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NEW TRENDS OF LOCATING CORPORATE R&D IN DEVELOPING AND EAST EUROPEAN COUNTRIES BY TRANSNATIONAL CORPORATIONS AND THEIR IMPLICATIONS*

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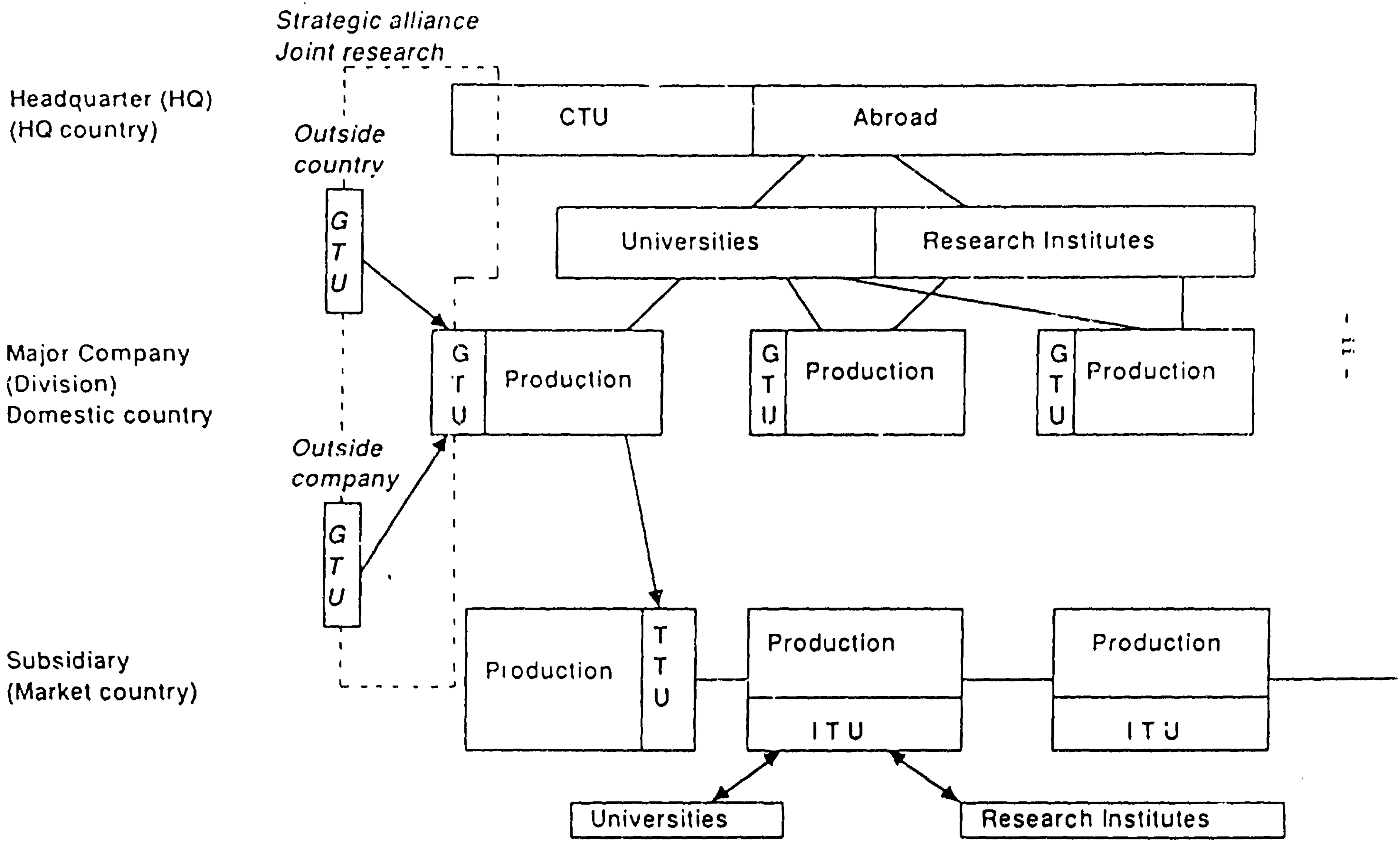

Summary

Corporate R&D activities have, in the past, been mostly confined to the home countries of the companies. But, in recent years, due to the changing environment for globally competing companies, the necessity of multi-sourcing of innovations has gained prominence. More recently, it has come to include efforts to exploit the cost differentials. Transnational corporations (TNCs) have started performing some of their strategic R&D in some developing and East European countries. The total costs of carrying out R&D in countries like India and Russia, with scientists having corresponding qualifications as those of their counter parts in Western countries, are estimated to be 1/10th of the costs in industrialized countries. Moreover, the demand for R&D personnel, in specific fields, has been more than the supply in industrialized countries. On the other hand, over the years some developing countries have built up surplus pools of scientific and technical personnel. Due to the collapse of formerly planned economies and subsequent financial crisis the scientific community in East Europe is now seeking R&D contracts for even paltry sums from the Western firms. Hence, this trend shows signs of emerging as a phenomenon similar to that of establishment of off-shore production facilities in low-cost countries.

In this phenomenon, the main interest groups or actors are TNCs, host countries, scientific community, and home countries of the TNCs. Implications of the emerging phenomenon are of different significance to different actors. The TNCs interest lies in, apart from the access to scientific talents, their low wages in host countries. The host countries expect benefits from such R&D investments in the form of reduction in brain drain, technology transfer etc. Reduction in public spending on R&D, induces the scientific community to look towards companies for financing research projects. This gives a control over science and technology developments to the companies and may have implications not only for the scientific community, but also for the society at large. Although, presently not of great significance, if the new trend of relocating corporate R&D into low-cost countries emerges as a phenomenon, it may have implications to the economies of home countries of TNCs.

1.0 Prominent Features of the Emerging Phenomenon

The corporate R&D structure performs four types of functions - facilitate technology transfer (technology transfer unit - TTU); product development for the local markets (indigenous technology unit - ITU); development of products and processes for the global markets (global technology unit - GTU); and basic research in generic technologies for long term corporate use (corporate technology unit - CTU) (Ronstadt, 1977). These R&D functions, especially, in the high-tech industries such as pharmaceuticals, chemicals, microelectronics, biotechnology and new materials have become more science based and research intensive (Freeman, 1982). This necessitated multi-sourcing of innovations to maintain competitiveness.

The literature indicates several motives for globalization of R&D. These include - market related (size and proximity); technology related (tapping the foreign S&T resources); cost related (exploiting the cost differentials); technology monitoring (especially competitor analysis); non-R&D related (national policy pressures) etc. The type of R&D function performed abroad is directly related to the motives. This relationship can be summarized as follows :

R&D Functions Abroad

motives	technology transfer	local product development	global product development	long term basic research
market	X	X		
technology/ science			X	X
costs			X	X
monitoring	X			
non-R&D (e.g. Govt. pressures)	X	X		

The emerging trends in the location of R&D, being a new strategy little research has been done. The trend suggests that the motives for location of R&D in developing and East European countries are both cost and technology related. Other observations are :

- R&D functions carried out in some developing and East European countries by TNCs, in recent years, relate to products of strategic importance to the companies' global operations.
- TNCs which are performing global R&D in low-cost countries are observed to be mostly those dealing with new technologies (biotechnology/microelectronics/new materials).
- TNCs R&D activities are giving rise to new types of organizations and a new class of entrepreneurship (scientific entrepreneurs) in the host countries.

2.0 Analytical Explanations

In recent years, two sets of factors have changed TNCs' behaviour of confining R&D functions to their home countries. First, the increasingly globalized basis of competition created the need for generation of new products on the basis of distinctive characteristics of national/regional markets (Pearce, 1991). Second, the general trend shows the increasing role of basic science in major technological advance and generation of innovations through cross-fertilization between scientific disciplines. These ongoing paradigmatic changes in S&T, especially in electronics, pharmaceuticals and new materials are creating pressures on the capabilities of the companies. These pressures can be reduced through external acquisition of knowledge and multi-sourcing of innovations (Chesnais, 1988). The conditions for research and access to resources for carrying out research varies around the world and therefore, subject to costs involved, relocation of R&D may in the long run improve the competitive position of the company (Sigurdson, 1990). In the generation of new technologies, the innovative potential in the foreign country does not necessarily have to be more advanced than the potential in the TNC's home country. Technology expertise can be complimentary (Dörrenbächer and Wortmann, 1991).

Selection of location of R&D depends on several criteria. These include - proximity to a manufacturing site; availability of local universities; ability to build up a critical mass of local researchers; attractiveness of sources of technical excellence, e.g. universities, customers or suppliers, etc.; and availability of excellent communication systems (Meyer and Mizushima, 1989). Available evidence on the emerging trends suggests that different elements of the new technologies prefer different types of technology en.ironments.

technology

science	modern	conventional
high	Developed countries →	ADCs & East Europe
low	↓ NIEs	LDCs

R&D into direct product design and development prefers Newly Industrializing Economies (NIEs - Hong Kong, Singapore, Rep. of Korea and Taiwan province of PRC), which have a sophisticated technology base, but relatively not so strong a science base. On the other hand, R&D into generic and disembodied technologies prefer Advanced Developing Countries (ADCs - e.g. Brazil, China and India) and East Europe, which have a relatively high science base, but do not have sophisticated technology base. ADCs and East European countries have built up general capabilities for the total system, which probably is more suitable for R&D into generic technologies. On the other hand the NIEs have built up specialized capabilities in a few components of the system (especially superior manufacturing technologies) and this expertise seems to be more suitable for direct product development.

3.0 Implications for the Corporate R&D Management

In the overall phenomenon of the globalization of R&D, the emerging patterns are only of marginal significance. However, from the perspectives of individual TNC and the low-cost host country, the implications assume greater significance. With the liberalization of economies alround the world, the business environment is likely to become highly competitive in the 1990s. To be able to compete successfully, the companies need to be highly innovative. This is likely to increase the R&D costs of the companies. One way of reducing R&D costs and still be innovative is to locate R&D, at least some portions of it, in low-cost countries.

To adopt such a strategy, the companies should have a good knowledge of the type of R&D environment required for the type of technologies they are dealing with. Specialized capabilities of countries may require division and allocation of R&D activities to centres in different countries. This means, the company should build up capabilities to first integrate all the parts of R&D performed in different countries and then transfer the knowledge to production units, which are in turn, probably, located in different countries, manufacturing different parts of a system.

In the context of the emerging phenomenon, some unique cross-cultural problems may arise, hindering the accomplishment of organizational goals. The problems and tasks will have to be set differently in different countries with different cultural settings to obtain the best results. Researchers from the company's labs in industrialized countries may look down upon their counter parts from low-cost countries and underplay the latter's role, especially because of the latter's low compensation. Moreover, researchers from the laboratories in industrialized countries may perceive the researchers from low-cost countries as a threat to their jobs and may not cooperate with them.

