UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

Distr.
LIMITED
E/ECWA/NR/SEM.3/16
13 August 1981
Original: ENGLISH

ECONOMIC COMMISSION FOR WESTERN ASIA

Seminar on Technology Policies in the Arab States
Organized by ECWA with the Co-operation of UNESCO
14-18 December 1981
Paris, France

INDIAN TECHNOLOGY EXPORTS AND TECHNOLOGICAL DEVELOPMENT:

LESSONS FOR DEVELOPING COUNTRIES

by

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* The opinions expressed in this document are those of the author and do not necessarily reflect the views of the United Nations Economic Commission for Western Asia.

81-4314

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1. Introduction

The process of technical chage in developing countries is one of the least understood subjects in the study of development.[1/] Despite the attention that such matters as international transfer of technology to the Third World, the role of transnational corporations, the choice of appropriate technology and the building up of local technological capabilities have received in recent years, we still lack a proper appreciation of the fact that considerable technical progress is taking place in enterprises in developing countries, and that such progress has significant implications for their future role in the restructuring of world trade and industry.

1/ A full discussion of this theme is contained in S. Lall: *Developing Countries as Exporters of Technology*, London; Macmillan (forthcoming).

* This paper draws heavily upon research being conducted by the author for the World Bank on technolcgy exports by India. The sponsorship of the Bank is gratefully acknowledged but the views expressed here are attributable only to the author. The author has also benefited from the research assistance provided by Mr. Rajiv Kumar, New College, Oxford.

Technical progress in developing countries is, however, different in its nature from what is normally understood by 'technological change' or 'innovation' in the advanced countries. In the latter, there is a general tendency to identify innovation with major, discrete advances in productive knowledge. Clearly, developing countries are not 'innovating' in this sense of the word. A great deal of technical progress, however, takes the form of 'minor innovation' of changes in products and processes in their production and application in the diffusion phase of new technologies - it is such 'minor innovation' which occurs in developing countries as they import and assimilate new technologies. The fact that it is described as 'minor' should not lessen its economic importance: on the contrary, every student of economic history stresses the fundamental role of 'minor' innovation in the development and commercialisation of technology.

The fact that developing countries have the capability to undertake extensive 'minor' innovations in the process of assimilating a broad spectrum of modern technologies does not, of course, rule out the prospect that they will continue, for the foreseeable future, to be dependent on the advanced countries for significant inputs of new technology. Developing countries over time will tend to specialize in technologies to which their capabilities are best are best suited - relatively small-scale, less expensive, lower-income based products and processes - while the developed ones will specialize in technologies at the 'higher' end of the scale.

By the very nature of the phenomenon, however, these matters are difficult to study empirically. The sort of detailed plant-level research required has yet to be undertaken in most developing countries (a major exception is the work of a team financed by the Inter-American Development Bank and the Economic Commission for Latin America, based in Buenos Aires and directed by Jorge Katz). One relatively easy method of gaining some knowledge is, however, to analyse exports of technology by developing countries. Exports of technology may be defined as consisting of sales of turnkey industrial projects (civil construction is not included here), consultancy services abroad and the setting up of direct investments (or joint ventures) by firms from developing countries. Their examination does not show the whole range of technical progress under way in the exporting countries, but it does reveal examples of technical learning where the technology has been assimilated, reproduced and brought up to standards of international competitiveness. Furthermore, it highlights the comparative advantage of industrializing economies - the building up of new capabilities which show where their future areas of strength lie, and where, by implication, other developing countries further down the industrialization ladder may be expected to follow in due course.

Technology exports as an indicator of technological development are therefore of clear relevance to a consideration of technology policies. This paper proceeds as follows: Part II briefly describes the extent of Indian technology exports, drawing upon empirical work recently conducted by this author for the World Bank. Part III discusses the determinants of technological development underlying these exports, paying particular attention to the role of technology policy. Part IV draws the main conclusions.

