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THE ORIGIN AND DIRECTION OF INDUSTRIAL RESEARCH AND DEVELOPMENT IN INDIA

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Summary

This paper surveys the trends in industrial R & D in India over the last two decades. It shows that there has been a rapid rise in R & D expenditure and a shift in its composition towards in-house corporate R & D and away from R & D in government laboratories, which is explained by the laboratories' lack of market orientation and manufacturing experience. According to cross section studies of corporate R & D, larger companies aim towards larger technological advances and take a longer view; but the overall composition of corporate R & D shows no discernible change. This apparent inconsistency is explained by the development of the technology market. Much R & D was triggered off by the need for import replacement arising from import controls till 1965 and later by the need for product diversification in the recession. But construction of new plants and mechanization for speeding up operations, activities where sustained R & D can yield large firms a steady flow of innovations, were unimportant or infrequent, and the demand for technology they gave rise to was largely met by imports.

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Interviews conducted in the course of two studies of transfer of technology to India undertaken in 1968 and 1969 [1; 2] suggested that companies that did their own R & D got a better return on their technology imports in a number of ways; they unpackaged their technology requirements and imported only those components that they could not generate economically or fast enough, they informed themselves better about the technology market before entering it as buyers and they got a greater benefit from technology imports in terms of their own product and process development. The experience of the firms doing R & D stood out so clearly that a more comprehensive and detailed study of industrial R & D was indicated. The rapid expansion of R & D and the application lags involved suggested that the study should extend over a reasonably long period. Hence the sub-sample of 16 firms with significant R & D activity that emerged from the 1968-69 surveys was expanded and 84 firms were studied in detail in 1972 [3; 4; 5]. A number of them were again followed up in 1978. The present paper summarises the results of the studies stretching over almost ten years supplemented with published information from other sources.

The plan of the paper is as follows. Section I summarizes the available information on the volume of industrial R & D expenditure in and outside the corporate sector. Section II gives a classification of R & D on the basis of its time horizon new knowledge required and probability of success. Section III discusses the major factors affecting R & D in Indian firms. Section IV deals with the problems that beset non-corporate R & D. The conclusions of the paper are summarized in Section V.

I. EXTENT OF R & D

Whilst national estimates of R & D expenditure have been published from time to time, the isolation of industrial R & D from them presents some problems. Our estimates are summarized in Table 1. Of the considerable expenditure that the government includes in its own R & D, we have included only the expenditure of the Department of Electronics and the railways. The expenditure of the Defence R & D Organization and the Department of Space Research also probably contains industrial elements, but they cannot be identified and have been excluded.

The expenditure of all industrial laboratories of the CSIR is included; it is an overestimate in so far as they do significant non-industrial work. The estimates for government departments and CSIR laboratories include administrative expenditure and are not strictly comparable with those for private and government companies.

Another possible source of understatement in corporate R & D expenditure is non-reporting companies. A committee which made a comprehensive investigation of R & D in private companies /6/ discovered a number of companies that reported R & D activity but did not claim income tax rebate for R & D expenditure.[1/] or could not specify how much they had spent on R & D; further, the committee's list of respondents excludes a number of companies which have long been known to be engaged in R & D. Indian companies, especially large ones, receive a large number of questionnaires from various government committees and do not necessarily respond to all of them. Hence it is possible that the R & D expenditure of private companies is significantly understated.

Finally, the point made in the next section about the confusion in Indian firms between R & D on the one hand and trouble-shooting or technical services should be borne in mind. Statistics of corporate R & D probably include a borderline element of what is not R & D on a rigorous definition.

The outstanding feature of R & D expenditure is its rapid growth throughout the period since 1958. This impression will withstand any correction for inadequate coverage in the early years. The next most striking feature is the fall in the share of the CSIR and the industrial associations. In 1958, virtually all the industrial research was being done in CSIR laboratories. By 1965 the share of CSIR and industrial associations had fallen to 70 per cent. By 1974 their

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1/Under the income-tax law, one-third more than the actual R & D expenditure can be charged in the computation of taxable profits, providing the tax officer is satisfied about the nature of the expenditure.

Table I

Industrial R & D expenditure, 1958-1974[a]

(Rs. million)

	1958	1965	1968	1970[b]	1974
Central ministries					100
Central government enterprises	–	17	22	38	145
Council of Scientific and Industrial Research[c]	28	77	102	117	194
Industrial associations	–	6	9	11	28
Privately owned companies	2	18	90	131	367
	30	118	223	300	834

a/ Financial years running from April to March; for instance, 1958 refers to the year from April 1958 to March 1959.

b/ For enterprises whose expenditure was not available, the previous year's figure was repeated.

c/ For 1968 and subsequent years, the actual total expenditure of laboratories doing industrial work. For earlier years it is assumed that the ratio of industrial laboratories' expenditure to total CSIR expenditure was the same as in 1968.

Sources: Council of Scientific and Industrial Research, Annual Report 1979 (New Delhi), Appendix 8, Committee on Science and Technology, Report on Science and Technology 1972-73 (New Delhi), Tables I, II and V-B.

Department of Science and Technology, Handbook of Research and Development Statistics, 1974-75 (New Delhi, 1977).

share was less than a quarter. The corresponding rise was in the share of private and public companies.

Apart from this shift fron independent to in-house research, there was a rapid rise in the number and expenditure of consultancy firms which are not included in Table 1 [7]. Its R & D element is not definable, but that it is substantial is clear from the fact that the R & D divisions of a number of companies, especially in the public sector, have been hived off into separate consultancy firms - for instance in metallurgy, fertilizers and railways. Thus R & D organizations that are directly responsive to the demand of manufacturing companies, whether they are in-house establishments or independent ones, have gained as against those whose income is fully or largely independent of the work done. The causes of this shift are examined in section IV below.