4.0 Implications for the Host Countries

There are two opposing views that have been influencing the policies in the past regarding the impact of TNCs' R&D activities on the host countries. One view considers inward R&D investments to in general beneficial to economic growth, by creating indirect positive effects for the host country at a lower-cost. The counter view argues that R&D activities by foreign firms tend to tap into unique local R&D resources with little or no benefit to the host country. (Dunning, 1992). Our study suggests that in the context of developing and East European countries, where the scientific resources are under utilized, the counter view may not hold much strength.

Depending on the type of R&D being performed, the impact on the host economy varies. Each type of unit has distinctive linkages with the local subsidiary, the parent organization and with local sources of technology. The ties are virtually non-existent for a TTU, strong for an ITU, stronger for a GTU and the strongest for a CTU (Westney, 1988). The most important indirect benefit of all, is that TNCs' R&D activities are infusing the scientific community in host countries, with "commercial culture", which is necessary for reaping the benefits of science. In developing and East European countries scientists have, so far, pursued science research mostly for proving the principles. Industrial sector being weak did not take up the task of converting this knowledge into products. TNCs, through their mission oriented R&D, are inculcating cost and time consciousness among researchers. These activities are also giving rise to a class of scientific entrepreneurs by allowing researchers to purchase and commercialize the knowhow for bye products (The Economic Times, Sep 28, 1991).

Introduction

In an effort to build up technological capacity, over the years, many developing countries, have built up large reserves of scientific and technical (S&T) manpower. Still the full potential benefits of such trained manpower could not be realized. Such efforts mostly resulted in an increase in the number of educated unemployed or in brain drain. The reasons for this situation are two fold - one mis-match between requirement and training in human resource planning; two slow pace of industrialization. Moreover, such industrialization also mainly took place through ready-made technologies transferred by the transnational corporations (TNCs). TNCs tended to confine R&D activities to their home countries and in the few cases where some R&D activities were performed outside the industrialized countries, they were limited to adaptation, local technical services or in very few cases to product development for the local market[1].

In such a paradoxical situation, two new developments are taking place - scientification of new technologies and globalization of corporate R&D. For the last decade or so, due to scientification of new technologies and increasing international competition, global sourcing of innovations has become a necessity. Prior to these deliberate globalization efforts, partly through merger and acquisition, companies have already expanded their R&D outside their home countries, mainly into other industrialized countries. However, in recent years, globalization of R&D has come to include efforts to exploit the cost differentials. Since the mid-1980s, TNCs have started locating some of their strategic R&D in some developing countries. Since the beginning of the 1990s, similar trends are also emerging in East European countries[2]. R&D activities being carried out in these countries, relate not only to products required for the local markets, but also to those of strategic importance to the company's world wide operations. This move by TNCs is facilitated by the availability of large cadres of research personnel at substantially lower wages and adequate infrastructure in these

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[1] Studies in the late 1970s and early 1980s (Creamer, 1976; Ronstadt, 1977; Behrman and Fischer, 1980; Hirschey) have confirmed these conventional practices of TNCs.

[2] For the purposes of this study East Europe includes former Soviet Union.

countries. The total costs of carrying out R&D in countries like India and Russia, with researchers having corresponding qualifications as those of their counter parts in Western countries, are estimated to be only 1/10th of the costs in Western countries (Granstrand et al. 1992 and Valiukov, 1992). Hence, this trend shows signs of emerging as a phenomenon similar to that of establishment of off-shore production facilities in low-cost countries.

Apart from the high cost factor, there has also been a shortage of R&D personnel in industrialized countries. For instance, two Swedish companies ASEA and Ericsson alone would require 150 percent of all electronics engineer graduates in Sweden. The problems are similar in other emerging areas such as biotechnology (Lars Håkanson, 1990). Such shortages are also common in the rest of Europe, USA, and Japan (OECD, 1988; Business Week, Nov 30, 1992). On the other hand, in some developing countries such talents have been lying dormant due to under-utilization by the indigenous industry. In most of these countries either the industrialization did not take place at a corresponding level, or the existing industry, because of their low emphasis on R&D has not been able to fully utilize the available trained manpower. The availability of specialized biotech researchers is many times greater in India, with its conglomeration of knowledge activities in biotech and software, than in Sweden (Granstrand et. al, 1992). The collapse of formerly planned economies and subsequent financial crisis are forcing a drastic restructuring of R&D systems in East Europe. The scientific community in East Europe is now eagerly seeking R&D contracts for even paltry sums from the Western firms.[3]

In the emerging phenomenon, the main interest groups or actors are the TNCs, the host countries, the scientific community and the home countries of the TNCs. It has different significance to different actors. The TNCs interest lies in, apart from the access to scientific talents, the low wages of S&T personnel in host countries, so that

[3] East European governments have started offering their R&D infrastructure to foreign companies by publishing capabilities and other details of their R&D systems. See "Innovation Research & Development - Poland 1993". Pub. by Business Foundation in cooperation with the Government of Republic of Poland.

their R&D costs could be lowered with out compromising their innovativeness. The host countries expect benefits from such R&D investments, in the form of reduction in brain drain, technology transfer, strengthening the indigenous innovative capabilities etc. Although the scientific community in developing and East European countries is well trained in theoretical aspects, they lack the experience of converting this knowledge into products. International corporate R&D activities are expected to transfer such application skills to the scientific community in the host countries. The native industries are also expected to gain from technology spill-over effects, turnover of research personnel and linkages with the TNCs R&D units. Due to the economic recession and the trends toward market economics, the national governments are reducing public spending on R&D. This compels the scientific community to look towards companies for research funding. This gives control over the direction of S&T development to the companies and may have implications not only for the scientific community, but also for the society at large. Although, presently not of a great significance, if the new trend of locating corporate R&D in low-cost countries emerges as a phenomenon, it may have implications to the economies of home countries of TNCs.

The purpose of this paper is to examine the emerging trends in R&D location strategies of TNCs and draw possible implications for the management of industry and the host countries. The paper is divided into six sections. The first section gives selected empirical evidence of the emerging trends in the location of TNCs' R&D. The second section brings out the characteristics of the emerging trends. The third section offers theoretical and analytical explanations for the emerging strategies. The fourth section draws possible implications for the industry and corporate R&D management. The fifth section draws implications for the host countries and the last section offers policy recommendations and conclusions.

1.0 Selected Empirical Evidence of The Emerging Trends in TNCs' R&D Location Strategies

Developing Countries

There has been a noticeable increase in the technological capacity of developing countries. Their share in the world R&D expenditure rose from 2.5 percent in 1970 to 6.2 percent in 1987 and that of R&D scientists and engineers from 8.5 percent in 1970 to 11.2 percent in 1987[4] (UNESCO, 1987 & 1990). Developing countries have also more than doubled their share of world patenting between 1963-70 and 1974-84. Among the developing countries, Taiwan province of PRC, Rep. of Korea, Brazil, Mexico, Hong Kong and India are currently among the leading patent filers in the U. S. R&D activities of TNCs are often relatively important not only in industrialized countries, but also in some developing countries. The data are fragmentary, but in Australia, Belgium, Canada, the U. K., West Germany, Rep. of Korea, Singapore and India, in the 1980s, the share of national R&D expenditure accounted for by foreign owned firms exceeded 15 percent (Dunning, 1992).

Table 1, adopted from Hagedoorn and Schakenraad (1990), shows the international distribution of technology cooperation agreements in new technologies. Data presented in the table give information only on cooperation agreements reached between two or more firms and excludes own R&D units, sub-contracting, research sponsored in the universities abroad etc. These cooperation agreements represent only one of the many forms of globalization of R&D.

The "Triad" (USA, Western Europe and Japan) account for more than 90 percent of the total technology cooperation agreements reached world wide. However, the data also reveal that in information technologies, the non-triad countries account for over 8 percent of the total agreements, and in new materials, the figure raises to almost 10 percent, with a figure of over 5 percent in biotechnology. A large section of these agreements

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[4] Because of the labour intensity of R&D activities, the developing countries account for a higher proportion of personnel employed in such activities. For instance, in 1986, India employed 172,370 people in R&D activities and was ranked sixth as a global employer (UNESCO, 1987 & 1990 as given in Dunning, 1992).

involving non-triad countries cover projects between companies from the newly industrialized economies (NIEs) and the triad (Hagedoorn and Schakenraad 1990).

Table 1. International Distribution of Technology Cooperation Agreements in New Technologies (at the end of 1990).
(numbers and percentages)

country/region	biotechnology	information technology	new materials
W. Europe	233 (18.4)	509 (18.7)	118 (17.2)
W. Europe-USA	245 (20.2)	599 (22.0)	133 (19.3)
W. Europe-Japan	38 (3.1)	177 (6.5)	49 (7.1)
USA	428 (35.3)	707 (26.0)	139 (20.2)
USA-Japan	155 (12.8)	406 (14.9)	94 (13.7)
Japan	58 (4.8)	95 (3.5)	88 (12.8)
Others	66 (5.4)	225 (8.3)	67 (9.7)
Total	1213 (100)	2718 (100)	688 (100)

Source : MERIT-CATI Databank. As Given in Hagedoorn and Schakenraad (1990). p. 8

Many firms from industrialized countries have begun to tap the S&T resources in developing countries for their corporate R&D. Prominent among them in India are Sweden based biotechnology firm Astra AB, the US based Texas Instruments (TI)[5]. Several others include Hewlett Packard (HP), IBM and Digital Equipment Corporation (DEC) from USA, the Bull of France (Far Eastern Economic Review, March 2, 1989). Netherlands based AKZO Chemicals assigned an R&D task on contract basis to the National Chemical Laboratories (NCL) in India to devise a key ingradient for refining

[5] AB Astra conducts research to develop drugs and diagnostics, using recombinant DNA technologies, to be marketed world wide (see case study)
Texas Instruments set up a centre for research into computer aided design software to build and test the next generation of integrated chips. Three other such centres of TI are located in Dallas (USA), Tokyo (Japan) and Bedford (UK) (Economist, March 4, 1991). The centre also carries out research in Artificial intelligence (Alan Cane, 1987).

petroleum. NCL successfully developed the substance, Zeolite (UNDP-World Development, Sep 1991)[6].

International Business Machines (IBM) together with the Tata group of India is establishing a US$ 33 million joint venture to manufacture high-end personal computers. The joint venture will serve as a procurement centre for supplying IBM's operations world wide. Besides manufacturing computers, IBM's interest lies in utilizing India's vast pool of cheap engineering talent in developing systems software. An existing Tata software company (Tata Consultancy Services - TCS) has already been designing software for IBM's laboratories around the world, on sub-contracting basis (Carl Goldstein, Financial Times, Oct 10, 1991).

To utilize the hard working, talented and low-cost engineering pool available in China, Hewlett-Packard is establishing a world wide R&D centre for integrators in Shenzen, China. Integrators are microprocessor based instruments for data interpretation in various types of testing equipment (Far Eastern Economic Review, April 30, 1992).

GEC-Marconi of USA and Varitronix of Hong Kong have joined hands to develop and manufacture Liquid Crystal Displays. Motorola of USA has linked up with Cal-Comp Electronics of Taiwan province of PRC to develop and manufacture pocket secretaries (hand held computers) for global markets. Glaxo Inc. of UK and Singapore's Institute of Molecular and Cell Biology have teamed up on a research project to study the causes of brain disease[7].