II. Technology Exports by India

India has emerged in recent years as a major industrial power in terms of the value of its manufacturing production. It has, however, also suffered from a poor record of growth in income and industrial growth and in the expansion of exports of manufactured products. In comparison to the group of so-called 'newly industrializing countries' comprising the export-orientated high growth economies of South-East Asia and Brazil and Mexico, India's performance appears rather poor; erratic bursts of growth punctuated by declines and periods of stagnation. Much of its industry suffers from substantial excess capacity and remains inward-looking and highly protected. In some major areas of activity it is technologically well behind international frontiers.

The evils of excessively inward-looking import-substituting industrialization are now well-recognized in the development literature. What is insufficiently appreciated is that a parallel policy (which need not necessarily accompany the protection of domestic production) of protecting domestic technological development may yield significant benefits which are not revealed by more aggregate data on industrial or export growth. There may be several reasons why a healthy building-up of domestic technological capability is not reflected in a rapid growth of these aggregates. What we need, then, is to look at technology exports themselves.

Most of the industrializing developing countries now undertake some form of technology exports (the evidence is reviewed in Lall op. cit.). Some of the larger ones undertake technology exports (TE) in all its forms, while the smaller ones specialize in particular forms of TE. Let us first review the evidence of Indian TE.

According to the (patchy) evidence at hand, India's TE at the end of 1979[1] stood as follows:

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1) Note again that civil construction projects are excluded. The value of such projects (completed and in hand) by the end of 1979 came to about Rs. 19 billion (U.S.$ 2.4 billion).

Industrial Turnkey Projects (completed and in hand)		Rs. 8,540 m.	($1.1 billion)
Consultancy Earnings Abroad:	1975-6	Rs. 40 m.	
	1976-7	Rs. 75 m.	
	1977-8	Rs. 95 m.	
	1978-9	Rs.152 m.	
	Total 4 yrs.	Rs.362 m	($46 m.)
Value of Foreign Equity (in 192 ventures in production and under implementation)		Rs.795 m	($100 m.)

It should be noted that different units of measurement have been used to quantify the different forms of TE and no simple method is available to aggregate them. Nevertheless, we can examine the sectoral distribution of these various stock and flow figures to gain some insight into the relative areas of 'revealed comparative advantage' of Indian technology exporters. Table 1 sets out the percentage distribution of the three forms of TE by the main manufacturing and other activities.

In the most general terms, industrial project exports seem to cover a greater range of activities than other TE. Each form of TE does, however, have its own particular areas of specialization. For each, the two main activities account for over 60% of total foreign activity: power generation and distribution for turnkey, metallurgy and power generation for consultancy, and textiles and paper and pulp for direct investments. The only activity which occurs more than once is power generation. Otherwise the different

Table 1

INDIA

Industrial Distribution of Project, Consultancy and Direct-Investment TE

(Percentages)

	Project Exports (Excldg. Civil Constr)		Consultancy Exports 1/		Direct Investment 2/	
	% Total	% Mfg	% Total	% Mfg	% Total	% Mfg
Manufacturing						
Textiles, Yarn	2.6	2.9	2.0	4.1	28.2	29.8
Sugar	5.3	5.8	4.9	7.7	3.6	3.8
Other Food Processing	0.3	0.3	0.1	0.1	10.2	10.8
Cement	10.9	12.0	0.5	0.7	–	–
Steel Mills, Other Metals	6.5	7.2	24.5	39.0	1.2	1.3
Chemicals	0.7	0.7	10.7	17.0	6.4	6.8
Paper & Pulp	0.5	0.6	–	–	29.4	31.1
Simple Metal Prod.	0.2	0.3	–	–	6.0	6.4
Machinery, Machine Tools	5.6	6.2	–	–	3.8	4.0
Power Generation	28.2	31.2	14.3	22.7	–	–
Power Distribution	27.1	30.0	–	–	–	–
Transport Equipt.	0.8	0.9	–	–	3.3	3.5
Electronic, Telecomm.	0.9	1.0	–	–	–	–
Other Mfg.	0.7	0.8	6.1	9.7	2.4	2.5
Sub-Total	90.5	100.0	63.1	100.0	94.5	100.0
B. Other						
Steel Structures	4.6		–		–	
Water Treatment, Sewage	4.9		–		–	
Railways	–		7.2		–	
Other	–		29.7		5.5	
Sub-Total	9.5		36.9		5.5	
TOTAL	100.0		100.0		100.0	

