Local Development and Exports of Technology

The Comparative Advantage of Argentina, Brazil, India, the Republic of Korea, and Mexico

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Abstract

This paper analyzes technology exports from five of the most industrially advanced developing countries -- Argentina, Brazil, India, Korea, and Mexico. It explores the nature of the exports and of the exporting firms, identifies the competitive advantage underlying different types of technology exports, and analyzes the comparative advantages of the five countries in these exports. Based on an analysis of different strategies toward the trade in the elements of technology, it summarizes tentative lessons about relationships between trade in the elements of technology, country and firm strategy, and local technological development.

Abrégé

Le présent document traite des exportations de technologie de cinq pays en développement parmi les plus avancés sur le plan industriel : l'Argentine, le Brésil, la Corée, l'Inde et le Mexique. Il examine en détail la composition de ces exportations et la nature des sociétés exportatrices, met en lumière les facteurs qui assurent la compétitivité des diverses catégories d'exportations de technologie et étudie les avantages comparatifs de chaque pays dans ce domaine. Après avoir analysé les grandes orientations que ces cinq pays ont adoptées en matière de commerce de technologie, dans les différents aspects que recouvre ce terme, il indique brièvement ce que l'on peut conclure, à titre provisoire, des rapports existant entre ces échanges, la stratégie du pays, la politique commerciale des entreprises et l'évolution des connaissances techniques au niveau national.

Extracto

En este documento se analizan las exportaciones de tecnología de cinco países en desarrollo que se cuentan entre los de industrialización más avanzada: Argentina, Brasil, Corea, India y México. Se explora la índole de las exportaciones y de las compañías exportadoras, se identifica la ventaja competitiva en que se basan los distintos tipos de exportaciones de tecnología y se analizan las ventajas comparativas de los cinco países respecto a esas exportaciones. Sobre la base de un análisis de las diferentes estrategias en materia de comercialización de los elementos de tecnología, en este trabajo se resumen algunas lecciones que se pueden aprender provisoriamente acerca de las relaciones entre el comercio de los elementos de tecnología, la estrategia del país y la firma y el grado de desarrollo tecnológico del país.

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Contents

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1. Introduction

The past decade has witnessed the emergence of a handful of semi-industrial economies as international suppliers of technology and technical services. 1/ A better understanding of this new phenomenon is necessary because a number of important issues having to do with the nature of technological progress in developing countries and changing comparative advantages therein are involved.

While technology exports from developing countries are a relatively new -- and to some, an unexpected -- phenomenon, from a historical perspective, they may be seen as the result of a gradual accretion of skills and knowledge, which together with the accumulation of physical capital, underlie the process of economic development. 2/ As the more developed of these countries have industrialized, their trade structure has changed. On the import side these countries have substituted domestic production first for consumer goods and then for intermediate and capital goods. On the export side they have reduced the share of primary commodities and increased that of manufactured products. As their economic base has grown they have acquired greater production experience, and in those sectors where they have had a longer production tradition, they have developed some measure of local technological capability to substitute for previously imported technology inputs. Thus it is not surprising that as part of their maturation they have

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1/ Initial studies were by Katz and Ablin (1978) on Argentina and by Lall (1982) on India. In addition to the studies on which this paper is based (see sources to table 1) research has been undertaken by UNIDO on Argentina, Portugal, Yugoslavia, and Egypt, as reported in UNIDO (1981), UNIDO (1983), and Sagafi-Nejad (1982).

2/ For a historical perspective on technology transfers from the now developed countries see Rosenberg (1982).

started to export technology and technical services, sometimes in conjunction with direct foreign investment, in those areas where they have acquired technological capability.

These exports are of particular interest because they exemplify the changes in comparative advantage that accompany industrialization. For example, one of the important findings from other studies that is corroborated and amplified by the study of technology exports is that some technological effort takes place regardless of the policy environment, such as the degree of inward versus outward (trade) orientation or the emphasis on technological self-sufficiency. 3/ One of the new insights that has been gained by the study of technology exports is that the trade policy environment — and characteristics such as natural resource endowment, market size, the degree and type of competition -- do affect the direction of technological effort. Furthermore, it appears that technology exports not only reflect a country's underlying comparative advantage, but that they may also dynamically change that comparative advantage by broadening and deepening technological capability.

Technology exports are to be accounted for in terms of variables at three different levels: (i) firm; (ii) sector; and (iii) country. In the short run, the principal variables at each level are: (i) underlying technological capabilities and international orientation of the firm; (ii) industrial base and the distribution of specialized technological capabilities; (iii) government policy, particularly regarding trade, and the state of the economic cycle. In the longer run, the variables include: (i) companies' technological strategies, (ii) level of development of local capital goods, consulting

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3/ For summaries of the largest set of firm level studies of technical change in developing countries, see Katz (1978 and 1982) and Teitel (1984).

engineering, and science and technology infrastructure; and (iii) overall resource endowment, and government actions and policies regarding industry, trade, education, and science and technology. The effect of the different influences of firm strategy, industrial development, resource endowment, and government policy on technology exports as well as on technological development will be examined in this paper.

The paper provides an overview of technology exports from five of the most industrially advanced of the developing countries -- Argentina, Brazil, India, Korea, and Mexico 4/ -- and explores what lies behind those exports. Section 2 identifies the different types of technology exports and summarizes data on their volume, destination, and sectoral composition. Section 3 isolates some of the key characteristics of the exporting firms and identifies the competitive advantages underlying different types of technology exports. Section 4 analyzes the comparative advantage of the five countries in these exports. Section 5 explores some of the interaction between trade in the elements of technology, country strategy, and local technological development. Section 6 summarizes the findings and conclusions.

2. Aggregate data on technology exports

As there are various definitions of technology exports in the literature, 5/ it is necessary to start by stating what we mean by technology and to distinguish some of the elements involved in different types of technology

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4/ A collection of studies that includes the five on which this paper is based as well as studies on Hong Kong, Taiwan, and Egypt is forthcoming in *World Development*.