Bundo Yamada (1990), discussed the strategies of Japanese TNCs that are involved in R&D abroad, especially in developing Asian countries. Japanese firms have started following a policy that has been referred to as "glocalization", indicating that while the basic management strategy is determined on a global basis, complete attention is paid to

[6] India was selected as a location for R&D by TNCs because of its strong educational system in theoretical sciences and engineering that supplies a large pool of technical manpower (Texas Instruments and other company reports).

[7] The reasons for such alliances include, reassessment of strengths of Asian partners by TNCs; to be close to the manufacturers of the end products; access to financial resources and talent; to be able to shift resources at home to more sophisticated activities (Business Week, Nov 30, 1992).

localization. Localization includes such things as transfer of technology, development of local suppliers, strengthening local design and development activities etc.

Among the Japanese companies, there is now an increasing trend towards "international specialization by region". The corporate strategy of Japanese companies divides the world into four regions, the United States, Europe, Asia and Japan, in which product development, production and sales are carried out in a coordinated manner for each region through regional management subsidiaries. Matsushita Electric has extended the "four region" concept to the technological domain and has established overseas research centres in North America and Taiwan province of PRC. This will be an important strategic consideration in the "glocalization" of Japanese companies. Aiwa established an R&D centre in 1988 in Singapore to develop new products such as a radio cassette unit with compact disc player for the global markets. Aiwa is also planning to set up an Asian regional management centre in Singapore. Matsushita and NEC have established integrated circuit design facilities in Singapore. TNCs like Sony are establishing a coordinated regional group structure in Singapore, independent of Japan and encompassing R&D, component purchasing, production, marketing, financing and personnel (Yamada 1990).

Another trend that has been emerging among the Japanese companies has been to transfer the entire "technology for low-end products" i.e. R&D, production and marketing, to firms in developing countries, so that the Japanese operations can concentrate on high-end products. Hitachi, for instance, has formed an alliance with Goldstar of Rep. of Korea, under which Hitachi is providing 1M DRAM technology to Goldstar. Many other Japanese companies have started to set up R&D centres in Asian countries for designing new integrated circuits: Taiyo Yuden has begun to design hybrid ICs in Rep. of Korea; Seiko Epson has started to design ASICs in Taiwan province of PRC; Fujitsu has begun to design ASICs both in Taiwan province of PRC and Singapore; Toshiba is transferring all proto-typing, development and production of low-end video cassette recorders to Samsung Electronics in Rep. of Korea, so that it can concentrate its own resources on high-end market models (Yamada 1990).

N ⁄o-Nordisk, a Danish biotechnology company is setting up a factory and a laboratory in Brazil, to produce biotechnological products, including enzymes. The US$ 5 million investment aims to benefit from both domestic and export markets (Financial Times, May 8, 1987).

Nestle, a Switzerland based TNC, deals with food technology, bio and plant sciences. It has a central Nestle Research Centre (NRC) in Switzerland, and a network of technology development centres spread over 10 countries. NRC conducts research of general nature on the food and the development centres deal with specific projects to develop new products, processes and methods of manufacture and to improve the existing products. Two of the Nestle's development centres are located in developing countries, one in Singapore and the other in Ecuador. A third is planned to be opened soon in Ivory Coast. Since the 1980s, Nestle has been following a two fold strategy in developing countries: 1. production and marketing of products which are also marketed globally. 2. developing new products, using locally produced raw materials and based on traditional local food habits (regional markets). The two development centres in developing countries play a vital role in the second strategy (Biotechnology and Development Monitor, No. 8. Sep 1991).

To facilitate R&D activities, TNCs are transferring advanced design tools, process technology and quality control knowhow to developing host countries. Research personnel in host countries are being trained by TNCs locally and at their facilities in home countries. For instance, in Penang, Malaysia some TNCs along with local companies have sponsored establishment of a skills training centre that trains local engineers in every thing from drafting and basic electronics to computer aided design and robotics (Business Week, Nov 30, 1992).

East European Countries

UK's Densitron Computers Ltd. and Hungary's Cellware Ltd. together developed 9000 gate chip, which is a new universal basic building block for massively parallel processors (Electronic World News, July 27, 1990). Cypress Semiconductor (USA) has acquired licences for chips designed by Interevm, the largest chip manufacturer in the USSR and is also participating in joint designing of semiconductors (Electronics Weekly, July 25, 1990). Soviet biotechnologists have licenced three potential treatments for AIDS to Oxford Virology, a British company for commercialization (Financial Times, Jan 3, 1991). Institute for Silicate Chemistry in Russia has signed an agreement with Corning of USA to assign 100 of their scientists to do basic research on glasses and optical devices for the Corning (Scientific American, 1993). AT&T, an US based telecommunications company has assigned R&D tasks in optical-fibre to 100 fibre-optic scientists and technicians at the General Physics Institute in Mascow, at a salary of US dollars 60 each per month (Economist, May 30, 1992).

Fakel Experimental Design Bureau in Kalingrad, Russia and Space Systems /Loral of USA have established a new company that will develop electrical thrusters for spacecraft, based on Russian designed "Hall thrusters". These devices would reduce the fuel consumption of satellites and extend their lifetime. The United Technologies of USA is funding a joint research program on solid-flame technology at the Institute of Structural Macrokinetics in Chernogolovka, Russia (Scientific American, 1993).

Russian Academy of Sciences has setup an company in the US to apply and commercialize its technologies. The firm, Russian-American Science, has established agreements with Science Applications International Corporation (SAIC) in McLean, Va., USA, in such areas as acoustic sensors, specialized high-powered generators and environmental remediation (Scientific American, 1993).

Many groups of researchers, who can not form companies are joint ventures, are freelancing by making research-for-cash deals. Researchers under Boris A. Babian of the Institute of Precision Mechanics and Computer Technology in Mascow, a super computer designer, are now working for Sun Microsystems of USA, on computer design and parallel processing software. Sun pays them about US dollars 100 each a month.Such deals are now supplementing the incomes of thousands of Russian scientists (Scientific American, 1993).

1.1 AB Astra's Location of R&D India - a case study[8]

AB Astra, is a Sweden based transnational pharmaceutical company. It has its research laboratories in Södertälje (Astra Research Centre and Astra Pain Control), Gothenberg (AB Hässel) and Lund (AB Draco) in Sweden. In addition, AB Astra owns 25 percent of the equity in the Swedish biotechnology company, Symbicom AB. Outside Sweden, AB Astra's R&D is located in the U. K., Neuroscience Research Unit in London and Clinical Research Unit in Edinburgh. AB Astra's R&D budget exceeds US dollars 130 million per year, amounting to about 20 percent of the sales of Astra's products world wide.

Astra Research Centre India (ARCI) in Bangalore was established by AB Astra in 1987. The Government of India recommended that the research centre be set up as a non-profit organization. The companies, including Astra, utilizing any invention or know-how will pay royalty to the centre. Such income will be used for expanding the research activities at the centre. The centre is entirely funded, both for capital and projects requirements, by AB Astra. By 1991, AB Astra has invested about Indian Rupees 120 million, with an annual budget of about Rupees 5 million, accounting for approximately 2 percent of AB Astra's total annual R&D budget. Every year the budget proposal from the centre is reviewed by a research committee of AB Astra.

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[8] This case study is taken from Prasada Reddy and Jon Sigurdson (1993/a) - Strategic Location of R&D and Emerging Patterns of Globalization : The Case of Astra Research Centre in India. Mimeo. Research Policy Institute, Lund University, Sweden.
Also see Ramachandran, J. (1991) - "Strongly Goal-Oriented Biomedical Research - Astra Research Centre India". Current Science, Vol. 60. Nos. 9&10, May 25.
Sampath, Kumud (1990) - "Astra Research Centre, India - A Unique Experiment in Strategic Collaboration". BioSpectra. Nov-Dec.
Shetty, Archana (1991) - "Astra Research Centre - Straining for Success". SCI-TECH, The Economic Times, India. Sep 28.

Objectives of ARCI

1. The pursuit of scientific research leading to the discovery of new diagnostic procedures, novel therapeutic products, and targets for rational drug design, for diseases afflicting large populations in both developing and developed countries.
2. To achieve the above objective, by employing the powerful tools of molecular biology, immunology, cell biology, molecular dynamics and molecular graphics in highly focussed and time targeted projects.
3. To closely interact with the research groups of AB Astra, Indian Institute of Science and universities in India and abroad, through collaborative efforts, extra mural support to projects of mutual interest, and sponsoring scientific meetings on relevant topics.

Motives

- Astra's awareness that India had much to offer in the way of scientific competence and talent, particularly in molecular biology, biochemistry and biophysics.
- Astra's corporate policy of strong commitment to scientific research through collaboration with academic scientists in programs geared to the discovery of innovative drugs to combat diseases.

The scientists educated in India have made significant contributions both within and outside the country to the advancement of chemical and biological sciences. Indian scientists have occupied responsible leadership positions in major biotechnology R&D establishments in the world. So, Astra felt that a centre for creative applied research in India would be able to attract and retain Indian scientists. Although not stated explicitly, another important motive is the lower costs of R&D in India.

Type of R&D Activities

In the initial stages, short term projects with limited objectives were initiated. During the first two years, ARCI successfully developed the know-how for the preparation of several crucial reagents used in molecular biology research. Such tools were not available in India and were being imported from the U.S.A. or Europe. The design and development of diagnostic procedures, using DNA probes and immunological methods, for the diagnosis of some infectious diseases were also successfully carried out. In addition, basic research on molecular biology, protein structure, gene coding etc. was also pursued.

By 1991, ARCI has filed patent applications for nine items - Diagnosis of plasmodial infections; A novel procedure for the detection of parasites, using DNA probes; A method of obtaining antigens of cysticercus cellulose for immunodiagnosis of neurocysticercosis; A novel secretion vector to produce biologically important peptides; A new method for the diagnosis of tuberculosis; New recombinant plasmids; A new method for the diagnosis of virulent bacteria; A novel expresson vector; and A novel method for the detection of M.tuberculosis DNA. Applications for international patents are being filed by AB Astra, the parent company.

The know-how for producing the basic tools of DNA recombinant technology, have been transfered to a local company called GENEI (Gene India). Genei manufactures enzymes, DNA molecular weight markers and nuclic acids based on ARCI technology, and exports some of these products to USA.