Sources: Tables 2, 11 and 17 of Ch. I.

Notes: 1/ Power generation consultancy has been counted here as a manufacturing activity (in contrast to Table 11 of Ch. I) in order to keep comparability with turnkey figures.

2/ The one power distribution affiliate has been left under non-manufacturir (as in Table 17 of Ch. I), as it is not concerned with manufacturing distribution towers overseas.

modes of TE seem to have different advantages abroad, due to their market (demand) conditions, to their own peculiar nature, or to the technological strengths of Indian industry.

Thus, turnkey exports are particularly suited to large infrastructural projects where foreign equity investment is rarely permitted and the export of discrete items of equipment are not as remunerative as a large 'package'. Here the strength of BHEL (Bharat Heavy Electricals Limited, a public sector firm) and Tatas in the manufacture and installation of power generating equipment, and of Kamanis and Tatas in power transmission equipment, has enabled India to win significant foreign orders. It may have been possible for these enterprises to set up foreign affiliates to manufacture their products (rather than participating in their user industries), but presumably scale economies, skill shortages and government policies in the host countries have rendered this unfeasible for the time being.

Consultancy exports tend to be especially important in process industries because of the central significance of basic process design (and the associated detailed engineering) in plant construction. In engineering industries the use of consultants is much more restricted to specific problem solving, and the basic technology transfer functions tend to be undertaken by the equipment manufacturer and/or the user, either as a turnkey job or a direct investment. Thus the specialization of Indian consultants in metallurgy, power generation and chemicals partly reflects the nature of the consulting industry. It also, naturally, reflects the accumulation of experience in a number of enterprises sponsored by the government or encouraged by it to participate in project design together with foreign consultants.

The pattern of direct investments reflects the technological, marketing and managerial strengths of Indian industry, to the extent that any of these has been developed sufficiently to yield a source of international 'monopolistic advantage' to the enterprise concerned.[1] According to the

1)This point is analysed at length in S. Lall: 'The Export of Capital from Developing Countries: India', forthcoming in J. Black & J. H. Dunning (ed.) Proceedings of the 1980 Conference of the International Economics Study Group, London: Macmillan.

product cycle type of reasoning, a developing country's overseas investment should be in the simplest and most widely diffused technologies, and the significance of textiles, food processing and metal products in Indian investments accords with this. However, the existence of significant investments in fairly complex technologies like precision tools, pulp and paper, trucks, tractors, jeeps and other automotive products (as well as some projects like mini-computers in the pipeline) calls for a more cautious analysis. Moreover, the . weaknesses of Indian enterprises on the marketing side suggests that their advantages lie in the technological and managerial spheres. Their technological advantage clearly does not arise from advanced R & D capabilities in the sense that it does, say, for U.S. multinationals. It is, rather like early Japanese foreign investments, based on the ability to reproduce and commercialize a technology (which may be fairly complex and large-scale) in the peculiar conditions of LDCs. We find examples where the techniques and products involved are 'intermediate' in the sense of not competing directly with developed country enterprises; however, we also find examples where they are 'advanced' and compete with identical products made by established mutlinationals (rayon, minicomputers, carbon black, etc.).