5/ See for example the definitions in the papers on technology exports from developing countries in the special issue of *World Development* (forthcoming, 1984).

exports. Technology consists of technological knowledge, procedural methods, and organizational modes used to transform inputs into outputs. 6/ Trade in technology thus consists of the transmission of information, means, and technical services needed to establish and to operate productive facilities. 7/ These transfers include: patents, licenses, knowhow, plans, blueprints, engineering data, training, operating manuals, capital goods, and various technical services. They may be transferred singly or in varying combinations, including very aggregated modes such as in the cases of direct foreign investment or turnkey plants (where a contractor undertakes to arrange for and deliver a whole package including product and process knowledge, engineering services, and capital goods in the form of a working plant).

The literature on technology exports from developing countries usually includes licenses, patents, consultancy, technical services, direct foreign investment, construction, turnkey plants, and various combinations of capital goods and technical services. For analytical purposes it is useful to distinguish different elements present in these flows. Four broad types of elements may be distinguished:

(i) Basic technological knowledge: product and process knowledge and related conceptual and basic design engineering;

(ii) Technical services for:

6/ For alternative definitions see Bell, Ross-Larson, and Westphal (1984, this issue), Cooper and Sercovich (1971), Dahlman and Westphal (1982), and Teitel (1981, 1984).

7/ See Dahlman and Westphal (1983) for an elaboration of what is involved in technology transfer.

(a) identification and assessment of new projects (pre-investment studies)

(b) design, detailing, procurement, and supervision of the establishment of new facilities (project engineering),

(c) start-up, operation, debugging, maintenance, and quality control (production engineering); and

(d) design, testing, and adaptation of new products, processes, and equipment (product and process engineering),

(iii) Management services for:

(a) the organization and implementation of new investment projects (project management), and

(b) overseeing the operation of productive facilities, including relationships with suppliers, labor, and purchasers (production management).

(iv) Embodiment activity: physical construction, fabrication, assembly, and erection of productive facilities or capital goods to given design specifications. 8/

Basic technological knowledge, technical services, and management services all fit within our broad definition of technology; embodiment activity does not. These four elements are packaged in different combinations and proportions in the flows that are being called technology exports. Two problems are faced when analyzing these trade flows. First, it is difficult

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8/ We owe the use of the term embodiment activity to Larry Westphal. See Westphal, Rhee, Kim, and Amsden (1984) -- hereafter cited as Westphal et al. -- for a more extensive definition and a very effective illustration of its use.

to separate out the weight of each of the four elements without much more detailed information about the flows than is typically available. We will do our best to indicate their relative weights with the information we have at our disposal.

Second, there is a major inconsistency in the treatment of construction and of capital goods, which we have decided to resolve by including capital goods as part of technology exports. Both construction and capital goods exports consist primarily of embodiment activity, although they also embody technology and may be accompanied by technical services. But whereas construction exports are conventionally included in the literature on technology exports from developing countries, capital goods that are not accompanied by complementary services related to design, installation, and start-up generally are not. That is, the literature includes only turnkey plants or exports of capital goods that are also accompanied by technical services. However, even turnkey plant exports include important elements of embodiment activity. In addition, some turnkey exports may consist simply of packaging together foreign technology and foreign design services with locally supplied embodiment activity to implement those designs, and thus reflect mostly project management and organizational elements -- as well as embodiment -- rather than elements of product and process technology or technical services.

Similarly, while some made to order capital goods consist simply of the manufacture of machinery and equipment and the fabrication of structural elements in accord with detailed design specifications provided by the purchaser or his agents (i.e. "pure" embodiment activity), others may also include domestic project, process, and design engineering, needed to translate the requirements of the specific function the capital good is to serve into its design. Furthermore, while it is true that many capital goods exports consist simply of standard machinery and equipment conventionally produced in the country, insofar as they do not just embody designs obtained from abroad, they incorporate local design and other technical services, and thus can be considered to have elements of technology export. In light of this, it is more consistent to also include the export of all capital goods in the universe of what is being called technology exports.

The term technology exports is clearly a misleading label for the flows being discussed. Westphal et al. (1984) use the expression "exports of capital goods and related services." Although that is a better description of the flows, it virtually eliminates the connotation of the technological elements. For lack of a better term we will continue the practice of labelling the flows as technology exports. What is more important than the label for the collection is to know what the collection consists of for each country. These distinctions will be important for assessing the revealed comparative advantage of the countries.

2.1. Overview of technology exports

In table 1 we present the data that could be collected on five kinds of technology exports: (1) construction exports, which may include technical services, such as construction design, and project management in addition to embodiment activity; (2) licensing, consulting and technical services (LCTS) exports, which may include product and process knowledge, management services, and a wide variety of technical services ranging from pre-investment studies to product, process, project, and production engineering; (3) direct foreign investment (DFI) that is believed to include some technological elements such as product and process knowledge, technical services, and production management, along with the equity participation that distinguishes it; (4) project exports, which package together capital goods and various technical and