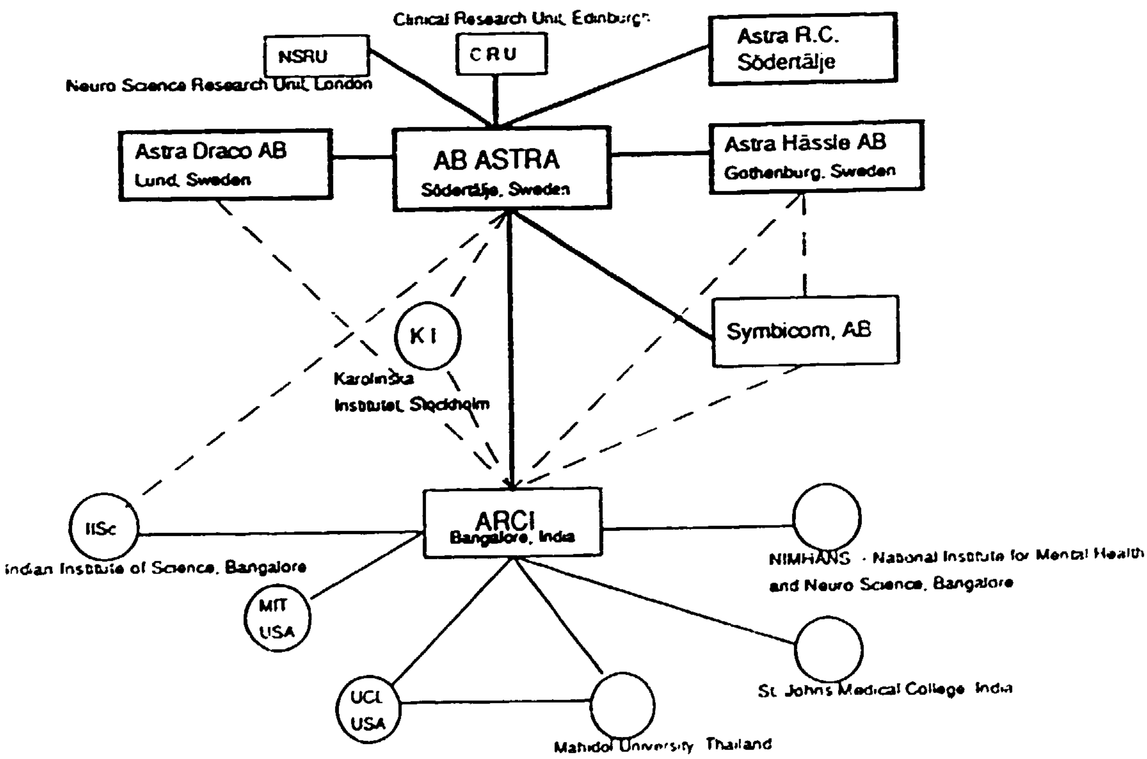
The centre is now undertaking projects to discover a novel class of anti-bacterial agents. In selecting the long term projects, expertise available at ARCI and the research units of AB Astra are optimally utilized.

Extension of AB Astra's Research Network Through ARCI

Figure 1 shows extended network of AB Astra through ARCI. ARCI views its relationship with AB Astra as a strategic collaboration, which gives the centre an opportunity to work with the research units of Astra as an equal partner and facilitates complementarity of collaborators' research efforts.

There are several joint R&D projects in which Astra's laboratories in Sweden and ARCI are collaborating. ARCI and AB Draco have, for instance, collaborated in a research project on eosinophilcationic protein found in the lungs. This protein has anti-parasitic properties, but in large quantities can damage the lungs of asthma patients. AB Draco focussed on the development of a protein inhibitor to be used in asthmatic therapy, while ARCI concentrated its efforts on the isolation of anti-parasitic qualities. Astra's laboratory in Gothenberg, Symbicom in Lund and ARCI are collaborating on a project. In addition, ARCI also caters to other specialized needs of Astra's units world wide. AB Astra has a fellowship scheme for contacts among its R&D personnel in different units including ARCI.

Extension of Astra's Global Research Network



One of the objectives of ARCI is to collaborate with research groups in Indian Institute of Science and universities in India and abroad. ARCI has close collaboration with the Indian Institute of Science in Bangalore. AB Astra has also endowed a chair of "Astra Professor" at the Indian Institute of Science (IISc). In addition, ARCI also collaborates with the National Institute of Metal Health and Neurosciences (NIMHANS) and St. John's Medical College on specific projects of mutual interest.

ARCI also collaborates with research institutes abroad. There is a "tripartite" research effort to develop a drug for malaria, between ARCI, University of California, USA. and Mahidol University, Thailand. ARCI is also involved in a long term research project on Thioredoxin with the Karolinska Institute in Sweden, with the latter supplying the peptides to ARCI for further research. In another project funded by AB Astra, ARCI is collaborating with the Massachussetts Institute of Technology (MIT), USA. The know-how is being developed at ARCI, while the manufacturing and the down stream processing will be done at the MIT. This is a unique case of a developing country research institute sponsoring research in a developed country.

ARCI - An Instrument for the Emergence of A New Class of Entrepreneurs

Astra Research Centre in India is infusing the scientific community with "commercial culture", by licensing the know-how to researchers for commercialization of bye-products. When a bye-product, which Astra is not interested in commercializing, is developed, the researchers are allowed to purchase the technology and start their own firm. This is giving rise to a new class of scientific and technical entrepreneurs. For instance, the results of research at ARCI, the know-how for producing the basic tools of DNA recombinant technology, have been transfered to a newly formed local company called GENEI (Gene India). The company was formed by two Indian scientists. Before this technology transfer by ARCI, India was importing these products from USA. or Europe. Apart from supplying to laboratories in India, GENEI, now, also exports some of the products to laboratories in USA. (The Economic Times, September 28, 1991).

Through its mission oriented and time bound research, ARCI is transferring application and product development skills to the scientific community.

Problems of ARCI

ARCI, being located in a developing country, faces a few unique problems. First of all the basic tools of its R&D work (DNA recombinant) were not available in India and imports were delaying the progress of biotechnology research in India. Hence, the first two years of ARCI's time had to be spent in developing the know-how for producing these tools.

Secondly, ARCI is finding it difficult to identify a suitable manufacturer for the transfer of its know-how for manufacturing the diagnostic kits. One of the major problems being faced by the technology transfer team of ARCI, is the lack of technology and expertise among the local recipients to develop marketable products on a mass scale (for the products that are not being taken up for manufacturing by AB Astra).

Lastly, there is the problem of inadequate patent protection in India. In DNA recombinant technologies, the novelty is the product. The process of discovery is complicated, but once the product is obtained, its propagation can be achieved by many ways. In pharmaceuticals, the Indian patent laws protect only the process, but not the product.

ARCI case study shows that, if the opportunity and facilities are provided, scientists in developing countries also can contribute to the global technology developments. The case study suggests that the TNCs dealing with biotechnology (because of its basic science base) seek to locate R&D in places where scientists and professionals are available, and reputed research institutes are in proximity.

2.0 Characteristics of the Emerging Phenomenon

The corporate R&D structure performs the following types of functions - facilitate technology transfer (technology transfer unit - TTU); product development for the local markets (indigenous technology unit - ITU); development of products and processes for the global markets (global technology unit - GTU); and basic research in generic technologies for long term corporate use (corporate technology unit - CTU) (Ronstadt, 1977). In recent years, an additional function of product development for the regional markets (regional technology unit - RTU) is also becoming prominent (Prasada Reddy and Jon Sigurdson, 1993/b). These R&D functions, especially, in the high-tech industries such as pharmaceuticals, chemicals, microelectronics, biotechnology and new materials have become more science based and research intensive (Freeman, 1982). The scientification of many new technologies coupled with the increasing global competion seem to necessitate multi-sourcing of innovations to maintain competitiveness.

The literature indicates several motives for globalization of R&D by TNCs. These include - market related (size and proximity); technology related (tapping the foreign S&T resources); cost related (exploiting the cost differentials); technology monitoring (especially competitor analysis); non-R&D related (national policy pressures, image building) etc. The type of R&D function performed abroad is directly related to the motives. This relationship is summarized in figure 2. However, all these motives are not mutually exclusive.

Figure 2
Motives and Type of TNCs' R&D Located abroad

R&D Functions Abroad

Motives	TTU	ITU	RTU	GTU	CTU
market					
-uniqueness		X	X		
-size	X	X	X		
-proximity		X	X		
technology					
-upgrading subsidiary	X	X			
-proximity to mfg.	X	X	X		
-availability of researchers			X	X	X
-proximity to universities				X	X
cost related			X	X	X
monitoring	X				
non-R&D	X	X			

Source : A. S. Prasada Reddy and Jon Sigurdson (1993/b)

The emerging trends in TNCs' location of R&D, being a new strategy, so far, little research has been carried out. However, from the type of R&D being performed (GTU and CTU), it appears that the primary motives for location of R&D in developing and East European countries are both technology and cost related. Market related motives and proximity to manufacturing do not seem to be critical factors for GTU and CTU type of R&D[9]. From the emerging trends the following observations can be made :

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9 As stated earlier, to some extent TTU and ITU type of R&D was already being performed in developing countries, where market related motives are important. The focus of the present study is on the new trends of locating RTU, GTU and CTU type of R&D in developing and East European countries. However, RTU type of function is closely linked to the market related motives. RTU is more like an extension of ITU function, with the geographical scope of the product extended to several national markets with similar characteristics.

- The R&D functions carried out in some developing and East European countries by TNCs, in recent years, relate to products of strategic importance to the companies' regional/global operations[10].
- The motives for TNCs' R&D investments in developing and East European countries are both cost and technology related. Although developing countries lack high-tech industrialization, some of these countries have highly qualified scientists, both trained at home and abroad, who are available for work at relatively much lower wages. There are also some internationally reputed "academic enclaves" (universities/research institutes) in these countries. TNCs consider these scientific talents to be almost on par with those in industrialized countries and hence, could be utilized for generating new technologies.
- Developing countries into which R&D activities are being extended are, in general different from those which attract international production activities. Although there may be some common locations, R&D investments are being made in developing countries like Brazil, China and India, while production investments seem to prefer more rapidly growing economies - Indonesia, Malaysia, Thailand etc. It would appear as if R&D and production activities require different types of technology environment.
- TNCs which are performing strategic R&D in developing countries are mostly those dealing the new technologies (biotechnology or microelectronics or new materials). This suggests that R&D in new technologies can be performed in not so highly industrialized countries. This may be because of their closeness to basic science and therefore, R&D in these technologies can be performed whereever resources and facilities are available for basic science research. This may hold promising opportunities for developing countries.
- TNCs' R&D activities are giving rise to new types of organizations and a new class of entrepreneurship (scientific entrepreneurs) in the host countries, offering scope

10 While TTU and ITU continue to be the most predominant types of R&D being conducted in developing countries, RTU, GTU and CTU types are also spreading rapidly.

for human capital development and innovative capability building in host countries. In some cases scientists themselves are becoming entrepreneurs to commercialize their research results.

- Both in developing and East European countries, the scientists involved with TNCs' R&D activities are learning skills to research beyond proving the principles and find specific applications.
- TNCs' R&D units in developing and East European countries, work, often, jointly with TNCs' other R&D units located in industrialized countries on specific innovation projects (division of labour). This network relationship facilitates transfer and acquisition of specialized skills and expertise in host countries.