The industrial distribution of corporate R & D is shown in Table 2, which covers 300 private and 34 government companies. The distribution shows similarity to comparable estimates for the USA and the UK [8, pp 34-36]; as in those countries, chemicals, instruments, electronics, electricals, machinery and transport equipment are the relatively research intensive industries in India. The industrial breakdown of all national R & D cannot be worked out accurately, but a rough comparison with OECD estimates for 1963-64 [9] suggests a lower proportion being spent in India on aeronautics (about 9 per cent against 17-38 per cent in reporting OECD countries) and a higher proportion on other transport equipment (about 19 per cent against 6-9 per cent in major OECD countries) in 1974. The differences reflect the relative importance of the industries rather than differences in their research-intensity.

An important feature of corporate R & D in OECD countries is the high proportion of it financed by the government. This is virtually absent in India. The National Research Development Corporation, which sells technology generated by CSIR and other government laboratories, sometimes gives loans or equity capital to enterprises that buy the technology, but the amounts involved are small. By and large, government funds are spent in government laboratories, and not even in those of public enterprises. This is one reason why a large proportion of publicly generated technology never reaches the shop floor.

Finally in Table 3 we present some data on the relationship between the size of R & D activity and the research-intensity of firms. The sample refers only to privately owned companies and is too small in most industries to furnish reliable results. But one conclusion is clear for industries where figures for a sufficiently large number of observations are available, that the greater the R & D

Table 2

Industrial distribution of R & D expenditure in reporting companies 1974 a/

	R & D expenditure	Sales	Ratio of R & D to sales	Share of Central Govt. enterprises R & D	Share of Central Govt. enterprises Sales
	Rs. million			Percent	
Chemicals:	205.6	14658.5	1.40	21.5	24.1
(a) Inorganic	12.4	905.9	1.37	-	-
(b) Heavy organic	38.2	3059.1	1.25	86.6	91.1
(c) Synthetic fibres	23.7	2496.7	0.95	-	-
(d) Dyestuffs	17.4	1142.8	1.52	-	-
(e) Synthetic resins and plastics	20.9	1800.3	1.16	-	-
(f) Drugs and pharmaceuticals	82.5	3623.6	2.28	11.6	14.7
(g) Other	10.5	1630.1	0.64	15.3	13.4
Instruments	7.7	182.8	4.21	57.3	56.3
Electronics & Electricals	123.2	10777.3	1.14	47.5	38.1
Machinery	39.1	3322.4	1.18	26.3	38.2
Transport equipment b/	62.1	3209.0	1.94	75.4	45.2
Office and domestic equipment	33.5	5978.2	0.56	-	-
Metals	30.2	16586.7	0.18	41.7	71.3
Ceramics and glass	1.6	144.5	1.11	0.2	5.3
Cement	7.5	1598.3	0.47	-	-
Paper	1.5	6361.8	0.02	0.7	0.2
	512.0	62819.5	0.82	28.3	35.8

a/ Financial year.

b/ Excludes railways which are a departmental undertaking their R & D expenditure was Rs.44.6 million.

Source: Department of Science and Technology, Handbook of R & D Statistics 1974-75 (New Delhi 1977), pp 63, 64.

Table 3

Research-intensity and size of R & D expenditure in privately owned companies, 1969-71

	No. of reporting companies	Companies with R & D expenditure (Rs million)				All compa- nies
		Over 5	1-5	0.5-1	0.5 and below	
		Ratio of R&D expenditure to sales (per cent)				
Metals	6	0.58	-	0.10	0.17	0.53
Machinery	16	0.54	1.79	0.23	0.14	0.71
Transport equipment	11	1.21	0.28	0.34	0.10	0.90
Electricals	4	-	2.04	0.28	0.53	0.63
Electronics	4	2.39	-	4.41	6.15	2.43
Instruments	6	-	-	3.85	1.70	2.00
Chemicals	20	1.94	1.12	-	0.49	1.25
Dyestuffs	5	3.07	0.65	-	-	1.09
Drugs	10	3.41	2.05	1.33	0.35	2.[illegible]9
Cement	4	-	0.40	0.30	0.06	0.33
Ceramics and glass	5	-	1.82	1.07	1.06	1.43
Paper	4	-	0.[illegible]3	0.28	1.46	0.43
Textiles	4	0.71	0.33	0.57	-	0.60
Food	3	0.54	-	0.11	0.13	1.95
Other	3	0.20	-	0.26	-	0.21
	105 a/	1.11	0.93	0.32	0.32	0.94

a/ A consultancy firm in the original group is excluded.

Source: Calculated from Ministry of Industrial Development, Science and Technology, Report of the Committee on Peformance and Commercialisation of R & D in private sector industry (New Delhi 1974) expenditure of a firm, the greater its proportion of R & D to sales.1/ Similar results are obtained if firms are classified by sales instead of by R & D expenditure. Despite some contrary results, there is a clear correlation between size and research-intensity, unlike in Europe and the USA where Freeman found no significant relationship [8, p 206]. Obviously, the absolute size of Indian firms is small enough for economies of sale in research to obtain even in the largest existing firms.

1/ The conclusion of the Committee [6, p12] that research-intensity is the highest in firms under foreign ownership, next highest in independent firms and lowest in firms attached to large business groups is vitiated by aggregation across dissimilar industries.