Table 1: Comparison of Cumulative Technology Exports

(all values in millions of dollars) 1/

	Argentina		Brazil		India		Korea		Mexico	
	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases
A. Technology exports										
1. Construction exports	616 (7/82)	32	4,283 2/ (12/82)	147	6,024 (11/81)	n.a.	43,953 (12/81)	n.a. 3/	984 (9/82)	58
2. Licensing, consulting & technical services	60 4/ (12/82)	165	357 5/	112 (4/82)	500 6/	n.a. (n.a.)	472	363 (10/81)	51 4/	n.a.
3. DFI with a technological component (manufacturing) 7/	45 (6/81)	127	2059 (2/81)	95	129 (8/80)	67	34 (12/81)	23 8/	19	
4. Project exports	186 9/ (7/82)	118 9/	1,655 10/ (12/81)	n.a. 10/	1,858 11/ (6/82)	203 11/	2,570 12/ (12/81)	276 12/	41 13/	9 13/
Manufacturing	n.a.		n.a.	n.a.	921 11/	>101 11/	472 12/	102 12/	11 13/	6 13/
Other	n.a.		n.a.	n.a.	937 11/	>102 11/	2,098 12/	174 12/	30 13/	3 13/
5. Capital goods exports, 14/ 1975-1979 15/	1,969		5,855		1,813		5,760		1,711	
B. Other trade data for comparative purposes										
-- All commodity exports, 1975-1979	26,717		58,821		28,821		50,355		25,602	
-- Value of all commodity exports in 1979	7,808		15,244		6,996		14,952		8,817	
(value of all commodity exports in 1979 as % of GNP)	7.5		6.8		5.3		24.9		6.7	
-- Value of manufactured exports in 1979	1,884		5,733		4,085		13,281		3,174	
(value of manufactured exports as a % of all exports in 1979)	24.1		37.6		58.4		88.8		36.0	
-- Value of capital goods exports in 1979 14/	429		1,945		480		1,771		673	
(value of capital goods exports as % of all exports in 1979)	5.5		12.8		6.9		11.8		7.6	

1/ Shown in parenthesis under the values is the date through which the values are cumulative.
2/ Based on 58 of the 147 contracts.
3/ The number of cases through the end of 1980 (when the total value was $30,271 million dollars) was 1287.
4/ Refers to values actually received rather than to values contracted, which is the case for all the other data in categories 1-4.
5/ Based on 67 observations including 20 contracts for $69 million in mining.
6/ Based on estimate for values contracted reported in Lall (1984a).
7/ Consists of DFI in manufacturing since DFI in non manufacturing is undertaken mostly to obtain access to raw materials or to set up trading facilities and is less likely to include technological elements (except for Mexico when it was not possible to distinguish between DFI in manufacturing and in non-manufacturing).
8/ No current total figure could be obtained because no registry is kept by Mexican authorities but in 1977/78 the total value of Mexican investments in other Latin American countries (according to the registries of those other countries), was 23 million dollars. This included non-manufacturing investments, but the total 23 million has been kept because it is known that there has been an increase of Mexican DFI since 1978, and there has also been DFI in non-Latin American countries.
9/ Includes only exports of complete industrial installations and an $80 million contract for a nuclear power reactor for research sold to Peru. Total value of capital goods destined to industrial facilities exported by Argentina during 1975-1979 was 883 million.
10/ Includes only complete industrial facilities and made to order capital goods (as defined by the Brazilian Association of Equipment for Basic Industries — ABDIB). Complete industrial facilities account for at least $230 million of this amount through 36 contracts.
11/ Project exports are defined in India cover all those which involve the setting up of industrial plant abroad where the seller necessarily provides some technological services in the project.
12/ Based on what are called plant exports in Korea, which are defined as exports of complete productive systems, as well as the individual elements of such systems if their value exceeds $100,000. It includes exports to developed countries, oil rigs and coastal facilities but excludes transportation equipment which is also excluded in the Indian definition. Based on disaggregated Korean data available for 1980 and 1981 (which account for about 53% of plant exports through 1981), it appears that about 77% of the export values included some sort of technical service. If the same proportion was used to adjust the Korean data, it would still have the largest total values of project exports, although India's exports are concentrated more heavily in the manufacturing sector and value of its exports in that sector is about twice that for Korea.
13/ Includes only turnkey plants.
14/ Our definition of capital goods consists of SITC (revision 1) categories: 691, 692, 695, 711, 712, 714, 715, 717, 718, 719, 722, 723, 724.91, 726, 729.5 -->.9, 731, 732.2, 732.3, 732.4, 732.5, 732.7, 733.3, 734, 735, 861.
15/ The latest year for which comparable trade data could be obtained for all five countries was 1979.

Sources: Categories A1-A4: Individual country reports: Argentina, Soifer (1982); Brazil, Sercovich (1984); India, Lall (1984a and 1984b); Korea, Westphal, Rhee, Kim, and Amsden (1984); Mexico, Dahlman and Cortes (1984).
Categories A5 and Other Trade Data: Calculations based on World Bank trade data bank.

management services to implement investment projects that are combined in the creation of new productive facilities; and (5) capital goods exports, defined as structural parts, tools, machinery, instruments, and transportation equipment (excluding passenger vehicles and electronic parts and components).

Except in the case of capital goods exports, which are taken from standardized trade statistics, complete information for the other four categories could not be collected for all the countries, and when collected, did not always cover comparable periods or use the same definitions. The main problems occur in the categories of DFI and project exports. Details of definitions and coverage are given in the footnotes to table 1. It should also be noted that there is some double counting across the different categories. For example, most of the physical elements of project exports undoubtedly also appear in the totals for capital goods exports; the same is also true for machinery and equipment that are capitalized as part of a direct foreign investment participation. In addition, there may be some misclassification. For example, technical service exports packaged together with capital goods and embodiment activity may appear under the totals for project exports, or for construction exports, instead of under LCTS exports. Therefore, the totals should be interpreted as indicative of the relative orders of magnitude of the different types of exports involved, rather than as precise quantifications. The reader should also bear in mind, that -- with the possible exception of LCTS exports -- the flows may also include the value of raw materials and intermediate inputs used in embodiment activity, so they should be interpreted accordingly. 9/

9/ Sercovich (1984) has attempted to make some adjustments in order to exclude the value of raw materials and intermediate inputs.