Strategic Differences in Location of R&D in Developing and East European Countries

- In developing host countries TNCs are creating new R&D facilities, whreas in East Europe TNCs are utilizing the existing R&D infrastructure.
- Through their substantial R&D investments, TNCs are indicating a long term commitment to perform R&D activities in developing host countries. On the other hand, in East European host countries TNCs are not showing such lon term commitment. The forms of TNCs' R&D in East Europe (mostly sub-contracting of R&D or hiring of professionals) reflect short term project wise commitment.
- The strategic importance of East Europe also includes gaining access to portfolio of technologies held by the research institutes. TNCs are seeking to commercialize and market them globally. In developing countries, no such interesting portfolio of technologies are available.
- Developing host countries, especially the dynamic Asian economies, are also important emerging markets. So, from TNCs' perspective an R&D presence in these countries is vital. On the other hand, TNCs R&D in East Europe does not indicate host countries' importance as future markets.

Different Forms of TNCs' R&D Activities in Developing and East European Countries

The concepts of internationalization and globalization are used differently by different researchers. According to Riccardo Petrella (1992), internationalization involves joint R&D between two or more firms from different countries; multinationalization involves establishment of R&D activities by a firm in countries other than its home country; and globalization involves development of a global R&D strategy by the corporation both at the internal level (in-house R&D) and the external level (R&D alliances, mergers, acquisitions, university contracts etc.) in all R&D areas (basic, strategic, applied etc.). Casson and Singh (1993) consider internationalization as an approach in which overseas R&D units are given small and usually subordinate role in corporate research activity, whereas globalization involves a greater commitment to overseas R&D, based on systematic division of labour between laboratories in different countries. Internationalization is usually motivated by the need to support overseas production and marketing, whereas globalization is independent of such motives.

TNCs' corporate R&D activities in low-cost countries encompass the whole gamut of arrangements that are considered as parts of globalization process. Such R&D activities are being carried out with a strategic intent to improve the long term innovativeness and competitiveness of the corporation. Hence, the emerging phenomenon can be considered an off-shoot of globalization of corporate R&D by TNCs.

Several discernable forms of international corporate R&D can be observed in developing and East European countries. These forms, which are similar (except for R&D undertaken because of acquisitions and mergers) to international R&D activities in industrialized countries are :

- Own R&D Centres - considered as a part of in-house R&D facilities.
- Joint venture R&D (alliances) - with local firms or research institutes either to develop a new product or to carry out research into generic technologies. Such joint ventures are in some cases combined with production and marketing arrangements and in other cases they are independent of those activities.

- Sub-contracting of R&D - assigning a part or complete project to firms or research institutes/universities in low-cost countries on sub-contract or payment basis.
- Sponsorship of Research in Universities in low-cost countries - particularly in basic research or generic technologies for long term use.
- Hiring of Professionals and Facilities - prevalent mostly in East Europe. TNCs are involved in hiring a number of professionals and some facilities from the research institutes to work on the problems in which the TNC is interested. Such hired personnel include freelance researchers.
- Others Arrangements - some companies have sponsored the establishment of research institutes in low-cost countries as non-profit organizations. While the company funds most of the research, it retains the first right of refusal for the results of the research conducted at the institute.

R&D Environment in Selected Developing and East European Countries

During the course of their developmental efforts, many developing countries have considered science and technology education as a priority area and built up large cadres of scientific personnel. Among them some, including the large countries like Brazil, China and India, took up building up capabilities in basic science as the starting point, from which they expected to flow smoothly into down-stream activities of applied research, product design and development, and manufacturing. To their dismay, they have come to realize that the path from basic research to down-stream activities is not an easy one. They have failed to establish proper linkages between different stages of the science and technology system. As a result, these countries, now, have large stocks of highly qualified scientists and engineers in theoretical sciences, whose knowledge and skills are not fully exploited for economic growth. These cadres of scientific personnel are available for R&D work at substantially lower wages.

On the other hand a few other developing countries, especially the Newly Industrializing Countries (NIEs), attempted to build up S&T capabilities by concentrating on down-stream activities first. As a result they have built up strong competences in product design and manufacturing, and have now started moving toward up-stream activities of basic and applied research. To enable them to do so, these countries took up S&T education as a priority task and built up large pools of trained manpower. "One-tenth of the World's engineers and scientists are from the developing world and more than a dozen of them have won Nobel prizes in chemistry, physics and medicine" (Cherie Hart, 1991).

Some of the developing countries have also built up world reputed universities and research institutes. These places of higher education have not only been producing well trained graduates, but also significant discoveries in science and technology. TNCs R&D activities in developing world are observed to be concentrated in countries that have such centres of excellence, good education system and adequate supply of professionals. Often, R&D is conducted in collaboration with such research centres.

Under the communist system, in competition with the Western countries, East European and former Soviet Union countries have built up large R&D systems. During the cold war period, flush with funds, these giant organizations had worked on a range of high-technologies. However, the efforts of majority of these R&D systems were concentrated on military, nuclear, space and biotechnologies rather than on commercial technologies.

Kiser Research, an US firm that marketed Russian technology for several years opines that although Russian consumer technologies lag those in the West, they are leading in many industrial technologies such as welding, chemical processing, high-powered electrical equipment and metallurgy. Russia also has outstanding talent in mathematics and theoretical physics (Scientific American, 1993).

Table 2 presents comparative data on S&T indicators for selected developing and East European countries. The data illustrate the availability of scientific talent and the R&D environment in some of these countries. The S&T indicators in the table above suggest that some developing and East European countries are doing better than the lower ranges of the OECD countries. For the number of scientists and engineers engaged in R&D per 10,000 labour force, Brazil is doing exceedingly doing well on world patent activity. In terms of patent activity all the developing and East European countries in the table are doing better than the lower ranges of high income OECD countries. These figures seen in relation with the R&D expenditures as a percent of GNP suggest higher productivity of R&D investments in some developing and East European countries than in some of the OECD countries.

Table 2 Selected S&T Indicators - A Comparison

Country	R&D as % of GNP	R&D personnel per10,000 labourforce	% of world patent activity (1988)	No. of scientific papers (1981-90)	Mean citations per paper (1981-90)
Poland (1982)		21.8	0.7	35,886	2.93
Chile (1988)	0.5			10,141	2.19
Bulgaria (1982)		47.0	0.7		
Argentina (1981, 1982)	0.4	16.1	0.3	15,490	2.36
Brazil (1987,1985)	0.7	9.3	1.0	20,037	2.51
Hungary (1987, 1982)	2.7	20.5	0.31	21,072	3.32
Yugoslavia (1987)	0.8		0.04	11,965	2.61
Czechoslov-akia (1982)		31.1	0.15	26,764	2.38
Portugal (1987, 1986)	0.5	9.9			
Rep of Korea (1987)	1.8	32.0	0.56		
Taiwan province of PRC prov. of PRC (1988, 1987)		41.6	0.06		
High income OECD range (vario	1.3-3.1	23-77	0.03-26.6		4.3-7.3

Source : Charles Weiss, Jr. (1993). p. 14.

East European scientists have major achievements in scientific products. For instance, the soft contact lens is a Czech invention, and tranquilizers developed by Hungary are a major success in Japan. A group of researchers from former Yugoslavia have been shifted to Argonne National Laboratories in USA, to help scaling up an original gene-sequencing technique that forms the basic technology for the multi-billion dollar Human Genome megaproject (Charles Weiss, Jr. 1993).

The scientific community in East Europe was privileged and it consumed a large proportion of available resources. For example, more than 2 percent of Hungary's GNP was ear marked for R&D. These resources were allocated to the laboratories with out much consideration for the quality of work or the laboratories' contribution to the society. Consequently, the S&T establishment in former centrally planned economies, that is inherited from the communist period, is bloated and distorted, but consists of pockets of excellence that could be revived (Charles Weiss, Jr. 1993).

The structure of S&T systems in East Europe created a seperation between education, basic research, applied research and manufacturing with no proper linkages between them. Education was carried on in universities; basic research in institutes managed by the national academies of science; and applied research in institutes reporting to the national academies or to the ministries (Charles Weiss, Jr. 1993). Manufacturing took place in industries which had no proper linkages with the research institutes. With assured markets and quota systems, the firms had no incentives either to be innovative or to upgrade their technologies. The linkages among and between the institutes and the market, which are critical fo: application of S&T to economic development, were missing. This situation led to a duality with sophisticated research capabilities co-existing with poorly designed and manufactured products (Charles Weiss, Jr. 1993).

However, there are variations in the experiences of different East European countries. In 1965, Hungary made a legal provision making scientific research at the universities obligatory. This led to a revival of former science schools and establishment of professional relationships at the international level. Priority was given to R&D activities in the companies. By the mid 1980s, licence imports and cooperation with the Western partners increased. In 1986, more than 2000 industrial contracts with Western Partners were registered. However, these elements were not coherently integrated into the institutional system and the R&D policy (Ernö Pungor and Lajos Nyiri, 1993).

It is no surprise that much of the TNCs' R&D activities in East Europe is concentrated mainly in Russia and Hungary. Table 3 gives more data on number of publications and their citation rates for different countries. Data suggest that more scientific activity is being carried out in some developing and East European countries than in some OECD countries. Data also shows the special position of former USSR. Its scientific out put is second only to USA.

Table 3 Number of Publications and Relative Citation Rate in Different Countries in the 1980s.

(Relative Citation Rate - RCR - is the Ratio of Observed to Expected Citation Rate; Expected Citation Rate is calculated by Counting the Average Citation Rate of the Publishing Journal)

Country	No. of Publications	Relative Citation Rate
OECD		
USA	1,539,506	1.04
FRG	248,785	1.07
Japan	301,267	0.93
Austria	22,878	0.97
Sweden	69,689	1.20
Switzerland	52,300	1.20
Turkey	3,859	0.51
Finland	26,340	0.99
Greece	10,605	0.64
Portugal	3,123	0.66
East Europe		
Bulgaria	10,437	0.61
Czechoslavakia	29,690	0.81
Hungary	19,613	0.80
Poland	38,770	0.70
Romania	5,574	0.65
USSR	309,280	0.90
Developing		
Rep of Korea	4,685	0.64
P. R. of China	25,965	0.54
Mexico	7,744	0.70
Brazil	16,261	0.59

Source : T. Braun, W. Glanzel, A. Schubert - Database of the Information and Scientometrics Research Unit, Budapest. As given in Ernö Pungor and Lajos Nyiri (1993) p.32.

Hungary's scientific output in terms of papers published in science journals between 1981 and 1985 indicates greater success than the country's economic strength would suggest. While the Hungarian GDP was only 0.22 percent of that of OECD in 1986-87, publications had a share of 0.58 percent, while the citation rate is a more modest figure of 0.27 percent (Ernö Pungor and Lajos Nyiri, 1993).

The number of patents granted in the US, is often used as a measure of technological performance. The data in table 4 reflect Hungary's superiority over its East European neighbours in this regard. Hungarian researchers were granted 131 patents in 1989, ranking Hungary on par with Spain (132) or Norway (128) and slightly behind the USSR (160) and Republic of Korea (160). Over half of Hungary's patents were granted in the chemical industry sector. Incidentally this sector has the highest ratio of R&D expenditure to production in Hungary (OECD, 1993).