For all forms of TE, intermediate producer goods (power generation, power distribution, paper, steel, chemicals) tend to dominate over consumer and capital goods as far as the end user is concerned. The production of consumer goods abroad is not, apart from fairly undifferentiated products like textiles and sugar, important because of the protected nature of the Indian home market and low average incomes. That of capital goods is generally not in demand in most smaller and industrially less-advanced host countries; where it is, much of it is in 'higher' technologies than Indian firms can offer (or can persuade buyers to accept). The major machinery producer overseas, HMT (Hindustan Machine Tools, a public sector firm), specializes its turnkey and direct investment activity on products that are 'below' the capabilities and specialization of Western companies, and its own 'frontier'

R & D efforts are directed to products which are exported as such to developed countries, not in the form of TE to other developing ones.

Let us now quickly look at the destinations of Indian TE. Table 2 sets out the broad geographical distribution of the three forms of industrial TE as well as civil construction. It shows strikingly different patterns of TE: project exports, both civil and industrial, go mainly to the Middle East

Table 2

Geographical Distribution of Indian TE (%)

	Mid-East	Africa	S.E.Asia	Other (incl. unallocated)	Total
Industrial T.K.	54.0	13.8	25.3	6.9	100
Civil Construction	95.7	1.3	3.0	-	100
Consultancy	23.5	26.9	11.4	38.2	100
Direct Investment	1.5	30.0	66.0	2.5	100

oil countries, though industrial projects are considerably less concentrated than civil. Consultancy is fairly evenly spread, and the sale of such services as computer software leads to a large portion going to developed countries. Direct investments go mainly to South-East Asia and Africa, though there are indications that a tiny share of the Middle East will rise in the future.

The reasons for such a pattern are obvious. The Middle East is the world's largest internationally open market for civil and industrial construction Its high income combined with a lack of local industrial skills and labour power have led it to buy 'packages' which most other regions would not. As the region grows industrially and achieves its desired infrastructural investments, the pattern of TE would change accordingly. Africa, on the other hand, has low incomes, low levels of industrialization and low levels of skill. With the exception of Nigeria, it is not undertaking massive construction projects. Its needs for industrial technology are generally limited to simple consumer and intermediate products (again, Nigeria is an exception). South East Asia is a more advanced market in every way. There is very limited prospect for civil construction for obvious reasons; the advent of import-substituting industrialization renders direct investment the obvious form of selling technology.

The marginal role of 'other' markets, Latin Amaica and the OECD countries, hardly needs comment. Cultural and historical barriers as well as high shipping costs separate India from likely markets in South America, though efforts are being made to change this. The developed countries do buy certain forms of technical services and a few innovations from India, but are unlikely to attract much else for the foreseeable future.

So much for the review of Indian TE. It is clearly impossible to make a detailed comparison with TE by other developing countries in this paper. Such a comparison has been attempted, albeit on rather scattered data, by the author elsewhere[1]. What emerges from the comparison is that India seems to lead the Third World in the range, diversity, spread and technological sophistication. Some countries have greater TE in particular forms: Hong Kong is a much larger exporter of direct investments and is particularly strong in textiles and consumer electronics. Brazil is more advanced in terms of petroleum and automotive technology and Mexico in direct-reduction of steel technology, and so on (in the civil construction sector, of course, the Republic of Korea dominates the project export scene). But in general India leads the others in the technological capabilities revealed in TE.

In view of the poor performance of the Indian economy this may cause some surprise: certainly, in the light of the existing view of import-substituting policies as inefficient and self-defeating, it calls for some explanation. Let us turn, therefore, to a consideration of the determinants of technological development in a newly industrializing economy.

1) See S. Lall, Developing Countries as Exporters of Technology (op.cit.)

III. Determinants of Technological Development

The factors that determine the pace of technological development are a mixture of 'given' economic conditions and official policies, with the two closely intertwined in most cases. Let us start with those which are least policy-determined and work up to those which are most so.