Two striking features stand out from the aggregate data. First, since construction and capital goods exports are such an overwhelming share of the total (69% and 21% respectively -- see table 4), it may be inferred that the bulk of what is being called technology exports is really embodiment activity. Technical services are likely to be a distant second, followed by management services. Product and process knowledge is likely to be a very small share indeed. While elements of product and process knowledge may also be included in all the other categories, especially project exports, LCTS, and DFI, their share in them is likely to be extremely small. Project exports (which account for almost 8% of the total) are likely to consist largely of capital goods and construction (mostly embodiment activity) with some technical and management services. LCTS are less than 2% of the total and consist mostly of technical and management services rather than of product and process knowledge. DFI in manufacturing is not even half a percent of the total, and is likely to involve management services more than any other element. In section 3.3 we will analyze in more detail the nature of each of the categories of technology exports and present various anecdotes to illustrate the elements involved.

The other striking feature is that Korea accounts for almost two thirds of total technology exports for the five countries. Brazil accounts for 15%, India for 13%, Argentina for 4%, and Mexico for 3%. Korea's dominant role is due to the very large value of its construction exports -- Korea's construction exports alone account for more than 54% of total technology exports of the five countries. Differences in the composition of these exports, and in the revealed comparative advantage of the five countries in different types of technology exports will be analyzed in Section 4.

2.2. Destination and sectoral composition of technology exports

Table 2 summarizes the destinations of the different technology exports. Geographical, linguistic and cultural proximity appear to play an important role in the destination of the exports from the different countries, though the lucrative market offered by the oil rich Middle Eastern countries is reflected in the exports of Korea and India as well as in the value of the construction exports from Brazil. Most of the exports by Argentina, Brazil and Mexico are to the Latin American region, although Brazil has a more diversified range of destinations for its construction exports, and Mexico for its LCTS and capital goods exports. The concentration of these countries' capital goods exports in the Latin American region may be due, in part, to the special preference given by the Latin American Free Trade Association (LAFTA) to intra-regional trade. India exports primarily to the Middle East and Africa. Korea's exports are the most diversified; they do not seem to be as affected by geographical links.

Table 3 summarizes the sectoral composition of the different technology exports. In the non-industrial and infrastructural project areas, the main sectors are power generation and distribution, oil exploration, buildings and steel structures, and water projects of various kinds. In the industrial area there is a core of industries that appear time and again in the different types of technology exports across the five countries. The most prevalent are: steel, textiles, pulp and paper, chemicals, and various branches of capital goods. These are well established in the newly industrialized countries. With the exception of textiles, they are also industries in which capital goods are not standardized and in which there is a need for product, process, and project engineering services as well as for trained personnel. In addition, they are industries with relatively mature technologies where the

Table 2: Destination of Technology Exports

(percentage composition for each country and type)

	Argentina	Brazil	India	Korea	Mexico
Construction	1. Latin America 55 2. Africa, Asia, Middle East 45	1. Latin America 39 1/ 2. Africa, Asia, Middle East 61	1. Middle East (including Libya) 97 2. South East Asia 2 3. Africa 2	1. Middle East 94 2. Southern Asia 5	1. Latin America 100
Project exports	1. Latin America 99 Peru 48 Cuba 16 Urauguay 11 Bolivia 8 Others 16 2. Africa, Asia, Middle East 1	1. Latin America 75 2/ 2. Africa and Middle East 19 3. Developed Countries 6	1. Middle East (including Libya) 44 2. South and South East Asia 30 3. Africa 21 4. Other 5	1. Middle East 42 2. OECD countries 38 3. Asia (excluding Japan) 16 4. Africa 4 5. Latin America 0	1. Latin America 100 2/ Brazil 22 Bolivia 22 Costa Rica 33 Guatemala 22 Colombia 11
Licensing consulting and technical services	1. Latin America 88 Paraguay 25 Bolivia 13 Nicaragua 4 Other 43 2. Africa, Asia, Middle East 11 3. Europe 1	1. Latin America 71 2/ 2. Developed Countries 20 3. Africa and Middle East 9	1. Africa 27 3/ 2. Other and Unallocated 24 3. Middle East 23 4. OECD 15 5. South & South East Asia 11	NA	1. Latin America 45 2. Asia 25 3. Middle East 10 4. Europe 4 5. North America 1 6. Unknown 15
Direct Foreign Investment	1. Latin America 99 4/ 2. Europe 1 3. North America 1	1. Latin America 5/ 2. Africa	1. South East Asia 49 6/ 2. Africa 29 3. South Asia 10 4. Europe, U.S. & Australia 7 5. Middle East 5	1. Asia (excluding Japan) 78 2. Africa 11 3. Middle East 7 4. OECD 4 5. Latin America 1	1. Latin America 68 2/ Venezuela 46 Costa Rica 16 Argentina 11 Others 26 2. USA 26 3. Others 5

Capital goods 7/ (1975-1979)	Argentina	Brazil	India	Korea	Mexico
Africa	1	12	18	10	0*
Middle East	0*	3	26	26	3
Western Europe	7	15	13	18	5
Centrally planned	0*	0*	8	0*	1
Latin America	83	48	1	2	31
South Asia	0*	0*	13	1	0*
East Asia	1	1	17	8	0*
North America	5	16	5	23	59
Japan, Australia New Zealand, others	3	5	0*	12	2

1/ Distribution by value based on values for 10% of total 144 contracts which are known. Distribution by number of contracts is: Latin America, 73%; Africa, Asia, and Middle East, 26%; Europe 2%.

2/ Distribution based on number of contracts.

3/ Distribution based on data for 1978/79 which covers only 15% of the total value in Table 1.

4/ Breakdown based on total DFI of 21,641 (cumulative 1965-78, including non-manufacturing) cited in Eduardo White, "Latin American Joint Ventures: A New Way to Strengthen the Bargaining Power of Developing Countries vis-a-vis Transnational Corporations?" (mimeo), UNCTC, 1982.

5/ Percentage distribution not available.

6/ Distribution based on total values of manufacturing (82%) and non-manufacturing (18%) of DFI values.

7/ Same definitions of capital goods as used in table 1.