Table 4 Number of Patents Granted in the US for Selected Countries

Country	1981	1983	1985	1987	1989
Hungary	98	107	108	126	131
Czecho-slovakia	40	38	54	46	34
Poland	37	20	10	14	16
USSR	374	224	148	121	160
Netherlands	649	633	768	929	1078
Denmark	129	127	191	205	219
Spain	59	50	78	117	132
Portugal	4	6	4	5	10
Austria	283	272	322	349	402
Finland	142	116	203	275	231
Norway	94	67	92	136	128

Source : OECD (STIID). Adopted from OECD, 1993. p. 35

With the collapse of central planning system and subsequent financial crisis, the scientific community in East Europe and former Soviet Union is facing a severe crisis. With budget cuts in R&D funds, several scientists are now being laid off from their jobs. With the collapse of guaranteed support of the cold war period, in Russia, where about 95 percent of the 1.5 million scientists and engineers of the former soviet union worked, the scientists are facing an uncertain situation (Scientific American, Feb 1993). Added to this the relative wages of scientists compared to some other occupations have also fallen lower.. As a result, the former centrally planned economies are facing two kinds of brain drain - Internal brain drain, with scientists and engineers moving into other occupations where their knowledge and skills are of little relevance; External brain drain, with scientists emigrating to countries with brighter prospects. The remaining scientists are eagerly looking for contract research from Western countries/firms. Table 5 gives the average annual salaries of scientists in East Europe and Russia.

Table 5 Average Annual Salary of a 35 year old Scientist with a Ph. D. (US dollars, Jan 1992)

Hungary	4,000
Czecho-Slovakia	3,000
Poland	1,000
Romania	700
Bulgaria	400
Russia	360

Source : Sylvester Vizi (1993). p.104

Going with the general trend of liberalization and opening up of the economy, the previously classified research institutes in the former Soviet Union and East Europe are opening up their facilities for Western firms. The financial crisis of these institutes is forcing them to sell not only their previously secretly held high technologies, but also offer their services on contract basis to develop new technologies.

The transformation of East European R&D systems is underway, with Hungary leading the path. Decentralization of oversized institutes into smaller for-profit centres; strengthening of economic ties between different organizations; organization of holding type of R&D units and the establishment of joint ventures. A few large foreign companies including General Electric have also started setting up R&D activities in Hungary (Ernö Pungor and Lajos Nyiri, 1993).

In Czech and Slovak Republics, in the reformed system, State R&D institutes are required to operate on a self-financing basis and they are assessed according to their profit. The tax rate is the same as that for the production enterprises. It is expected that most of the R&D capacity will be privatised in the near future. In Oct 1991, there were proposals for privatising 58 R&D institutes in the Czech Republic, consisting of 13,000 personnel. About 90 percent of the privatised R&D institutes have the same legal status as Small and Medium Scale Enterprises (SMEs) (OECD, 1992).

Western firms are attracted by the scientific talent and infrastructure available, and their substantially lower costs in East Europe, compared to the costs in the industrialized countries. Western firms are also interested in commercializing the large portfolio of inventions these institutes hold. Forming joint ventures, the Western firms are now employing the researchers at the institutes in East Europe and Russia to carry out development work on many of these technologies.

"Interpatent", a joint venture with National Patent Development Corporation of New York, has won the marketing rights to technologies developed at Kurchatov and other research centres. Kurchatov Institute is experimenting with Russian plasma heating devices called gyratrons, on a sub-contract from General Atomics of USA. General Atomics inturn has a contract with the US dept. of Energy. The sub-contract valued at US dollars 90,000 covers the work of more than 100 researchers for a year. In the US that amount would barely cover one researcher (Scientific American, 1993).

3.0 Theoretical and Analytical Explanations

Corporate R&D performs the following types of functions - facilitate technology transfer (Technology Transfer Units - TTUs); develop new products for the local market (Indigenous Technology Units - ITUs); develop new products and processes for global markets (Global Technology Units - GTUs); and generate basic technologies for long term corporate use (Corporate Technology Units - CTUs) (Ronstadt, 1977). In recent years, corporate R&D structure is also undertaking an additional function of developing products for the regional markets (Regional Technology Units - RTUs). While the markets world wide are integrating in terms of standards and technologies, there are also some regional clusters emerging. National markets in these regional clusters share some common features and have common needs for specialized products. Such examples can be found in biotechnology - food processing (special types of food, taste etc.), pharmaceuticals (drugs for regional diseases) - or in microelectronics - special software (language or varied work environment). To cater to such regional markets, TNCs have been establishing RTUs (Prasada Reddy and Jon Sigurdson, 1993/b). In the past, TNCs tended to confine R&D functions, especially the GTU and CTU types, to their home countries and when the necessity arose performed mostly TTU and ITU type of R&D abroad. Even these limited R&D activities were mostly confined to industrialized countries and a few large developing countries. Such R&D was considered as additional and inevitable costs of technology transfer, so reduction of R&D costs was not a motive for locating R&D abroad. Studies in the late 1970s (Craemer, 1976; Ronstadt, 1977; and Behrman and Fischer, 1980), confirmed these conventional practices.

Behrman and Fischer (1980) in their survey found that some TNCs have located R&D in advanced developing countries. Among the developing host countries, the most important were Brazil, India and Mexico. However, TNCs' R&D activities in these countries were limited to adaptations, local technical services (TTU type) and in a few cases product development for the local markets (ITU type). The most critical incentive to locate these limited R&D activities was the presence of a profitable affiliate and a growing and sophisticated market with an adequate scientific and technical structure.

Table 6 gives Ronstadt's categorization of R&D abroad by the US based TNCs abroad.

Table 6 - R&D Abroad by the US Multinationals by Their Primary Purpose and Whether they were Created or Acquired.

Units	All R&D	TTU	ITU	GTU	CTU
Created	42	31	2	5	4
Acquired	13	6	7	0	0
Total	55	37	9	5	4

Source : Ronstadt, R (1984).

Table 6 shows that majority of the R&D units (56%) were TTUs created abroad. Very few ITUs were established abroad and only two were created. While all the acquired units were either TTUs or ITUs, the GTUs and CTUs were all created units. All the GTUs in the study were created by one US TNC, namely IBM, a company dealing with a new technology and all of them were located in other industrialized countries. However, the focus of this paper is the location of GTU and CTU types of R&D in developing and East European countries.

In recent years, two sets of factors have changed TNCs' behaviour of confining strategic R&D functions (RTU, GTU and CTU) to their home countries. The first relates to the increasingly globalized basis of competition, which created the need for generation of new products and improvement of existing productlines on the basis of distinctive characteristics of national/regional markets (Pearce, 1991). The second relates to contemporary developments in science and technology. The general trend shows the increasing role of basic science in major technological advance, and generation of innovations through cross-fertilization between scientific disciplines. These ongoing paradigmatic changes in S&T, especially in electronics, pharmaceuticals and new materials, are creating pressures on the capabilities of the companies. These pressures can be met partly by increasing in-house R&D within corporate structures, both nationally and internationally, or by R&D cooperation with other firms or through external acquisition of knowledge, knowhow and skills located in other organizations, whether universities or firms (Chesnais, 1988).

To meet these pressures, the TNCs have increased their spending on research during the 1980s, mainly in two ways - expansion of own R&D activities and sponsoring research in academic institutions. As a result, the corporate sector now accounts for substantial and rapidly growing part of total national expenditures on R&D in most OECD countries. Corporate sector is increasingly performing basic research. In Japan, such expenditures now account for 35 percent of the country's total spending on basic research. In the US corporate sector spent 17 percent of the total national expenditure for basic research in 1986. Each of the 14 OECD countries, for which trend data are available, have also reported substantial increases in the corporate sponsorship of research in the academic institutions (OECD, 1988).

The conditions for research and access to resources for carrying out research varies around the world and therefore, subject to costs involved, relocation of R&D may in the long run improve the competitive position of the company (Sigurdson, 1990). The patterns of scientific cooperation among countries and industries indicate the emergence of international market for investments in research, education and scientific and engineering personnel. The existence of such a market and the necessity of scientific knowledge for competitiveness is leading the corporations to direct their investments to those geographical areas which can best meet their research and manpower needs (OECD, 1988). In their search for ideal R&D locations, TNCs have crossed the conventional boundaries and started tapping the scientific resources wherever they are accessible, including those in developing and East European countries.

New and un-common locations for research are now becoming locations for international corporate R&D, as the TNCs recognize the talent available in countries like Israel (where the US company National Semiconductor carried out much of its work on new 32 bit microprocessor), Brazil, and India which has the world's third largest pool of scientists. In the near future, Rep. of Korea, which now produces as many engineers each year as the UK, Germany and Sweden combined. Singapore and other Pacific rim countries will become attractive R&D locations (OECD, 1988).

Moreover, the demand for scientists and engineers, and national disparities in the incentives offered to them, has led to reported shortages in several OECD countries. The mis-match between the outputs of higher education and the needs of the industry is giving rise to shortages of research personnel through out the OECD. In recent years, firms in the US, Japan, the UK, Germany, Finland, Netherlands, Sweden and other countries have reported difficulties in recruiting research personnel in certain categories, especially in engineering fields related to electronics, automation and CAD/CAM. In OECD countries, there has also been a decline in the intake of students in some fields of science and technology. This decline is likely to be more sharp in the future as a result of demographic changes in several countries (OECD, 1988).

Håkanson and Zander (1986) in their study of Swedish companies found that the reasons for internationalization of R&D include - the evolution of technical support functions at foreign subsidiaries to encompass more advanced product development tasks; difficulties in recruiting qualified personnel on the tight Swedish labour market; the exploitation of foreign entrepreneurial and technical talent, sometimes in compensation for stagnating R&D at home; advantages of proximity to customers and foreign research establishments; and through acquisitions abroad.

TNCs locate of more advanced R&D activities abroad to exploit the resources that are more expensive or not readily available at home. Such resources include university based research and specific knowhow in production engineering and the skills and sophistication of users (Håkanson, Lars and Zander, Udo, 1986). TNCs are also sensitive to variations in the cost of R&D inputs from country to country (Mansfield, et al. 1979). These observations of TNCs behaviour are also reflected in the trends of locating R&D in some developing and East European countries. Each of these loe-cost countries offers access to required resources with specific knowledge, at substantially lower costs vis-a-viz industrialized countries.

According to Granstrand, Håkanson and Sjölander (1992), the reasons for internationalization of R&D can be organized into two groups. "Demand-Oriented" factors - circumstances leading to establishment of R&D abroad to better serve the foreign national markets; and "Supply-Oriented" factors - refering to "characteristics in the local foreign environment that enhance the efficiency of R&D by providing, e. g. favourable access to skilled technical expertise perhaps at lower cost than available elsewhere, access to foreign universities and other research establishments, etc".

While the globalization of R&D has become a necessity, the primary motives for such moves differ among companies. From the literature survey (see Pearce, 1991; Dörrenbächer and Wortmann, 1991; L. Håkanson, 1992; Granstrand, et al 1992) the motives for location of R&D can be summarized as follows - market related (size, proximity and importance); technology related (to tap into foreign S&T resources); cost related (to exploit cost differentials and reduce R&D costs); monitoring (to monitor new developments in S&T, competitors' analysis etc.); and non-R&D related (pressures by national governments, improving the company's image etc.). However, these motives are not mutually exclusive. A TNC may locate R&D abroad for more than one motive.