II CONTENT OF R & D

It is customary to classify R & D by its time horizon. For instance, OECD studies distinguish between basic research which is exploratory and long-term, applied research which focuses more sharply on economic objectives and experimental development which has a more immediate perspective [10]. R & D in Indian firms tends to have a shorter horizon than in industrial countries, and some of what Indian firms term R & D is perhaps more in the nature of trouble-shooting and technical services. R & D emerged in most firms from quality control, technical services, material adaptation and plant construction; as the volume of required technical inputs rose, as scientists and technicians recruited for start-up operations had to be re-employed, or as the recurrence of similar technical problems made a systematic approach to them possible, ad hoc technical activities developed into R & D programmes.1/ R & D departments continue to deal with at least some of the problems earlier handled by stray technicians. Since it is impossible to separate these peripheral activities, we have put them into an additional class of their own. Our classification is thus: exploratory research, development and operational investigations. On a rough estimate, research scarcely absorbs 2-3 per cent of corporate R & D, though presumably more of the CSIR laboratories' R & D. Development probably absorbs 30-40 per cent of the

1/For a fuller account of the origin of R & D activities in Indian companies, see [3].

expenditure; the rest is devoted to operational investigations.

There is some evidence from the early sixties, summarized in Table 4, which suggests that the time perspective of R & D lengthens with the size of firms. Most of the R & D of small firms was concentrated on adaptation of raw materials and on process improvement; large firms, on the other hand, spent about 40 per cent of their R & D budget on equipment construction and product improvement. These results are confirmed by another survey done in 1970 [11, p 12].

Table 4

Composition of R & D expenditure in 60 companies[a/]

Annual sales (Rs.million)	Expenditure on				
	Equipment %	Raw materials %	Process %	Product %	Product utilization (%)
under 10	-	60	30	10	-
10 - 20	5	50	30	10	5
20 - 50	10	30	25	25	10
50 - 100	20	25	25	20	10
Over 100	20	25	30	20	5

a/Mainly in engineering and chemicals, surveyed in 1963-64.

Source: Economic and Scientific Research Foundation, Research, Technology and Industry (New Delhi 1965)

(a) Operational investigations

Operational investigations relate to current problems being thrown up by manufacturing operations - problems of raw-materials supply, manufacturing problems and customers' problems. There is a premium on solving them quickly; and speed dictates the solution of the problems on the basis of existing and easily available knowledge. For instance, 2,000 motor starters were once held up on the production line in Larsen and Toubro for lack of silver salt. The R & D department proceeded to find out what was being used in place of silver salt by competitors, what was earlier used in starters, which patents in the relevant group used silver salt, how other patentees had tried to get around those patents, and so on. Ultimately, it came up with a compound which was superseded by silver salt in starter manufacture in other countries but seemed the most economical substitute in India.

(b) Development

Development may be broadly defined as work directed to translate proposals known to be possible into manufacturing operations. It is closely related to the erection or operation of equipment, and its time horizon is longer than of operational investigations - often as long as the time required by new investment projects, and some times longer. Ideas worked on in development may come from the market, the technical staff, literature, patent descriptions, or purchased know-how. In a recent development of a diesel engine, for instance, Tata Engineering and Locomotive Company started with a field study of the performance of the engines it was fitting into its existing range of trucks. The study furnished information about the required improvements in engines, which pointed towards the necessary modifications. The modifications led to the development of new markets for the engines; the latest into which the company has entered is marine engines. Similarly, Jyoti Limited developed a series of low capacity water turbines following realization that there was a market for small hydro-electric generating plants in hilly areas that was not met by the equipment in the market [12, pp 65 ff].

In a case where development was taken up for its technical interest, Excel Industries was manufacturing phosphoric acid from the commonly used red phosphorus. It was possible to make it out of white phosphorus, but was known to be more hazardous. The use of white phosphorus was cheaper if equipment costs and risks could be kept down. The firm worked out a single-stage process to make phospheric acid from white phosphorus using a stainless steel reactor and a cold purification process for arsenic removal, and finally manufactured a high-quality product with lower capital costs than a conventional plant. From phosphoric acid it went on to develop processes to manufacture various organo-phosphoric pesticides [13, pp 70-74].

(c) Exploratory research

Basic research starts with a small stock of accumulated knowledge, and tries to make a substantial addition to it. It may be theoretical or applied. Theoretical research may be defined as research directed towards establishing new theoretical structures to explain scientific phenomena, or to work out limits to the application of known theories. Whilst theoretical research is financed on a small scale by big firms abroad, it is more or less unknown in the R & D activity in India. Unichem gives a prize of Rs.10,000 for theoretical research in India, but finds the response discouraging.

Applied research may be termed as research directed to find products or processes of economic value where little is known. A firm is interested in research in a new field if it can thereby establish a lead over other firms that would yield superprofits for a few years. A common type of applied research that is done in India is molecular manipulation by chemical and pharmaceutical firms. The number of chemical compounds that can be made under laboratory conditions is almost unlimited, and chemical and pharmaceutical firms often construct new compounds and try them out for their possible value as drugs, dyes, etc.

In this type of research, building up of new compounds is just the first step, generally an inexpensive one. In the next stage, called screening, its general chemical and biological properties are investigated. If the exploration shows promise, the possible uses of the compound are more thoroughly investigated. This process is most elaborate in the case of drugs. A product that has shown promise on screening undergoes pharmacological testing on animals; various dosages and combinations are tried out for their therapeutic and toxic effects. If found useful and non-toxic on animals, the drug might be tried out on human patients - in other words, tested clinically. If it passes clinical tests, it will be packed in various forms designed for maximum effectiveness and stability in storage and put on the market.