* Means less than .5 percent.

Sources: Same as for table 1.

Table 3: Breakdown of Technology Exports by Sector of Destination

(percentage composition for each country and type) 1/

	Argentina		Brazil		India		Korea		Mexico	
Construction	1. Pipelines	61	1. Hydroelectric projects	27	(not available)		1. Buildings	59	1. Hydroelectric project	44
	2. Industrial construction	15	2. Roads and railroads	25			2. Civil engineering	13	2. Pipelines	23
	3. Airports	10	3. Other	15			3. Plants	8	3. Water systems	21
	4. Hospitals	8	4. Urban construction	14			4. Ports	8	4. Buildings	5
	5. Non-industrial construction	7	5. Ports and airports	10			5. Roads	8	5. Ports	3
			6. Water systems	10			6. Power & communications	5	6. Highways and communications	2
			7. Communications	3					7. Electromechanical	1
									8. Sanitation	1
Project exports	1. Nuclear power	43	1. Alcohol distilleries	42	1. Power generation and distribution	42	1. Offshore oil drilling	39	1. Glass production	33
	2. Food processing	22	2. Food and drinks	19	2. Fabricated metals, machinery & trans.	13	2. Steel structure	25	2. Oil exploration	22
	3. Meat packing	11	3. Basic metal industries	17	3. Cement	11	3. Water desalination and treatment	11	3. Food processing	22
	4. Pharmaceuticals	10	4. Fabricated metals, machinery & transport	16	4. Textiles and yarn	10	4. Cement	9	4. Chemicals	22
	5. Steel	7	5. Others	6	5. Basic metal industries	10	5. Power generation and distribution	5		
	6. Chemicals	3			6. Steel structures	5	6. Tires	4		
	7. Glass	2			7. Sugar	5	7. Fabricated metals, machinery & transport	3		
	8. Others	2			8. Water desalination and treatment	3				
Licensing consulting and technical services	1. Administrative & accounting services	2/	1. Telecommunications	70	1. Basic metal industries	35	1. Fabricated metals, machinery & transport	24	1. Steel	50
	2. Engineering studies		2. Chemicals & petrochem.	7	2. Power generation & distribution	14	2. Chemicals, rubber and plastics	15	2. Oil exploration and refining	11
	3. Feasibility studies		3. Basic metal industries	5	3. Civil construction	13	3. Engineering services	12	3. Power generation	7
	4. Technical services in hydroelectric & electrical sectors		4. Other manufacturing	5	4. Computer software	13	4. Building construction	11	4. Paper	4
	5. Chemicals & drugs		5. Fabricated metals, machinery & transport	4	5. Chemicals & drugs	11	5. Cement	10	5. Glass	4
	6. Transportation systems		6. Pulp and paper	4	6. Fabricated metals machinery & transport	6	6. Textiles, apparel, leather	7	6. Water systems	5
			7. Food and drinks	4	7. Sugar		7. Power generation and distribution	5	7. Textiles	4
									8. Chemicals	2
									9. Management systems	2
									10. Unknown	3
Direct foreign investment	1. Pulp and paper	2/	1. Steel	2/	1. Textiles and yarn	31	1. Non-metallic mineral products	45	1. Capital goods	31
	2. Food processing		2. Elevators		2. Pulp and paper	22	2. Chemicals, rubber, & plastic products	13	2. Metal products	31
	3. Textiles		3. Bicyles		3. Fabricated metals	22	3. Metal fabrication & machinery	13	3. Glass	16
	4. Household appliances		4. Pulp & paper machines		4. Food Processing	18	4. Wood & wood products	12	4. Chemicals & rubber	11
	5. Chemicals & drugs		5. Cold storage facilities		5. Chemicals & drugs	4	5. Food, beverages and tobacco	10	5. Textile fibers	13
	6. Agricultural machines		6. Metallurgy		6. Other	3	6. Textiles, leather apparel	4		
	7. Metal products		7. Soft drinks				7. Other	3		
	8. Electrical equipment									
	9. Motor vehicles									
	10. Other capital goods									
	11. Plastic products									

Capital goods 3/

Rank	Argentina SITC 4/		Brazil SITC 4/		India SITC 4/		Korea SITC 4/		Mexico SITC 4/	
1	719	25	7323+	16	719	14	735	39	711	19
2	714	12	711	13	711	13	691	9	719	16
3	7323+	11	719	12	695	11	734	8	722	16
4	712	9	714	10	691	9	722	6	714	11
5	731	6	722	7	722	8	731	6	7323+	7
6	711	4	718	6	7323+	7	714	5	723	6
7	718	4	712	6	717	6	861	5	7299	5
8	695	3	735	6	715	5	7299	4	861	4
9	722	3	734	3	718	4	719	4	731	3
10	715	3	717	2	731	4	723	3	718	3

1/ Composition based on the same data as in Table 2.

2/ Actual percentage distribution not available.

3/ 691, structural parts; 695, tools; 711, non-electrical power machiner; 712, agricultural machinery; 714, office machinery; 715, metalworking machinery; 717, textile machinery; 718, special industry machinery; 719, non-electrical machinery and parts; 722, electric power machinery; 723, equipment for distributing electricity; 7299, electrical machinery (n.e.s.); 731, railway vehicles; 7323+, trucks, includes division 7323, 7324, 7325, and 7327; 734, aircraft and parts; 735, ships and boats; 861, precision instruments.

4/ Standard International Trade Classification, Revision I Code.

Sources: Same as in table 2.

technological frontier has not been moving very rapidly and there is relatively easy access to technology worldwide. 10/ This confirms the expectation that most of the trade takes place in industries where the technology is more easily acquired, having been around for a long time, and where the world frontier can be easily kept up with.