Over time, technology related motives are observed to have become more important than market related motives (Cantwell, 1992). The impetus for globalization of R&D is increasingly being provided by the need to "know-how" rather than "know-what" to develop (Dunning, 1992). Market related motives are observed to lead mostly to TTU, ITU and RTU type of R&D functions, whereas technology and cost related motive are important for GTU and CTU functions. However, depending on the growth of the market and the change in the orientation of the company, R&D units abroad are graduated to perform increasingly higher order R&D functions. Burstall et all. (1981), link the evolution of a R&D centre's capability from a limited unit to that with a comprehensive research capacity to the scientific and industrial capacity of the host economy (Warrant, 1991). In recent years, due to international division of labour and diffusion of technologies, the technological capacity of some developing countries has improved dramatically. These countries are now able to handle increasingly complex technologies and not only improve up on them, but also in some cases generate new technological methods in niche areas. In the case of East European countries, R&D capacity in many complex technology areas already existed. What is required is to give commercial perspectives to such R&D capabilities. TNCs are now attempting to utilize these S&T capacities in developing and East European countries by establishing GTU and CTU types of R&D.

The geographical market scope of the products that a firm produces is reflected in the type of R&D unit it locates abroad. Home market companies, tend to establish only low level technical support or test facilities. Global market companies tend to establish both low level research support centres as well as global or corporate product units, depending on their requirements (Behrman and Fischer, 1980). New technologies have a higher level of technical standardization (universal standardization) compared to the conventional technologies. Therefore, in these industries, there is less need for TTU and ITU types of R&D. With this geographical scope of the products in perspective, the companies dealing with new technologies seek to establish more GTU and CTU and in some cases RTU types of R&D. The schema presented in figure 3 shows that as more firms shift towards global market orientation it will be reflected in the types of R&D established abroad, i.e. there will be more global or corporate R&D laboratories (Warrant, 1991). The first column shows the geographical orientation of the company, the subsequent columns show the type of R&D unit likely to be set up based on such orientation.

Figure 3

Schema for Transnational R&D

Geographical market orientation	Type of R&D unit			
Behrman & Fischer, 1980	Ronstadt 1977	Hood & Young, 1982	Behrman & Fischer, 1980	Burstall et al. 1981
home market companies	technology transfer units	support laboratory	regional scientific, chemical staff	specialized/ limited research capacity
	indigenous tech-nology units	legally integrated R&D lab	animals & farm facilities	
host market companies	global product units	international	applied R&D laboratory new product	
world market companies	corporate tech-nology units	independent R&D laboratory	research mission laboratory	comprehen-sive research capacity (e. g. IBM)

Source : Francoise Warrant (1991)

Tapping the foreign S&T resources is the primary motive for establishing GTU and CTU types of R&D abroad. However, faced with the increasing R&D intensity of technologies and reducing profits, TNCs are increasingly concerned about reducing R&D costs. This has to be achieved with out compromising the primary objective of generating new technologies and improving the innovativeness of the company. One way of achieving these twin objectives is to carry out R&D, at least some parts of it, in low-cost locations that have required S&T capacity. In the generation of new technologies, the innovative potential in the foreign country does not necessarily have to be more advanced than the potential in the TNC's home country, i.e. industrialized countries. Technology expertise can be complimentary (Dörrenbächer and Wortmann, 1991).

Selection of location of R&D by TNCs depends on several criteria. These include - proximity to a manufacturing site; availability of local universities and professionals; ability to build up a critical mass of local researchers (most important for global technological research); attractiveness of sources of technical excellence, e.g. universities, customers or suppliers, etc.; and availability of excellent communication systems (Meyer and Mizushima, 1989). Even in the selection of low-cost locations, it is observed that TNCs have followed the same criteria. Although, developing countries are lagging behind the industrialized countries in industrialization, some of them have internationally reputed academic institutions. TNCs consider them as almost on par with the academic establishments in the developed world. Therefore, when the R&D is close to basic science research, it becomes cheaper to perform in developing countries (Prasada Reddy, 1993). It is also observed that different elements of new technologies prefer different types of technology environments. These preferences in turn determine the direction of R&D related investments, as dipicted in figure 4.

Figure 4

engineering

science

	sophisticated	conventional
high	Developed countries →	ADCs
low	↓ NIEs	LDCs

R&D into direct product development or industrial application technologies (e.g. product design and hardware technologies) are observed to prefer Newly Industrializing Economies (NIEs - Hong Kong, Singapore, Rep. of Korea and Taiwan province of PRC), which have a sophisticated engineering base, but relatively not so strong a basic science base. On the other hand, R&D into generic technologies or disembodied technologies seem to prefer Advanced Developing Countries (ADCs - e.g. Brazil, China and India), which have a relatively high basic science base, but do not have sophisticated engineering base. ADCs for a long time followed import substitution policies and built up broad, but general capabilities for the total system (basic research, applied research, product design and manufacturing), which seems to be more suitable for R&D into generic technologies. On the other hand the NIEs followed export-led strategy and built up specialized capabilities in a few components of the system (especially superior production engineering) and this expertise seems to be more suitable for direct product development.

Differences between New Technologies and Conventional Technologies

In conventional terms, technology flow is perceived as unidirectional from the parent company to the affiliate abroad. R&D abroad, primarily, dealt with adaptation of transferred technologies and, in some cases, additional innovation needed to serve the local markets. A recent study of German companies by Micheal Wortmann (1990) indicated that in recent years there has been a qualitative change in the R&D performed abroad by the German companies, especially in the high-tech sectors. The companies have started considering foreign R&D as a source of knowledge and technology.

Almost all the firms involved in this emerging trends, of locating strategic R&D in low-cost countries, have been the firms dealing with new technologies. Most of the R&D activities carried out abroad in new technologies have global or at least regional orientation. New technologies have a higher level of standardization compared to the conventional technologies and therefore, their products have global market scope. The adaptations required for local environments are marginal or nil, compared to the conventional technologies which required either extensive adaptation or special design and development for each market. Hence, there seem to be very few TTU and ITU type of R&D centres in new technologies. That is why, perhaps, among the companies studied by Ronstadt, only IBM (a new technology firm) had GTU and CTU types of R&D centres abroad (Ronstadt 1984). Wortmann (1990) also mentions the special case of IBM's research in Germany. He states that almost all products are designed not for a specific region but for the world markets. Product manufacturing need not take place in the same country where R&D took place.

Francois Chenais (1988), citing Michalet and Delapienes (1978) also discussed the case of IBM. By the mid-1970s, IBM had set up a world based set of R&D activities organized independently of its manufacturing affiliates. The tasks assigned to the laboratories did not necessarily match those of the subsidaiary's production units to which the given laboratories formally belonged. The development tasks were distributed on a world wide basis among all the other laboratories. IBM has successfully carried out sourcing and centralization of scientific and technical knowledge and resources on an international scale. Chenais (1988) further states that "the centralization of external scientific and technological knowledge is not limited to 'science based' or R&D intensive industries, but has been equally important in industries such as food processing, where innovation relies heavily on inter-industry transfers of technology" (p. 507).

Some developing countries have R&D capacity in new technologies and satisfy both technology and cost related motives. Using their concept of "life cycles of technology systems" Perez and Soete (1988), explain how inventions in new technologies can occur in developing countries and why the new technologies offer greater opportunities to developing countries. In the development phases of a new technology system, Phase I (introduction), involves original design and engineering. Therefore, the S&T knowledge required will be high, whereas relevant skills and investment required will be low. In phase II (rapid growth), the focus is on improvements to product and production process. Since the technological solution is already embodied in the equipment, the S&T knowledge required will be low. But the skills and investment required will be high. In phase III (productivity and firm's growth), the focus will be on scaling up the plant, and managing the firm's growth. The capital costs and management skills required can be very high. By then the S&T knowledge required will become low. In phase IV (maturity), the whole system is standardized and further investments in technological improvements results in diminishing returns. Firms and locations with low-costs of production will become competitive, but fixed investment costs will be high. As a result, save for the need for high level of externalities and of S&T knowledge, entry into the new technologies is easier for developing countries. This partially explains the cases of electronics and biotechnology innovations occuring outside the industriallized countries.

However, as the system evolves, it may require not only constant technological effort, but also a growing flow of investment to generate synergies for self-sustained growth processes. The technology systems profounded by Perez and Soete form an element of a larger whole - a techno-economic paradigm. Each new techno-economic paradigm generates and diffuses new type of knowledge, skills and experience and provides a favourable environment for easy entry into more and more products within those systems. The firms and countries that had accumulated great advantages in the superseded technology systems face increasing costs in getting rid of the experience and the externalities of the "Wrong sort" and in acquiring the new ones. New comers that, for whatever reason, acquire the new knowledge and skills faster. "That is why these periods of paradigm change have historically allowed some countries to catch-up and even surpass the previous leaders". Two favourable conditions exist for laggards to catch-up. Firstly, there is time for learning, since everybody else is also in the learning stage. Secondly, the entry thresholds being low, given a reasonable level of productive capacities, qualified personnel and locational advantages, an opportunity is open (Perez and Soete, 1988). Although, some of the developing countries have these knowledge generating capacities, they did not possess the skills and capital to convert this knowledge into products. TNCs are now providing an opportunity, by transferring these application skills and capital to developing host countries, to enter the new technology systems.

As noted before, multi-sourcing of technologies an essential pre-requisite to remain competitive in new technologies, because of their science base and rapidity of change. Hence, several TNCs have started forming cooperative alliances with other firms both abroad and within the country. Table 7 shows the different forms of technology cooperation agreements entered into by the firms dealing with new technologies, underlining the crucial role of multi-sourcing of innovations, new ideas and technology.

Table 7. Different Forms of Technology Cooperation in New Technologies (at the end of 1990)
(numbers and percentages)

Form	Biotechnology	Information Technology	New Materials
joint venture research corporations	164 (13.5)	458 (16.9)	177 (25.7)
joint R&D	362 (29.8)	749 (27.6)	173 (25.1)
technology exchange	84 (6.9)	328 (12.1)	54 (7.8)
direct investments	234 (19.3)	357 (13.1)	65 (9.4)
customer-supplier relations	186 (15.3)	245 (9.0)	42 (6.1)
uni-directional technology flows	183 (15.1)	581 (21.4)	177 (25.7)
TOTAL	1213 (100)	2718 (100)	688 (100)

Source : MERIT-CATI Databank. As Given in Hagedoorn and Schakenraad (1990). p. 7.

Joint R&D seems to be the most popular form of cooperation in both biotechnology and information technologies. In biotechnology, direct investments is the second most important form of cooperation. According to Hagedoorn and Schakenraad (1990), in biotechnology large companies have considerable cooperative agreements with small high-tech firms through minority share holdings, R&D contracts and licencing agreements. In information technologies, uni-directional technology flow is the second most popular form of cooperation, largely due to second-sourcing agreements. In new materials, joint ventures, uni-directional technology flow and joint R&D each account for about 25 percent of the total agreements.