Size of market: The size of the domestic market (and, naturally, the length of industrial experience) is of crucial significance in affecting the nature of technological development, because it determines the extent to which capital goods industries can be successfully established. It has been argued above that every sort of production activity creates some sort of technological capability, from the smallest of village industries to the most complex of modern machine building. However, the potential for learning beyond small adaptations to imported capital equipment can only be realized if there is a domestic capital goods production base. Rosenberg[1)], among a number of other scholars, has emphasized the crucial role of machine building (especially machine tools building) in the generation and diffusion of technical change. Clearly, the size of the home market, depending upon such given conditions as size of country, per capita incomes, income distribution and the like, will be a factor of prime importance. Exporting does, of course, offer the possibility of undertaking capital goods production (with large inherent scale economies) even in small markets, but the complexity of basic capital goods design and engineering means that production for export will be either confined to simple labour-intensive operations within an international framework of production by MNCs (as with electronics) or else be conducted by MNCs with designs entirely imported from abroad. While this may be conducive to economic growth for other reasons (as we have witnessed for a number of the newly industrialising countries), it will not give the economy a base for the export of the entire technology involved. For most complex technologies a necessary period of domestic production is required if the entire technology is to be mastered.

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1) N. Rosenberg, Perspectives on Technology, Cambridge: Cambridge University Press, 1976.

Skill Availability: The importance of having sufficient numbers of technically trained personnel who can act as the receptacles of learning at the higher levels, and who can then transform problems of production and application into feasible solutions (i.e. innovations) is so obvious that it hardly needs stressing. We need not dwell on this at greater length, but it takes us into broad fields of education, science and training policy which are well-known in their own right.

Promotion of Local R & D: The explicit encouragement of technological work by a government can take two general forms: the creation of a research infrastructure not directly related to the production system and the encouragement of R & D within production enterprises themselves. The Indian government has gone into both, with special emphasis on the setting up of a large number (34) of national research laboratories under the Council of Scientific and Industrial Research (CSIR) responsible for developing a large variety of industrial and agricultural technologies (with special emphasis on atomic, space and electronic technology) and on the commercialisation of domestic innovations by the National Research Development Council (NRDC) and the Inventions Promotions Board. Table 3 below shows total R & D expenditures in India in the public and private sectors up to 1972, and the numbers of scientific and technical personnel employed in formal R and D activity.

Table 3

Research and Development Expenditures and Employment in India

Year	R & D Exp. (Rs. m.)	R & D as % of GNP	Total scientific and technical emp. in R & D.
1958-9	290	0.23	20,724
1968-9	1,310	0.44	73,634
1971-2	2,140	0.54	103,767

Source: National Committee on Science & Technology, An Approach to the Science and Technology Plan, New Delhi, 1973.

The table shows that the formal R & D effort has grown rapidly in recent years, increasing over seven-fold in terms of expenditure (in current rupees) and five-fold in terms of the technical personnel employed, and more than doubling its share of GNP. Later estimates show R & D to be reaching 0.9% of GNP by 1978-79. While the effort is small in relation to developed countries, in absolute terms it is quite large, and not unimpressive for a developing country.

Formal R & D figures may, however, be misleading for two opposing reasons. First, they may overstate the amount of technological work that is applied to production. A large part of the money may be spent on scientific work that is unrelated to the production system, given the gaps that exist between the scientific and industrial establishments of developing countries. Second, they do not take account of technological work undertaken outside formal R & D institutions within the production enterprises in the normal course of their investment and manufacturing activity. As we have argued above, and as has been documented in detail for Argentina, this is the chief source of technical progress in developing countries. Given that their development in technology is bound to be mainly of the 'minor' variety, of assimilating and adapting technologies developed abroad, technical progress can be quite rapid even without investments in 'basic' scientific and research work, and with fairly modest investments in applied development work.

As for the promotion of R & D within manufacturing industry, in-house R & D has been encouraged by means of various fiscal and other incentives: highly accelerated depreciation allowances for research equipment; tax allowances of 120% of the current expenditures on R & D; privileged access to foreign exchange for the import of equipment, samples, journals, etc.; special awards for innovation. The tax incentives have been particularly successful in encouraging firms to set up separate R & D units or to seek official recognition for units already in operation.