Nevertheless, each country has more exports than the others in at least one industrial sector where it appears to have reached special prominence. Argentina seems particularly developed in nuclear energy, pharmaceuticals, and agricultural machinery; Brazil, in renewable energy technology and some metalworking industries; India, in power generation and distribution; Korea, in plywood and shipbuilding; and Mexico, in petroleum refining, petrochemicals, and glass.

The differences can be explained in terms of country specific factors underlying special technological efforts in these sectors. The Argentine government has long pursued a policy of self-reliance in nuclear energy, while a large domestic market has encouraged the application of metalworking skills and entrepreneurial resources toward the development, among other things, of agricultural equipment. In Brazil there has been a long tradition of using biomass as an important energy input, which was given more emphasis as a result of the energy crisis. In India the manufacture of electrical equipment has been concentrated in one large state owned firm (BHEL), which now ranks among the largest and most integrated in the world because of India's market size. In Korea: the country has exported plywood in considerable volume in the past and has presumably benefitted from the learning associated with the

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10/ To some extent, the micro electronics revolution is changing this. Even such traditional industries as textiles are increasingly being affected by the advent of electronics based manufacturing.

establishment of successive plants; and shipbuilding, which was promoted by the government, uses many of the construction related activitities in which Korea appears to have a strong comparative advantage. In turn, the Mexican government supported the strengthening of technological capability in the petroleum sector after experiencing a painful lesson in technological dependence when foreign technology was cut off in retaliation for its expropriation of the oil industry; and there is a technologically dynamic, vertically integrated glass group that has been quite active in export markets in glass products, glassmaking equipment, and glass technology.

The exports reflect the heterogeneity of the technological capabilities acquired and of the technological efforts undertaken by the countries. In this they reflect the diversity of the countries' circumstances. The heterogeneity is with respect to the classification of the technologies by the sectors served, by the engineering and scientific principles involved, and by the type of technological elements present in the exports. But, there is uniformity with respect to the general absence of basic proprietary product and process knowledge, the concentration in a common core of infrastructural and industrial sectors, and the systematic, if highly specific, influence of variables such as natural and human resource endowments, government policy, and firm strategy. We will expand on the interaction between these variables in the next sections.

3. Nature of the exports and of the exporting firms

This section begins with a description of the firms involved in technology exports and summarizes some of their distinguishing characteristics. It then identifies the competitive advantages underlying different categories of technology exports, relates them to different types of firms, and uses the distinctions established to explore the nature of the five categories of technology exports.

3.1. The exporting firms

Technology exports are performed by firms specialized in three different areas: construction; engineering and consulting; and manufacturing (including, as a subset, capital goods producers). With the data that has been collected to date it is not possible systematically to analyze the characteristics of the exporting firms. 11/ Nevertheless, it is apparent that in all of the countries surveyed most of the exporting firms are locally-owned and controlled -- even in Argentina, Brazil, and Mexico, where there is the greatest presence of foreign investment. This suggests that technology exports do indeed reflect increasing local technological capabilities. As to foreign-owned technology exporting firms, the evidence available supports the idea that their activities as technology suppliers to other developing countries owes a great deal to the experience, skills, and knowledge that they acquired in the host country where they have operated, usually over extended periods. This skill and knowledge is over and above whatever technical contributions were channelled to them by their parent system. 12/

The available evidence also indicates that large firms account for most of the value of the different types of exports. 13/ Relatively large

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11/ Sercovich (1984), however provides basic information on the size, ownership, and other characteristics of different types of exporting firms in Brazil.

12/ The evidence here is based on two dozen cases recorded in manufacturing and engineering firms in Argentina, Brazil, India, and Mexico.

13/ In the case of Korea, for example, large business groups or chaebol account for 96% of the total contract value of project exports, although they account for smaller shares of DFI and LCTS.

firm size may give some advantage in technology exports, perhaps simply because larger size often coincides with a stronger international orientation as well as a greater capacity to transfer technology due to better organizational arrangements and larger staffs that can be assigned to such activities.

Nonetheless, some smaller firms are also involved in technology exports. Involvement in technology exports for most of the small firms is more a random event than a permanent activity, except for a very few small manufacturing firms that have developed specific technological advantages that they seek to sell abroad. Most small firms are often unaware that they have any technology or skills worth exporting until they are contacted by an interested foreign party, who knows something about their technological capabilities or experience and wants to get access to them.

However, construction firms, engineering and consulting firms, and producers of made to order capital goods tend to consider their technology exports more of a permanent activity. 14/ These firms' technology exports are basically an extension of similar types of activities that they perform in the local market. Technology exports by large manufacturing firms are in many cases also an extension of their local sales of technology and technical services. Technology exports are therefore the manifestation of the broader phenomenon of the growing technological activity that is taking place in the domestic markets of these more industrially advanced developing countries.

14/ Even in countries which are less export oriented such as India, Argentina, Brazil and Mexico, these firms view their export market as an important activity to balance out the downward swings that occur in the domestic demand for their services.

In seeking to understand what is behind technology exports from developing country firms, it is important to consider how the firms developed the technological capabilities behind those exports. The exports reflect a number of skills and capabilities related to experience these firms have acquired in the operation of production systems, in the design and execution of new projects, and in the creation, development, and application of new products and processes. Technology exporters in process oriented industries such as cement, chemicals, steel, textiles, pulp and paper initially acquire production capability directly from abroad, through a formal inflow of foreign technology such as a turnkey plant, a joint venture, foreign licensing, or formal technical assistance from foreign capital goods suppliers. In contrast, small firms using discrete production technologies such as capital goods producers, as well as construction and some engineering firms, typically acquire technology indirectly, by copying foreign products, imitating foreign production processes, and receiving informal assistance from foreign equipment suppliers. As these firms grow and become more formalized, however, they usually make greater direct use of foreign technological elements.