Of these stages screening is a relatively inexpensive and small scale process, and many Indian firms do it. Some foreign firms are understood to get compounds screened in India, and pass on the promising ones to their central laboratories. Pharmacological testing is a capital intensive large-scale process for it requires large numbers of animals of standardised breed kept in comfort and isolated as far as possible from outside sources of infection. Some Indian firms avail themselves of pharmacological testing services provided by the Central Drug Research Laboratory; hardly any do their own. Formulation, the last stage of the process, is required in operational investigations also, and all firms that do any R & D do formulation research.

III. MAJOR FACTORS AFFECTING CORPORATE R & D

Our survey of corporate R & D practices threw up four major features worth discussion: (a) the make-or-buy decision, (b) priorities, (c) personnel policy, and (d) patent law.

(a) The make-or-buy decision

A great deal of technology is bought within the country by Indian firms in a package with domestically produced plant. The employment of technologists also is a common form of purchase of technology. But the sale or purchase of technology by itself is extremely rare, as shown by the fewness of the cases unearthed by the Committee or Private Sector R & D [6] or patent assignments reported to the Patents Office [14]. Hence the only alternative to R & D is normally import of technology, which requires government permission and which has been subjected to progressively detailed restrictions.

The decision whether to make a technology or to import it depends on the current resources of a company, and principally on its plant (especially in the capital-intensive chemical industry) and on the number and the specialization of its technologists [3]. If a technology involved the building of a new plant or was entirely outside the experience of technologists, a company would be inclined to buy it. If a technology was within the basic line of the company but would require a substantial increase in R & D manpower or would take long to generate internally, the company would be inclined to buy it. The general tendency was to concentrate R & D resources on projects with a short pay-off and modest capital requirements.

(b) <u>Priorities</u>

In all companies immediate problems tend to have priority over long-term projects. Most began R & D in the late fifties or early sixties when industries were being built up to cater to the domestic market under a regime of stringent import controls [15; 16]. The first-generation industrialization threw up a host of production problems which either could not be solved by foreign technology suppliers or were cheaper to solve with on-the-spot R & D. Further, forced import substitution deprived firms of materials commonly used abroad, and local substitutes had either to be developed or to be adapted to imported production processes. Often imported processes malfunctioned in Indian conditions and required adaptive R & D. Thus R & D was initially concentrated on short-term production problems.

In contrast to the policy on import of goods, policy on technology imports was liberal till 1966 [1; 2]. Hence R & D was focussed on import replacement in goods, and avoided import replacement in technology. Companies had to reckon with the possibility that by being the first to import a technology a competitor might capture a market

or steal a march. Hence there was much competitive import of technology, and the accent was on R & D with a short pay-off.

After 1965, however, industrial growth slackened, and the technology import policy was tightened up soon after. Competition in product markets became keener while simultaneously the competitive pressure to import technology was reduced. The technology import agreements of the late fifties with a duration of ten years began to end in the late sixties, and government approval of their extension was most difficult to get. Hence after 1965 companies rapidly stepped up their R & D outlays. But they did not aim at major advances in technology; instead, they concentrated on cost reduction, product improvement and diversification. There was no change in the short horizon of R & D policies, but whilst R & D in the early years concentrated on material and production problems, it became more market-oriented in recent years.

(c) Personnel Policy

Most companies have no personnel policy as such; the idea of recruiting scientists with certain qualities and building up their capability over time - of investment in human resources - is virtually absent. When questioned, most companies were of the view that turnover in their

R & D departments was too high to permit long-term personnel development.

An extremely high proportion of present-day R & D managers were trained abroad. Some entered the corporate world directly, generally when companies were building plants with foreign knowhow; a few were initially recruited by technology suppliers. But most did not come directly. The largest source - or conduit - of corporate R & D personnel at all levels has been the government laboratories. In financial year 1974 CSIR laboratories spent Rs.21000 per scientist against Rs.37000 in the private sector; their ratio of capital to current expenditure was 24 per cent against 45 per cent in the private sector [17] - difference that have persisted over the last two decades at least. Thus private companies offer scientists better salaries as well as more R & D resources. They cannot offer comparable non-material satisfaction in the form of academic papers and conferences at home and abroad; but this has apparently not proved a hindrance in drawing off scientists from government laboratories. It is, however, remarkable that few corporate R & D workers came straight from universities, and then generally at junior levels.

In spite of the high turnover, few scientists and technicians who enter the corporate world leave it. There is a steady trickle abroad, which was more substantial in the slump of late sixties; there was a selective exodus of steel technolgists in the early seventies, and of oil technologists after the oil boom. Some technologists have started their own business. But most move within the corporate sector.

The turnover is distinctly less among R & D managers. This partly reflects their greater age, higher salary and hence lower mobility. But it is also due to greater work satisfaction. It is noticeable that technical staff turnover is less in companies with a consistent record of successful R & D. Their salaries are definitely not higher than in other companies; a congenial work environment probably explains the stability of their staff better. They are also generally companies with a managing director or at least a strong director with a technological background. In this respect our conclusion is similar to that of Project SAPPHO [18].

(d) Patent law

A handful of chemical and pharmaceutical firms which tried to develop their own technology ran into trouble with foreign patents in the sixties. In a case that became famous,[1/] Unichem Laboratories produced tolbutamide on licence from Haffkine Institute of Bombay which had aptented the process.

1/Farbwerke Hoechst vs Unichem Laboratories and others. Bombay High Court suit No.132 of 1962. Judgment of 11 July 1968.