A few large firms (like TELCO, though other Tata firms have recognized R & D units) have not sought recognition for their R & D, perhaps because of secrecy or a desire to avoid bureaucracy; however, almost all major firms now have recognized research facilities in both public and private sectors. By end 1979 there were some 550 recognized units in the private sector, and over 60 in the public sector. The number of recognized units was rising rapidly, and in 1977-79 over 100 units per annum were accorded this status. Table 4 sets out industry-wise R & D in 1974-5 to 1976-77, the latest years for which data are currently available.

The rapid growth of in-house R & D by manufacturing units, especially in the private sector, has been striking. However, industrial R & D only comprises under 10% of total science and technology expenditures in the country (as compared, say, to 75% in the U.S. and 65% in the U.K. and Japan). The bulk of it is accounted for by the non-manufacturing research establishments run by the CSIR , and here the returns in terms of commercial application in industry have been extremely poor. Thus, the sheer quantity of resources, financial and human, invested in formal R & D activity in India cannot explain the building-up of its technological capabilities.

Protection of Local Learning: Factors such as large markets, experience, skilled manpower and formal science and technology programmes usually accompany technological learning. They are, however, necessary but not sufficient for such learning. A certain amount of 'elementary' learning (about shop-floor productivity-raising improvements) is inherent to the manufacturing process, and proceeds almost automatically regardless of who owns the facilities and what government policies are. Learning beyond this level to modify existing process substantially, to redesign the product or reproduce the facilities elsewhere, requires a more conscious, directed effort on the part of the enterprise concerned

Table 4

India

INDUSTRY GROUP-WISE BREAK-UP OF R & D EXPENDITURE IN PRODUCTIVE SECTORS (1974-75 TO 1976-77)

Industry-Group	R&D Expenditure (Rs. lakhs)[1] 1974-75	1975-76	1976-77	No. of Enterprises[2]
1. Metallurgical Industries	203·45	300·91	317·28	25
2. Fuels	278·50	388·34	564·13	13
3. Boilers & Steam Generating Plants	9·28	9·76	20·06	2
4. Prime Movers	66·42	62·58	75·57	2
5. Electrical & Electronics Equipment	940·86	1232·30	1649·02	82
6. Telecommunications	161·14	301·51	517·80	10
7. Transportation	685.25	825·02	882·77	14
8. Industrial Machinery	151·75	172·64	238·09	25
9. Machine tools	111·88	155·86	191·76	6
10. Agricultural Machinery	89·91	151·78	112·27	5
11. Earth Moving Machinery	32·99	40·13	74·98	1
12. Miscellaneous Mechanical Engineering Industries	60·09	42.51	29.40	3
13. Commercial Offices & Household equipment	13·74	14·38	16·32	1
14. Medical & Surgical Appliances	—	—	0·06	1
15. Industrial Instruments	44·19	47·66	54.93	16
16. Fertilizers	334·91	383·06	475·63	8
17. Chemicals	561·96	586·01	717.98	59
18. Photographic Raw Films & Materials	7·22	113·79	40·50	1
19. Dyestuffs	135·33	151·17	190·94	9
20. Drugs & Pharmaceuticals	728·60	804·08	948·35	37
21. Textiles	151·74	151·78	183·54	11
22. Paper & Pulp (including Paper Products)	41·58	56·11	37·40	8
23. Sugar	0·98	1·15	2·00	1
24. Fermentation	1·86	4·94	3·56	1
25. Food Processing Industries	21·70	56·32	72·03	6
26. Vegetable Oils & Vanaspati	4·94	6·31	5·54	2
27. Soaps & Cosmetics	159·01	151·93	171·90	5
28. Rubber Goods	13.03	11.40	17.03	4
29. Leather, Leather Goods and Pickers	—	—	—	—
30. Glue & Gelatins	—	—	—	—
31. Glass	6·05	12·30	18·42	4
32. Ceramics	46·11	31·33	38·00	3
33. Cement & Gypsum Products	89·49	111·56	193·81	2
34. Timber Products	9·84	5·47	6·77	2
35. Defence Industries	9·57	7·10	4·46	1
36. Miscellaneous Industries	63·08	111·27	113·19	2
37. Non-Profit Research Organisation	138·18	180·22	195·04	13
38. Contribution by Private industries to Co-operative Research Associations	181·09	167·90	211·11	—
TOTAL	5545·72	6850·58	8391·64	385

