned mainly with the generation of knowledge of some phenomenon or other;

4 The knowledge generated from pure research and phenomenon-oriented research is made available to scientists and technologists in several ways and through several channels;

5 Technological events are usually initiated within technology, in the presence of ambient science. With a few exceptions, it is usually difficult to establish an unique correlation between an important technological advance with a piece of knowledge generated by pure research or phenomenon-oriented research; and

6 In general, technology feeds upon knowledge generated in the technological field, while pure research and phenomenon-oriented research feed upon knowledge generated in the field of pure research and phenomenon-oriented research. However, there are several interconnections across the two spheres of activity.

62 Source of Ideas for R and D

Ideas and proposals for research, development and innovation arise from different points within a firm. For instance,

1 Innovations by competitors stimulate new projects;

2 New developments in science and technology may suggest new lines of research and innovation;

3 The sales and production divisions may make suggestions for new lines of work;

4 Customers often point out defects and ask for an improvement in a firm's product; and

5 Any individual or department in a firm is a potential source of new ideas.

In a study of over 100 industries, it was observed that

1 Sixty per cent of the topics originated from the R and D department;

2 Seventeen per cent from the sales department;

3 Nine per cent from the management; and

4 Four per cent from the customers.

R and D department was the more important source of ideas in the chemical, pharmaceutical and food areas, the sales department was particularly an important source in the metallurgical industry, and the Government was the important source in the electronics and aerospace industries (26, 35).

63 Dissemination Media

The media for dissemination of knowledge that may result in a major invention or improvement of an existing technology are many and varied. These include

1 Document (External)

Book, periodical, technical report, patent, standard, specification, thesis, trade publications, government publications, review and trend report, preprint/reprint exchange, card service, indexing and abstracting services, etc.

2 Information dissemination centre

Documentation centres, information analysis centres, clipping services, associations, etc.

3 Vendor/Supplier/Contractor

Representative of or document generated by, vendor/supplier/contractor.

4 Customer

Representative of or document generated by, the agency for which a project is carried out

5 Consultant/Adviser/Guide

6 Meeting

7 Mass media

8 Formal course

9 Through colleagues

10 Institutional source

Other institutional research projects; colleagues in the institution, documents generated within the institution.

11 Personal experience in similar, related, or other work.

631 *Example*

William J Price mentions the pattern of link between the scientific community and the research activity of the US Air Force Office of Scientific Research (= AFOSR). It is a two-directional communication — information for finding solution to the scientific problems of the Air Force and the availability of information to the users. The link or coupling is established in the following ways (15):

1 Part of what the AFOSR purchases through contracts and grants is primarily designed to provide communication. The symposia and related sponsored research helps the AFOSR to keep abreast of the developments in science and technology; and

2 Direct involvement and participation of scientists through AFOSR contracts. For instance,

21 Trips to Air Force installations to provide consultancy service;
22 Membership on *ad-hoc* groups to study the feasibility of various exploratory-development programmes;
23 State-of-art review, either oral or written;
24 Special purpose symposia specifically designed to bring technologists and scientists together;
25 Special lecture tours;
26 Feasibility studies on research phenomenon to package them in a form more likely to be useful; and
27 Direct consultation with aerospace industries.

64 Differential Use of Media

The differential utilisation and performance of the different media of information in R and D activity have been studied by Allen and others (1). The process of diffusion of technological information and the several sociological, institutional and human factors affecting it within a scientific and technological community have been examined (2). The MIT Conference on the Human Factor in the Transfer of Technology (12), the University of Nottingham Symposium on Accelerating Innovation (5), and the report of Gilmore and associates (11), are examples of such studies. There have also been a large number of " user studies " over the past three decades (7, 37).

641 *Documents as source for ideas*

In a survey of 1082 technologists in UK, it was found that only 12 per cent used documents at the start of work, and once the investigation was underway, if they had not already consulted the documents it was unlikely that they ever would. Of the population studied, 60 per cent reported documents as major source for ideas or major stimulus for ideas. Impersonal channels of communication appeared to be preferred at the " interest " stage (14). These findings are similar to those of Allen, Gerstenfeld, and Gerstberger in a study of engineers in the R and D departments of biological and aerospace industries (4).

Allen has pointed out the effect of such use of information on the success of firm in landing government contracts (3).

642 *Group relationship*

The structure of formal and informal relationships among the groups in the laboratories appear to have an effect on the information flow pattern. Allen and Cohen (3), using sociometric methods, have compared in two laboratories the choice of communication methods — such as, technical discussion, critical incident information, and research ideas — with the research worker's choice of social contact. In the case of one laboratory there was considerable overlap between the socialisation network and communication of ideas generated by research. In another laboratory there was overlap between social contact and both technical discussion and research ideas. In the second laboratory, it was also noted that the Ph Ds communicated little with non-Ph Ds; on the other hand, the non-Ph Ds preferred to socialise and communicate with Ph Ds. The organisational structure of the institution is shown to have considerable influence on the communication patterns of R and D groups.

643 *Information from within and from outside a firm*

Myers report (28) based on a study of 560 decisions in railway, housing, and computer industries, indicates that 50 per cent of the decisions were based largely on technical information transferred by one using-firm to another; and about 50 per cent by information generated within the using-firm. The single most important media for such transfer of information was the vendor or potential supplier (15 per cent); and the Government was ranked next (10 per cent). The Governmental information was used differentially from the vendor information.

Gilmore's survey of industrial organisations indicates that the "Personal Channel" — supplier, customer, consultancy, and meetings — is the most widely used as external channel of information for problem solving (11).

644 *Source of information to farmer*

Among farmers, the prevailing culture of their communities was found to influence the rate of diffusion of information and the differential use of communication channels. The use varied in relation to the stage in the adoption process that the farmer had reached and in relations to the farmers' adoptor category. For instance, mass media sources were important at the awareness and interest stages; neighbours and friends were important at the evaluation and trial stages. The early users of a new technique tend to rely on sources of information beyond the experience of their peer group; and after they have successfully used the modern technique, they become the model for the less expert group (24).

65 TECHNOLOGICAL GATE KEEPER

Studies on information flow in an organisation also indicate that some individuals act as "Technological Gate Keepers."

A larger proportion of the technical personnel in the organisation turn to them for information and were the preferred choice in technical discussion. Such a person tended to be exposed to a great extent to documents and personal contacts outside the organisation. They received most of the information from outside the organisation and helped to disseminate it among the personnel within the organisation (2).

7 Conclusion

The key role of technological change as a factor contributing to the economic growth of a country is evident. Technological change, in its turn, is dependent on R and D activity. But, there is a time-lag between the generation of an idea by research and its incorporation into the mainstream of production of commodities and services. This is true of the diffusion of technology from one country to another, from one enterprise to another, as well as diffusion within a firm. Several factors contribute and complicate the process of diffusion of technology. Any information dissemination system, whether it be national, regional or industrial, which seeks to reduce the time-lag between an invention and a subsequent innovation based on it, and thereby accelerates the process of diffusion of technology between countries, between enterprises and within an enterprise, should take cognizance of these factors.

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