4.0 Implications for the Corporate R&D Management

In terms of the overall phenomenon of the globalization of R&D, the emerging trends are still only of a marginal significance. With the liberalization of economies alround the world, the business environment is likely to become highly competitive in the 1990s. To be able to compete successfully, the companies need to be highly innovative. This is likely to increase the R&D costs of the companies. The technology is rapidly changing, especially in the new technologies. One way of reducing R&D costs and still be innovative is to locate R&D (at least some parts of it) in low-cost countries that have adequate scientific and technical resources. The trend of locating corporate R&D in low-cost countries is likely to emerge as a phenomenon similar to that of establishment of off-shore production facilities in low-cost countries in the 1970s. This will have implications for the competitiveness of the TNCs.

To adopt such a strategy, the companies should have an awareness of the type of R&D environment available in low-cost countries. Some low-cost countries have strong capabilities in basic science and software technologies, whereas some others are strong in product design and engineering. Such differences capabilities of countries may require division and allocation of R&D activities to centres in different countries. This means, the corporation should build up capabilities to first integrate all the parts of R&D performed in different countries and then transfer the knowledge to production units, which are in turn, probably, located in different countries, manufacturing different parts of a system (Prasada Reddy and Jon Sigurdson, 1993/a).

In the context of the emerging phenomenon, some unique cross-cultural problems may arise, hindering the accomplishment of organizational goals. The laboratories often behave as tight knit communities and each laboratory may be suspicious of its internal rivals (Casson and Singh, 1993). The problems and tasks will have to be set differently in different countries with different cultural settings to obtain the best results. Researchers from the company's labs in industrialized countries may look down upon their counter parts from low-cost countries and underplay the latter's role, especially because of the latter's low compensation. Moreover, the researchers from the laboratories in industrialized countries may perceive the researchers from low-cost countries as a threat to their jobs and may not cooperate with them (Prasada Reddy and Jon Sigurdson, 1993/a).

Such cultural misgivings may be overcome to some extent, if the laboratory in the low-cost country can quickly establish its credibility by contributing to the technological knowledge of the company. According to Meyer (1993) such "knowledge credibility" may not necessarily come from major R&D successes only. Even, significant applied work, in the short run, can contribute to the effectiveness of a foreign R&D centre. However, to be able to achieve credibility of an overseas R&D unit, must have a clear definition of the goal and the role of their laboratory, particularly in joint projects.

Another critical hurdle, TNCs may face in locating R&D in developing and East European countries, is the inadequate protection of intellectual property rights in these countries. The patent law in most of the developing and East European countries is not yet integrated into the international patent system. Even in countries, where the law is compatable with the international practices, the enforcement is lax. So, the firms locating R&D in these low-cost countries should find alternate methods of protecting their intellectual property. In the future, this may not pose such a big problem, as both developing and East European countries, because of the pressures by the industrialized countries, are gradually integrating their laws with the international regulations.

5.0 Implications for Developing Host Countries

The few studies that have been carried out on impact of R&D on the host economy are still inconclusive. The studies by Behrman and Fischer (1980) gave contradictory signals on the impact. According to them the benefits of these R&D expenditures are `non-specific´ and "tied mostly to whatever upgrading of local institutions the firm feels is necessary in order to improve the efficiency of its production and marketing operations". There appeared to be little diffusion of trained manpower into the local communities and little appreciation of the concept of àppropriate technology´ to assist the host countries. The authors, however, felt that considerably more data are needed before any empirical analysis could be attempted. Moreover, their studies included only TTU and some ITU type of R&D activities.

Generally, there are two opposing views that have been influencing the policies in the past regarding the impact of TNCs' R&D activities on the host countries. One view considers inward R&D investments to be in general beneficial to economic growth, by creating indirect positive effects for the host country at a lower-cost. These positive effects include technical support and assistance to local suppliers and customers, contract jobs from foreign R&D units to local R&D organizations etc. The countries that appear to have developed their policies according to this thinking are Austria and Singapore. The counter view argues that R&D activities by foreign firms tend to tap into unique local R&D resources with little or no benefit to the host country. Concentrating on the problems of little relevance to the local economy, they may represent a little more than a disguised "brain-drain", diverting scarce technical resources from more useful purposes (Dunning, 1992). However, in the context of developing countries, where the scientific and technical resources are under utilized, the counter view may not hold much strength. Costs involved are marginal, while the benefits are larger. The cost factor is that such R&D activities may create islands of "high-tech enclaves", with little diffusion of knowledge into the host economy. But such isolation of knowledge and skills can not be sustained over long term. Movement of researchers, need for local procurement of materials etc. are bound to diffuse new knowledge and skills through out the economy.

While analyzing the implications for the developing host economy, two questions need to be considered - What is the type of R&D being carried out by TNCs?; and What are its direct and indirect effects. Depending on the type of R&D being performed, the impact on the host economy varies. Westney (1988) states that each type of unit has distinctive linkages with the local subsidiary, the parent organization and with local sources of technology (figure 5). The strength of the ties with the local centres of science and technology varies across the four types. The ties are virtually non-existent for a TTU, strong for an ITU, stronger for a GTU and the strongest for a CTU.

The most important indirect benefit of all, is that TNCs' R&D activities are infusing the scientific community in developing countries, with "commercial culture", which is necessary for reaping the benefits of science (Prasada Reddy, 1993). In developing countries like India, inspite of strong capabilities in science, full benefits did not accrue to the economy. Scientists pursued science research for proving the principles, but not with an application orientation. Industrial sector being weak did not take up the task of converting this knowledge into products. TNCs, through their mission oriented R&D, are transferring application skills, and time and cost consciousness among researchers. These activities are also giving rise to a class of scientific and technical entrepreneurs by allowing researchers to purchase and commercialize the knowhow for bye-products (The Economic Times, Sep 28, 1991).

However, inspite of such large benefits, the developing host countries should not be lax about the potential mis-use of their scientific resources. Marie-Jose' Smits (1990) states that strict legislation on biotechnology activities in the industrialized countries may compel firms and researchers to relocate these activities to developing countries, where the legislation is lax. This, Smits warns, would mean that in the international division of labour, developing countries would take over the role of experimental sites to develop potentially hazardous products.

6.0 Conclusions and Recommendations

Scientification of new technologies and increasing competitive pressures to be innovative are necessitating multi-sourcing of corporate technologies. In their search for additional sources of technologies, TNCs have also started tapping S&T talents in some developing countries. Large developing countries, such as Brazil, China and India, have dual technology environments. At one end, there are high-tech S&T talents, which show complementarities with Western economies. At the other end, larger portion of the economy displays low S&T development. TNCs are attempting to exploit the former. The Third World scientists and engineers, who are working in industrialized countries, are playing a major role in TNCs R&D activities in their home countries by entering into alliances with TNCs, by establishing firms or laboratories to undertake R&D activities on contract basis.

In the overall phenomenon of the globalization of R&D, the emerging patterns are only of marginal significance. However, from the perspective of the developing host country, the implications assume greater significance. In the beginning such R&D activities may be directed by the needs of the TNCs' strategic interests, subordinating the national interests. But, a rapid expansion of the local market in the host country may prompt extensive local production and expansion of R&D activities, thus shifting the relative balance in favour of the host country. However, such benefits are likely to accrue only to host countries with large domestic markets (Prasada Reddy and Jon Sigurdson, 1993/a).

Although more research needs to be done before drawing any firm conclusions on the aspects discussed in this paper, the developing countries seem to have some fresh opportunities offered by the emerging phenomena. The international R&D, just like the international production activities benefitted the NIEs, can be expected to benefit the developing countries. Most important of all, international R&D would give a jolt to the sluggish R&D being performed by the indigenous industry in some of the developing countries. If the developing countries, by creating a proper investment climate, could persuade the TNCs to commercialize the research results in the country, the benefits would be much larger and quicker.

Recommendations

for Management of Industry

The companies, now, have an opportunity to cut their R&D costs by utilizing the scientific and technical potential in developing and East European countries. This will maintain their innovativeness and enhance the competitiveness.

Geographically dispersed R&D and production activities call for efficient coordination skills on the part of central R&D unit. Corporate headquarters should establish proper mechanisms for coordinating dispersed R&D activities and their essential links with dispersed manufacturing and other activities. Accomplishment of such a task involves development, monitoring and maintenance of three independent aspects of corporate structure - network balance; strategic direction; corporate infrastructure (Lars Håkanson, 1990).

As a means of managing geographically dispersed R&D and manufacturing activities, "organizational networks" assume importance. In a corporate network, each of the laboratories will have a local external network of its own. This is the main mechanism through which the local laboratory generates technological knowledge. The density and quality of the communication with the local partners is a measure of the laboratory's effectiveness to tap into the local network. The knowledge generated locally in a laboratory can only be diffused through out the company effectively only when local external network is linked to a strong internal network (Meyer, 1993). These linkages between local external network and global internal network can be clearly observed in the network linkages of ARCI, shown in figure 1.

Cross-cultural problems that are likely to arise in integrating the R&D activities performed in low-cost countries with those performed in the centres in industrialized countries need to be given a careful attention. To some extent these problems can be overcome by keeping the centres in low-cost countries, outside the corporate structure. In such cases, the partners in low-cost countries act as external experts or specialists and therefore, need not be fitted into the corporate heirarchy. This may reduce tensions between the labs in low-cost countries and industrialized countries.

Host Countries

Developing and East European countries now have an opportunity to integrate themselves with the international technology developments, provide meaningful employment to their scientific and technical personnel. Such international R&D activities will help stem the tide of brain drain. In addition to benefits of employment, international R&D activities, as noted earlier, will bringin several other benefits. Hence, developing and East European countries should create an attractive policy and R&D environment to attract such R&D investments. Such policy environment includes favourable foreign direct investment policies; tax and other incentives; nondiscrimination between indigenous and foreign firms in their access to national scientific resources.

The most important of all, from the perspective of R&D investments, streamlining of patent and other intellectual property protection laws in accordance with the international practices is essential. The commercial value of new scientific knowledge generated in TNCs' R&D activities does not necessarily dictate greater confidentiality. Intellectual property law could be framed in such a way that while affording protection to its owners, at the same time it facilitates the open and prompt publication of research (OECD, 1988).

Dispersed R&D activities of TNCs require excellent communication and other infrastructural facilities. The countries seeking to attract R&D investments should establish such infrastructural facilities on a priority basis.

National research institutes should be given the freedom and motivation to collaborate with foreign firms and to undertake sub-contract jobs from them. World wide, academic institutions are creating closer links with industry. In some countries, academic institutions are even launching commercial ventures of their own or in collaboration with the corporate sector, such efforts range from the exploitation of research and intellectual property to the creation of science parks and new companies (OECD,1988). However, here a delicate balance needs to be maintained. Short term commercial activities should be undertaken only to the extent that they do not reduce or interfere with the academic institutions' capacity to carry out basic research and education activities.

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