Regardless of the initial pattern of acquisition, the firms have usually had to undertake significant efforts to assimilate, adapt, and improve the technology. Foreign technology has often had to be adapted to local conditions (such as market size, raw materials, skill availability, existing technological infrastructure, and different local demand characteristics). 15/ In turn, local circumstances (including input and output prices, input quality and availability, relative factor prices, demand, competition,

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15/ This corroborates the findings reported in Katz (1978, 1982) and Teitel (1981).

and government regulations) as well as international "best practice" technologies have changed over time, and additional efforts usually have been undertaken to cope with these changes. As a result, these firms further developed their production capabilities, often through using additional inputs of foreign technological elements. In addition, to the extent that they have grown through their success, they have periodically expanded their productive capacity, and thereby have developed additional capabilities to evaluate and choose new technologies. Thus these firms are able to combine abilities and knowledge that have been acquired in production with experience in the design and execution of new projects that are better suited to local conditions in developing countries.

This is not to say that such skills and capabilities are acquired automatically through repetitive experience in production or in the establishment of new capacity. Quite the contrary. Usually these firms have pursued active strategies of knowledge acquisition, adaptation, and development that have involved deliberate technological effort. 16/ For the most part these firms have not made major technical breakthroughs, although there are a few cases of firms that have developed technologies that have then been exported.

What determines whether a firm should take advantage of its technological competence through activities aimed at foreign markets? What determines the means -- home based production, DFI, licensing and technical services -- through which it should undertake those activities? Answering these questions would require an analysis of the corporate strategies and of trade policies in the exporting and importing countries. It would involve ascertaining the

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16/ This is in marked contrast to the more common pattern in developing countries of firms which usually do not pursue active technological strategies. See Bell, Ross-Larson, and Westphal (1984).

degree to which the exporting firm could fully appropriate the value of its technological assets through different means and examining the nature of infrastructural and other constraints in the two countries. It is clear that domestic and international market circumstances play an important role in spurring or deterring the decision to go abroad. For instance, a slowing down in the level of domestic activity or a change in the structure of local demand combined with attractive foreign market opportunities may exert a strong influence to go abroad. This was the case in Brazil during the second half of the 1970s when it started exporting to oil rich countries in the Middle East and Africa. Unfortunately, a comprehensive analysis of these issues is not possible here. We will, however, attempt to identify the competitive advantage behind different types of technology exports.

3.2. Kinds of competitive advantage

Two broad kinds of competitive advantage underlie technology exports of developing countries. The first, and most obvious one, is that these countries can provide the same type of technology as developed countries, but at a lower cost. The second is that they can provide a differentiated technology that is somehow more appropriate to the importer. The advantage of appropriateness -- it should be noted -- implies greater cost effectiveness, once the attributes of the needs to be satisfied are fully specified and the costs of alternative ways of meeting them are evaluated.

In order to incorporate some notion of the source of the competitive advantage that is ultimately reflected in lower costs, it is useful to further subdivide the primary sources of competitive advantage, and to distinguish four types of underlying competitive advantage.

a. A cost advantage in providing basically the same type of process, product, or service, that could be supplied by developed countries, the advantage most likely being based primarily (but not exclusively) on lower labor costs. Exports based on this advantage can be expected to go to both developed and developing countries.

b. An advantage based on supplying an adapted or older process, product, or a technical service that is more appropriate to the needs of the purchaser, because of characteristics such as smaller scale, greater ease of operation, better knowledge of similar local environments, or better match between product attributes and local needs. Exports based on this advantage -- which is rooted in experience in developing country conditions -- may be expected to go to other developing countries.

c. A headstart in experience which may be reflected in lower cost or greater appropriateness, usually the result of country-specific conditions -- such as the availability of natural resources or government promotion -- whereby an acquired advantage in experience follows from a natural advantage. Exports based on this advantage may go to both developed and developing countries.

d. An advantage based on having developed a major technological breakthrough. Exports based on this advantage may also go to either developed or developing countries. 17/

17/ It is worth noting that in this paper we are concentrating on supply-side variables. A more complete account to explain the destination of technology exports would require due consideration of demand-side variables.

The first advantage is likely to apply for construction and engineering firms and to be reflected in lower costs -- of carrying out embodiment activities, due to lower wages for unskilled and semi-skilled labor; or of providing technical services, due to lower salaries for technical personnel in comparison to developed countries. Construction and project exports are not the only areas where this advantage may be realized. Examples of other exports based on lower labor costs are Indian exports of computer software as well as engineering consultancy and Argentinian exports of project engineering services (in this case, up to the late 1970s).

The second advantage is realized by firms that have undertaken deliberate efforts to modify and adapt their product, process, or organizational techniques to make better use of local resources, save capital, improve energy balances, or better meet particular local needs. In some instances the advantage may derive in part from the possession of an older technology that is no longer available from developed countries. Such cases are found in the export of old industrial plants originally imported from developed countries, used for several years, then refurbished and re-exported to a lesser developed country. Examples include exports of rennovated textile plants to African countries by Indian firms, exports of steel pipemaking plants to Nigeria and Bangladesh by a Korean firm, and exports of a small scale bicycle-making plant to Bolivia by a Brazilian firm.

The third advantage usually derives from situations where the abundance of natural resources has stimulated their use or where the government has promoted the development of a specific priority sector. 18/ Examples are nuclear energy in Argentina, alcohol distillation and charcoal based steelmaking in Brazil, power generation and textiles in India, shipbuilding in Korea, and petroleum refining and use of sponge iron for steelmaking in Mexico.

The fourth advantage is seldom encountered because few firms in developing countries set out to transcend the technological frontier and, of those that do, few are successful. Success has required a strong market need, or opportunity, combined with a high degree of technological competence. The examples from private firms we are aware of all come from Mexico: a process using natural gas to produce iron (exported to six countries); a process to produce non-woven textiles (exported to five countries), and a process to produce newsprint from sugar cane bagasse (exported to two countries). In other cases, the government has been directly involved through the efforts of its R & D institutes; or indirectly, through various forms of subsidies or incentives. Examples: a shale oil process developed by the state-owned Petroleos Brazileiros, which is being internationally commercialized; a Brazilian turboprop airplane (the Bandeirante), developed by the Brazilian airforce research institute, which has been very successful in the commuter aviation market in the U.S.; and a process to demetalize heavy crude oil developed by the government owned Mexican Petroleum Institute (exported to the U.S. and to several other oil producing countries).