Table 5

Firm's reactions to proposed changes in patent law, 1969

	Indian firms					Joint ventures and foreign firms				
	Yes	No	Reservation	No comment	Total	Yes	No	Reservation	No comment	Total
				(Number of firms)						
Abolition of patents										
Chemicals and drugs	1	2	1	3	7	–	5	–	–	5
Machinery and electricals	1	2	–	20	23	–	2	–	1	3
Other	–	3	–	5	8	–	4	–	1	5
Total	2	7	1	28	38	–	11	–	2	13
Abolition of patents in food, chemicals and drugs										
Chemicals and drugs	1	1	–	5	7	1	4	–	–	5
Machinery and electricals	3	3	–	17	23	1	1	–	1	3
Other	1	3	–	5	8	–	4	–	1	5
Total	5	7	–	27	38	2	9	–	2	13
Compulsory licensing at 4% royalty										
Chemicals and drugs	2	–	1	4	7	1	4	–	–	5
Machinery and electricals	3	3	–	17	23	1	1	–	1	3
Other	1	2	–	5	8	–	4	–	1	5
Total	6	5	1	26	38	2	9	–	2	13
Compulsory licensing on terms fixed by a Court										
Chemicals and drugs	1	1	–	5	7	–	3	1	1	5
Machinery and electricals	1	5	–	17	23	–	2	–	1	3
Other	–	3	–	5	8	–	3	–	2	5
Total	2	9	–	27	38	–	8	1	4	13
Reduction of term from 16 to 10 years										
Chemicals and drugs	1	–	1	5	7	–	3	2	–	5
Machinery and electricals	3	1	1	18	23	1	–	1	1	3
Other	2	1	–	5	8	1	3	–	1	5
Total	6	2	2	28	38	2	6	3	2	13

Source: Author's survey.

The major difference between the patents was that the Hoechst patent specified at a certain point that **sulphur** was to be eliminated from a thiouria "in a conventional manner", and at another point that the elimination was to be done by "a heavy metal oxide or a salt thereof". The Haffkine Institute patent specified elimination by hydrogen peroxide. The judge disallowed the defendants' plea that the Hoechst patent was so general as to cover millions of products of which only 220 had been synthesized by Hoechst and still fewer pharmacologically tested, and ruled that the two patents referred to the same invention and that Unichem had infringed Hoechst's patent.

In another instance aluminium phosphite, a concentrated fumigant, was patented and imported by a foreign firm. In the payments crisis in 1966 the Directorate-General of Technical Development asked the firm to produce it, but the firm said the process was too difficult to be tried in India. Thereupon Excel Industries produced the fumigant in 2 1/2 months and marketed it at half the cost of imports. The foreign firm then sent Excel a notice to cease infringement of its patent.

Such friction on patents between Indian and foreign firms led to a build-up of pressure in the late sixties for a new patent law. In anticipation of the change we questioned firms in 1969 on certain major proposals. The answers from

53 responding firms are summarized in Table 5. They show that while foreign firms were by and large against any liberalization of patent law (and some were a for greater protection than the law than current gave), Indian firms were by no means against patents: they were essentially in favour of greater access to patented know-how, and against foreign firms neither using their patents nor allowing them to be used. Further, the conflict of views was sharp only in chemical and pharmaceutical industries. In other industries Indian firms were divided or indifferent. Thus patents led to a conflict of interest only in the limited area of chemicals and pharmaceuticals where patents were being used to prevent firms from entering entire areas of technology.

After the Unichem judgment the Patents Office began to reject a larger proportion of applications on the grounds of vagueness or incompleteness. The proportion of examined applications so rejected went up from 5 per cent in 1968 to 11 and 16 per cent in the next two years /̲14, p 19_7.

A new Patents Act was passed in 1970. To prevent a recurrence of cases like the Unichem one the new Act limited patents in food; drugs and chemicals to a specific product made by a specific process. Since virtually any chemical or drug can be made by a variety of processes the scope of patent protection was greatly reduced. Compulsory licences could be given for food, chemicals and substances, and the royalty had to be below 4 per cent. The duration was reduced to 7 years, and an unrestricted right of utilization was given to the government, which has two drug companies of its own. For other inventions a compulsory licence was given the patent could be revoked.

Soon after the 1970 Act was passed consideration of patent applications in food drugs and chemicals was deferred until rules under the Act were framed. By the time the rules were framed two years later, 7402 applications for medicines had accumulated /‾14_7. In the next two years 530 patents in these fields were granted. By legislative as well as administrative action, therefore, patent protection to medicines was largely abolished. As a result foreign patent applications, which approached 5000 a year in the early sixties and 4000 in the late sixties, came down to 2300 in the early seventies. The new Act took away the monopoly power of transnational drug companies on their patents but in so far as it aimed at improving the access of Indian manufacturers to foreign drug technology it failed.

In responses to our survey foreign companies stated that abolition or reduction of patent protection would weaken the incentive to innovate. The evidence on the growth of

R & D expenditure [6; 13; 17; 19], sparse as it is, shows no slackening for the industry or for foreign firms after the passing of the 1970 patents Act. Thus the aftermath of the Patents Act gives no support to the proposition that patent protection in itself has a significant effect on the search for innovation. Nor does it support the notion that the government can influence the terms of transfer of multinationals' technology by patent legislation. Chemical and drug companies' control of their technology rests principally in their mastery of the processes, and is reinforced only marginally by patent protection.