Source: Department of Science and Technology, Research and Development in Industry 1976-77, New Delhi: Government of India, 1979.

Notes: 1) 1 lakh = 100,000

2) Number of enterprises in public and private sectors having officially recognized R and D establishments.

(either the final product firm or the capital goods manufacturer). More importantly, it involves the undertaking of a new and inherently risky activity of technological innovation. Even if the technology is not new and is well-known in developed countries, a developing country enterprise discovering a new product/process or redesigning capital equipment will face certain costs and uncertainties. Such costs will be met only if some of the uncertainties and risks are reduced by official intervention. Innovating enterprises in developed countries face the risk that their search activity will not yield products or processes that are significantly better than the ones they possess. Those in less-developed countries face a related but different risk: that their efforts to upgrade their existing knowledge will not lead to products or processes that can compete with established, commercialised and so risk-free technologies already in use abroad, which can be implanted by foreign enterprises or licensees. Thus, technological effort which may well be viable in the longer run may never be undertaken because the learning period is not protected against the very real threat of foreign technologies imported 'ready-made' into the country.

There are two main avenues for importing 'ready-made' technology from abroad: direct investment by foreign enterprises and the licensing of local enterprises (and intermediate positions such as joint ventures). The direct entry of wholly-owned MNC affiliates probably provides the most powerful means of importing a continuous stream of ready-made techniques and products based on the frontiers of technological work abroad. Licensing provides a channel of importing particular technologies for specified periods, and is much more limited. Joint ventures lie between the two, the strength of links with foreign technology depending on the nature of participation, the complexity of the technology and the relative capabilities of the two parties.

The import of technology in these forms can be said to stifle the growth of local technological capability if two conditions are met: first, the technology is such that local efforts can lead to an internationally competitive (and/or socially desirable) technology, and, second, that the technology importer does not himself undertake the investments locally to build up this capability. It may happen, for instance, that a multinational affiliate <u>has</u> to undertake local R & D work to adapt its processes to local climate, scale or raw materials, or to modify its product to local conditions. culture or official regulations. In this case it may well generate as much technological activity as a local firm, cut off from access to foreign technology, would have done. Even more, it may well generate it more efficiently, with more resources and with better scientific backup from abroad.

It may, however, happen that the multinational affiliate (or joint venture or licensee) remains passively dependent on its foreign partner for all improvements to technology, or for all technological work beyond the level of minor adaptation or detailed engineering. In this case, a viable technical capability to assimilate, improve and export the entire technology will not be built up in the developing country: the particular enterprise concerned will not find it economical to undertake the cost and risk of reproducing technological work already done (and proved) abroad, and its local rivals will not be able to compete on open markets if they try to build up their own independent technology. Any firm which is to remain competitive from the start would have to resort to foreign technology unless the industry was such that foreign technologies were totally irrelevant.

It should be noted that the protection of domestic production (by tariffs against imports) may go closely together with the protection of domestic learning, but it may not. Thus, an import substitution regime may do little to build up an independent technological capability and, on the other hand, an export-orientated regime may be strongly protective of local learning. The successes and failures of broad industrialization strategies such as import substitution or export promotion do not necessarily reflect their successes or failures in the sphere of technological progress. Japan provides an excellent example of successful export-promotion and high growth based on very strict protection of domestic learning.