IV. R & D OUTSIDE FIRMS

In Section I we noted the fall in the share of industrial research associations and CSIR laboratories in total R & D expenditure: now we shall turn to the reasons for this fall.

An obvious reason lies in the ownership of the results; companies own the results of their own R & D and the work done by consultants for them, but not the results of public or cooperative laboratories. Hence companies like to do or commission for themselves research that would give them a competitive advantage, and they tend to oppose industrial association's entry into fields of research that they consider particularly promising or likely to benefit competitors. Industrial associations have the best chance of success if they concentrate on problems of common interest to the industry. Some of the most widely applied work of South Indian Textile Research Association, for instance, was done in the blending of cotton and reduction of waste [20]. 90 mills used the results and saved Rs.7 million a year by waste reduction, Rs.1.5 million by better use of waste and Rs.15 million by substitution of Indian for imported long-staple cotton. On the other hand, the work of Cement Research Institute on mini-cement plants was not popular with its big corporate members.

Another difficulty lies in the more tenuous links with the market and the plant. For success, the results of R & D must be accepted by the market and embodied in the production process; R & D must be controlled by market feedback, and production must be responsive to R & D. Even in house R & D faces serious problems of adjustment with marketing and production, but they are somehow resolved through the command structure of the company. Such an adjustment mechanism is absent in the case of independent research. A striking case is offered by the Ahmedabad Textile Industry's Research Association, which decided in the early sixties that foreign techniques of making easy-care fabrics were unsuited to India. Fabrics made abroad had high crease recovery when dry, low moisture regain and a harsh grainy feel, while in India's hot humid climate consumers should prefer a soft fabric with high moisture regain and high crease recovery when wet. A process giving these features was developed and leased out to mills. But the fabric failed. Consumers associated a grainy feel with an anti-crease property; they would test the property by crumpling the fabric in the fist, and the fabric with low dry crease recovery did not perform too well in the test [20]. Similarly, a 20 hp tractor was designed in 1971 by Central Mechanical Engineering Research Institute, based on the Planning Commission's opinion that Indian farmers would prefer a smaller and cheaper tractor than the 25-35 hp models being imported or produced from imported designs. When the tractor was finally put on the market in 1974 by Punjab Tractors, they found that there was a large and established market for a 35 hp tractor and that the selling of the 20 hp tractor required a much greater price differential than the difference in costs. So they designed a 35 hp model, and by 1977 were selling 4200 35 hp tractors against 800 of the 20 hp model [21; 22].

The industrial research associations are at least located among the centres of their respective industries and guided by boards on which the industries are represented. CSIR laboratories have largely official boards, they are not allowed to sell their innovations directly to industry, income from the sale of technology forms a small proportion of their budget, and many of them are far away from industrial centres. The result is an even lower level of rapport with industry.

A significant proportion of firms studied by us had contacts with CSIR laboratories; some consulted their scientists, others used their equipment, a few gave them research projects or bought know-how from them. The firms that had contact with national laboratories tended to have multiple contacts. Most of the contacts were with a laboratory in the same town or region: the frequency of contact varied inversely with distance and difficulty of access.

Some laboratories had more interaction with firms, some very little, depending on their area of specialization and distance from an industrial region. But on the whole, the number of contacts, at least with firms interested in technology, did not show the laboratories to be divorced from industry; and firms are quire aware of the laboratories as repositories of talent as well as sophisticated equipment.1/

However, the contacts do not imply that the laboratories are successful sellers of know-how to firms; in fact, their income from sale of know-how is extremely low. Against the expenditure of CSIR's industrial laboratories of Rs.194 million the income of the National Research Development Corporation (the sole selling agency of technology generated by CSIR and other government laboratories) from the sale of know-how and technical services in financial year 1974 was Rs.4.3 million. The low level of income was partly due to the fact that less than half of the know-how that the laboratories considered utilizable was actually being used: of the 1726 processes reported to NRDC for exploitation, only 729 were licensed. But the rest, even if exploited, would not have raised CSIR's income proportionately, for 122 of them were released free of charge, 320 were dropped, and the rest would include some commercially unprofitable ones [17, p 72]. Thus

1/ Indradev [23] reaches similar conclusions in his study of electronics R & D.

even if all the know-how generated had been utilized, the income would not have been substantially higher.

The only NRDC licences that yielded a cumulative royalty over Rs.1 million by March 1977 were television sets and tractors - both distinguished by large markets, and not by earth-shaking advances in technology [24]. Yet by and large the value of output produced by an NRDC process was small - Rs.200,000 on the average - and the total output of Rs.400 million was much below 1 per cent of the country's industrial output.

The reason for this limited impact is that little market information goes into the choice of research projects, and that much of the developed technology has no promise of an economic return. Striking instances of ignorance about the market are to be found in the history of two products of the National Chemical Laboratory: nicotine sulphate, an insecticide, and cashewnut shell resin [12]. Work on both was begun in 1950; both were scaled up, licensed and produced. But both were edged out by cheaper substitutes by the late sixties - nicotine sulphate by mercury compounds and by organo-phosphates, CNSL resin by high-capacity synthetic ion exchanges.

Ignorance of the market goes with a lack of urgency in developing innovations. The impetus in the case of all innovations in Excel Industries studied by Atthreya [25] came from the market. The average lag between conception and first sale was 7 months, and on a total development cost of Rs.1.55 million the company built up annual new product sales of Rs.14 million [26]. Atthreya and Ved Prakash contrast Excel's speed with an average gestation lag of 7 years on six innovations of CSIR laboratories. The comparison is perhaps not between likes; but the point is valid and supported by other evidence [12].

To command a large market CSIR innovations would either have to be clearly superior to current technology or to be applicable to products with large markets. In both directions CSIR laboratories face difficulties. Most of their innovations are derivative and make small advances on current technology. This is not in itself undesirable. Small advances are easier to make and research into them is subject to less risk. But markets for them are also limited. Products with large markets, on the other hand, are produced in large plants. Much of the technological progress in their production is a byproduct either of the running of plants or of the construction of new ones. Laboratory research isolated from production as done by CSIR is less useful than innovation by manufacturing firms themselves; consequently Indian firms prefer to import technology from a producer abroad.

Occassionally, manufacturers backed by CSIR knowhow could not compete with those who imported technology. To eliminate such competition, a CSIR representative was put on the Foreign

Investment Board, which approves technology imports, in the late sixties; the CSIR was thus given a virtual veto on technology imports. But the proportion of projects where the CSIR can claim technology supply capability has been low. In 1975 for instance, CSIR took interest in 35 out of 400 technology import proposals /̅27_7; it would eventually demonstrate capability only in the case of a handful of those. Meanwhile, some firms in our survey complained that the CSIR was a major cause of delay in technology imports.

In supplying technology to small firms, which are CSIR's main customers, the laboratories face a different set of problems. A small manufacturer with limited capital cannot afford to take risks; he wants a proven technology. The NRDC is at best prepared to finance pilot plants; it sometimes shares in equity. But it does not undertake manufacturing. So it cannot sell technology on a turnkey basis, nor can it give a performance guarantee. Small firms also need other assistance when they take up new products or processes, for instance market information or finance, which the NRDC is not well equipped to supply /̅28_7.

Thus the divorce of government laboratories from manufacturing and marketing places them at a great disadvantage in generating and selling technology, which is reflected in the steady shift away from them and towards in-house R & D.

V. CONCLUSION

Finally we revert to two observations repeatedly made by cross-section R & D studies done from the early sixties onwards: (a) the remarkable lack of technology flows from central government laboratories to large industry despite the technological resources of the former and the demand for technology from the latter; and (b) the relationship between the size of firms on the one hand and their research intensity, level of ambition and foresight of their R & D on the other. How do these relationships - or coincidences - look in a dynamic context?

(a) Industry and government research

As discussed in Section IV, the inability of government laboratories to generate knowhow for large-scale industry is due to their deliberate, policy-based lack of manufacturing experience. Essentially for this single reason the laboratories cannot compete with either imported technology or know-how generated by in-house R & D. To be viable sellers of technology they have either to go into manufacture or to find a market among firms that can neither easily import technology nor do their own R & D - namely, small firms.

Electronics present an instance of the first kind. Here the Department of Electronics being allied to defence, had a freer hand in choice of activity and possibly a freer access to imported equipment. It set up a company, Electronics Corporation, whose main product was television sets. The technology of black-and-white television, being at least three decades old abroad, was well-known and did not have to be purchased. The government set up TV stations in one metropolitan city after another, and by banning imports of television sets and preventing Philips, the only multinational TV manufacturer operating in India, from making them, handed a captive market to ELCO. Initially ELCO's TV operation was a triumphant success. But soon local competitors sprang up with the technical assistance of a CSIR laboratory. As the growth of the market slowed in the last three years ELCO was bogged down with a poor reputation for after-sales service. The story is not yet over; nor does it have the moral that direct entry into manufacture is the best use of publicly produced technology, for ELCO's competitors obtained CSIR technology, through the NRDC and today provide it with a quarter of its revenue. The moral, if any, is that R & D based manufacture is risky and should not be based on a single product.

The second way, namely to sell technology to small firms, is the one that the NRDC has willy-nilly taken on behalf of government laboratories. But it does not obviate the need for manufacturing experience, for as indicated earlier, small firms want proven technology. The NRDC has progressively moved towards assuming the risks of commercialization by sharing development costs or participating in the capital of some licensees. This adaptation to the technology market has not, however, been rapid enough to prevent an erosion of the government laboratories' share in industrial R & D. A more effective solution would be to build full-scale plants embodying the technology developed, to sell them off at a profit once their success is proved, and thereby to create a large market for the technology from potential competitors of the first buyer.

(b) Size, research-intensity and composition of R & D

Cross-section studies show that larger firms have a higher research-intensity, aim at larger innovative advances and look further ahead than smaller firms. If this influence of size operated over time, industrial research-intensity should rise, and the rate of technological advance should accelerate.

Corporate R & D has risen so fast (Table 1) as to leave no doubt about a rise in research-intensity. But there is considerable doubt whether R & D has been directed towards more significant innovations or longer-term objectives. Successive studies show a shift in emphasis in R & D from import substitution in materials in the early phase of industrialization to the extension of product range during the post 1963 industrial recession. But plant extension or building of new plants with a firm's own technology was occasional, and major product or process innovations were extremely rare. That the technology of a number of industries including those doing R & D such as heavy machinery, power plants and fertilizer plants set up in the fifties and sixties has become obsolete also suggests a failure to keep up with world developments in technology.

The combination of rising research-intensity and a modest level of innovative achievement must lie in the size distribution of firms doing R & D. Given a threshold level of R & D expenditure, the number of firms crossing the threshold must grow as the output of an industry uses. But the overall composition of R & D will vary with the size distribution of firms doing R & D. Although this cannot be demonstrated in the absence of size distribution statistics available over a number of years, we would postulate that the influx of new small firms with modest and short-term R & D objectives has outweighed the influence exercised by growth on the composition of larger firms' R & D, so that overall industrial R & D has remained directed towards small short-term advances.