Returning to the case of developing countries it is argued here that what is broadly termed the 'protection of domestic learning' is the crucial factor explaining India's apparent lead in indigenous technological capabilities. Of the newly industrializing countries India is the only one which has consistently and over a long period pursued a policy of self-reliance in technology. It has placed close restrictions on MNC entry and on foreign licensing, and has forced local enterprises to invest in basic design capability. There is no doubt that this policy has had several costs: India is lagging well behind its competitors in several fast-moving technologies ; several sectors have not succeeded in fully absorbing their technology; resources have been wasted in unnecessary effort and mistakes; and many local adaptations may not be internationally efficient. Granting all this, the policy does seem to have generated considerable learning in a broad range of activities and, as the last section showed, it has led to the export of certain technologies where India has developed a competitive advantage.

The role of protection of learning also shows up clearly in some other developing countries which have TE. Brazil and Mexico, for instance, export mainly petrochemical and steel technology where the state has intervened to protect local enterprises, by setting up government-owned enterprises (PEMEX and PETROBRAS) or by subsidising private local enterprises. Argentinian enterprises have exported technologies mainly in relatively simple industries (food processing, metal products) where copying is easy and the large multinationals are not particularly active. Korean, Taiwanese and Hong Kong enterprises have, similarly, exported the rather simple technologies where there is the 'natural' protection given by the wide diffusion of the knowhow. And exports of civil construction knowhow have been fostered by the natural protection given by the nature of the activity and official policy. Korean enterprises have, however, advanced somewhat further because of the close links they have fostered with their government, their relatively large size and dominant positions in local production and exports, and the heavy official promotion of all forms of export activity.

IV. Conclusions

Technological development is a complex phenomenon, and little is known about its nuts and bolts in developing countries. The arguments advanced here are based on rather scanty evidence and speculation, and so must be treated with due caution. Given this caveat, what lessons does the foregoing analysis have for other developing countries?

First, the size of the country must be a crucial factor in determining the pattern of industry that can be efficiently established in it. Small countries clearly must not try to emulate the patterns of heavy industrialization followed by large ones. The example of India, in particular, is not recommended, because it has gone too far and too fast in its efforts to build up a comprehensive industrial base. Moreover, many industries where it is now internationally viable cannot be launched by countries with small markets. This necessarily limits the scope of technological progress in small countries, but such are the dictates of technological influences on efficient scales of production.

Second, India has created a large pool of skilled manpower which has served as a receptacle for technological learning. It need not be stressed that a country's educational structure must be geared to producing the right numbers of appropriately trained personnel to undertake the task of technological progress.

Third, officially sponsored science and technology programmes based in formal institutions divorced from production seem to be ineffective in promoting technological progress in industry. The bulk of effort must therefore be directed to stimulating technological activity in productive enterprises.

Fourth, the main message of this paper is that, given all the other requirements of technological progress, the enlargement of indigenous capability in basic design and development work (in industry) necessarily requires some protection of local learning. This protection has positive as well as negative aspects: the former includes subsidisation of R & D activity, protection of the market and the like, while the latter includes a forced reduction of dependence on imported ready-made technologies and a constriction of the activities of foreign companies. It must be emphasised that there are large potential costs in following these policies, though successful cases of technological protection like Japan lead us to believe that a properly managed policy can yield tremendous benefits.

Finally, the protection of domestic learning must not be a wholesale or continuous policy. There are large areas of industry where local enterprises cannot master the requisite technology or, having mastered it, cannot keep pace with its development. In this case there must be a continuous inflow of technology from abroad (Japan is again an excellent example) complemented by local efforts to absorb and reproduce it. The real art of technology policy thus lies in identifying a country's dynamic comparative advantage in the absorption and generation of technology, and India's experience shows that the acquisition of this art may well be a painful and expensive process.

OXFORD
2 February 1981