Our earlier studies [1; 4] suggested that large firms have a comparative advantage in both technology imports and in R & D - in imports because they can offer technology suppliers a larger market and in R & D because they can utilize a wider variety of results in a larger market. But whether they can translate this advantage into more rapid growth depends on the rate of growth and the composition of the demand for technology in the country.

Firms need technology to cope with external change, which may arise in a number of ways:

(a) Labour costs may rise and call forth the innovation of labour-saving machinery. This type of change is virtually continuous in industrial countries, but not so important in India.

(b) An increase in demand may require output levels that old techniques cannot cope with, and faster machines may be needed. This type of change is not uncommon in India, especially in transport and mining, but changes in techniques are not frequent enough to justify R & D and most technology is imported.

(c) A change in the structure of demand may require new products. For instance, military demand for superior arms and equipment in World War II triggered off innovations in a number of new industries - electronics, aeronautics, nuclear science, drugs. This type of demand for product improvement generally comes from industry and government, and is not significant in India. However, product innovation became important in the post 1965 recession.

(d) Finally, changes in the relative scarcity of materials may lead to adaptation of substitute materials. The adaptation of imported technology to India's resource endowment called for R & D in the first place, and has been the most important area of R & D. But the cost of imported technology itself has been kept down by government control on royalty; so therefore has the return on R & D to replace technology imports been.

The reasons for the lack of impact of R & D must therefore be sought in the way the Indian technology market has developed. At the rate of industrial growth achieved, major bottlenecks have been infrequent, and the demand for innovations to remove them has been too spasmodic to justify sustained R & D.

REFERENCES

1. National Council of Applied Economic Research, Foreign Technology and Investment: a Study of Their Role in India's Industrialization (New Delhi, 1971).

2. United Nations Secretariat, Division of Public Finance and Financial Institutions, Arrangements for the Transfer of Operative Technology to Developing Countries: Case Study of India. Document ES4/FF/AC.2/3 (New York, 1971)

3. Desai, A.V., Technology Management in Indian Companies, Long Range Planning 5 (1972) 6. pp 70-72.

4. Desai, A.V., Research and Development in India, Margin (NCAER, New Delhi) 7 (1975) 2.

5. Srinivasan, T.N., Bhagwati, J.N. and Desai, A.V., Investment, Innovation and Growth, in Srinivasan, T.N., and Bhagwati, J N, Foreign Trade Regimes and Economic Development: India (NBER, New York 1976).

6. Ministry of Industrial Development, Science and Technology, Report of the Committee on Performance and Commercialization of R & D in Private Sector Industry (New Delhi, 1974).

7. Industrial Credit and Investment Corporation of India, Seminar on Consultancy Services in India (Bombay, 1972).

8. Freeman, C. The Economics of Industrial Innovation (Penguin 1974).

9. OECD, Gaps in Technology: Analytical Report (Paris, 1970), p 136.

10. OECD, The Measurement of Scientific and Technical Activities (Paris 1970), DAS/SPR/70.40. The relevant chapter is also summarized in Freeman [5].

11. Industrial Credit and Investment Corporation of India, Conference on Research and Development in Industry (Bombay 1970).

12. Economic and Scientific Research Foundation, Research and Industry: Seven Case Histories (New Delhi 1966).

13. Indian Chemical Manufacturers' Association, Preliminary Survey on the Status of Research and Development in India (Bombay 1972).

14. Controller General of Patents, Designs and Trade Marks, Patents: Second Annual Report .... for the Year 1973-74 (Calcutta 1974).

15. Bhagwati, J N, and Desai, P India Planning for Industrialization: Industrialization and Trade Policies since 1951 (Oxford University Press, London, 1970).

16. Srinivasan, T N, and Bhagwati, J N, Foreign Trade Regimes and Economic Development: India (NBER, New York, 1976).

17. Department of Science and Technology, Handbook of R & D Statistics 1974-75 (New Delhi 1977).

18. Science Policy Research Unit, Success and Failure in Industrial Innovation (Centre for Study of Industrial Innovation, London, 1972).

19. Tariff Commission, Report on the Fair Selling Prices of Drugs and Pharmaceuticals (Bombay, 1968).

20. Srinivasan, K, Consultation as a Means of Technology Transfer; in Council of Scientific and Industrial Research, International Seminar on Technology Transfer, Seminar Papers Vol I (New Delhi, 1973).

21. Aurora, G S, and Morehouse, W, Dilemma of Technological Choice - The Case of the Small Tractor, Economic and Political Weekly 7 (1972) 31-33, pp 1633 - 1644.

22. Bhatt, V V, Decision Making in the Public Sector: Case Study of Swaraj Tractor, Economic and Political Weekly, Review of Management 13 (1978) 21, pp M30-M45.

23. Indradev, Utilisation of Electronics R and D in India, Physics in Technology 9 (1978)

24. National Research Development Corporation, 23rd Annual Report 1976-77 (New Delhi, 1977)

25. Atthreya, N H, Ten Studies in R & D (Indian Institute of Public Administration, New Delhi, 1967).

26. Athreya, N H, and Ved Prakash, Utilisation by Industry of Researches of the National Laboratories (Indian Institute of Public Administration, New Delhi, 1967).

27. Council of Scientific and Industrial Research, Annual Report 1975 (New Delhi, 1976).

28. Soundararajan, P, Development and Transfer of Indigenous Technology: Problems and Prospects, Small Industries Bulletin For Asia and the Pacific (United Nations, New York), 14 (1977), pp 69-73.