18/ Scarcity of a critical natural resource may also be the source of a headstart in experience because it may induce technological efforts to offset the relative scarcity. The latter is the case of Brazil, where scarcity of petroleum resources has led it to experiment with alternative fuels. In shale oil production, and in biomass fuels for example, cumulative outputs (based on local processes) are the highest in the world.

3.3. The competitive advantages behind technology exports

Using the distinctions developed above, and the information at our disposal, we now turn to assess the competitive advantage behind the previously defined categories of technology exports from the sample countries.

The fact that most construction projects have been won in bidding against competitors from developed countries suggests that technological adaptations are probably not the source of advantage. 19/ The advantage lying behind construction exports appears to be cost competitiveness. 20/ However, much more than simply lower wages is involved. This can be seen, for example, in the fact that India, despite its much lower wages and salaries, has not done nearly as well as Korea in penetrating the lucrative Middle East construction market. Korea's additional advantage seems to stem from management and organizational abilities, reflected in its reputation for quality and for completing projects on time and at the agreed price. There is also some evidence that many Indian construction bids have failed because India's labor intensive technology leads to higher project costs. 21/ In turn, a considerable portion of Brazil's construction exports is concentrated in large

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19/ One exception occurs in some Brazilian building construction exports to Africa: architectural designs that permit reduced exposure to the sun. Moreover, it is conceivable that lower construction costs could be the result of different construction technologies, but our data on construction exports are not detailed enough to be able to check on this.

20/ Political and other extra-economic influences are also often present. For example, even Brazilians acknowledge that although India had the lowest bid on an Iraqi construction project, the project was awarded to Brazil because of a barter type arrangement to offset Brazilian imports of Iraqi oil.

21/ Indian civil construction exporters reportedly find that they have to use more advanced, mechanized technology overseas than they use at home because of tighter time constraints and relatively higher labor costs abroad. See Lall (1984b).

projects which reflect the ability of Brazilian firms to schedule and control the wide variety of inputs needed on a large scale. This ability comes from experience acquired in large domestic construction projects -- such as the construction of Brazilia, the Transamazonic Highway, and the Itaipu hydro-electric project. 22/

Project exports include manufacturing projects and social overhead projects -- such as offshore oil drilling, power generation and distribution, steel structures, and water desalination plants. For Korea and India, social overhead projects tend to be either in the Middle East or in the OECD countries; and they are primarily based on a cost advantage. The overwhelming majority of Korea's social overhead projects appear to be performed in accordance with detailed design specifications provided by the purchaser or by foreign engineering contractors, implying that Korea's competitive advantage is based on the low cost at which those specifications can be embodied in physical facilities. Mexico's social overhead projects consist of oil exploration platforms exported to South American countries based on replication of imported technology. 23/ On the whole, social overhead projects thus reflect primarily embodiment capability.

22/ Some elements of appropriateness in project management may also be mentioned, such as the ability to operate under extremely unfavourable environmental conditions or to tackle unexpected mechanical problems in the field with a minimum of resources and to deal efficaciously with and rapidly train large contingents of non-qualified labor. These factors are often quoted concerning Brazilian companies which profit from their experience in operating in extremely unhospitable surroundings at home when, for instance, they go to build long railway and highway systems in Africa and Asia. See Sercovich (1984).

23/ The distinction between manufacturing and social overhead could not be made for data from Argentina or Brazil.

Many manufacturing project exports from all the countries just seem to be replications of foreign technology, but a large number of these exports include elements of adapted technology. This is more the case for India's project exports than for Korea's. 24/ Argentina's plant exports in pharmaceuticals, chemicals, and food processing also embody technological adaptations related to natural resource endowment. Brazil's manufacturing plant exports consist largely of alcohol distilleries and charcoal based mini-steel plants, both of which reflect headstarts in experience related to exploiting its peculiar natural resources endowment. Some of Mexico's plant exports -- glass making and small scale chemical plants, and cereal mills -- are also based on technology that was developed for or adapted to Mexican conditions.

With relatively few exceptions, DFI in manufacturing goes to other developing countries. 25/ It is hard to discern the underlying competitive advantage involved in DFI because of the many motivations for DFI that are

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24/ Korean manufacturing project exports include a $209 million cement mill to Saudi Arabia and an $88 million tire factory to Sudan. These two projects do not seem to be based on any specially adapted technologies but on cost advantages. But there is evidence that many of Korea's other smaller manufacturing plant exports did include some adaptation of the equipment in a more labor intensive direction. See Westphal et al. (1984). Brazil presents two cases of steel plant exports (to the USA and Portugal worth $25 and $18 million respectively) like the Korean cement plant export to Saudi Arabia. In both these exports price competitiveness and the technological backing of an advanced country firm were prime considerations of the recipients for their choice.

25/ Most of the small number of investments in developed countries seem to be motivated primarily by the desire to gain access to foreign technology, either through collaboration with foreign companies, or through the acquisition of foreign R and D facilities or engineering firms. However, a few are based on the desire to exploit real technological advantages, as in the case of a Mexican steel cable producer that developed a new production process and set up production facilities in the U.S. and Canada.

unrelated to technological elements. 26/ Technological advantages sometimes do appear, however, in the form of adapted technology as well as managerial and marketing skills. This seems to be the case for Korea and Brazil, with the adaptations being in the direction of smaller scale and greater domestic input intensity. Indian DFI also appears to have important elements of adapted technology, but the key factor seems to be management ability. In some cases, DFI appears to have been necessary to sell plant exports, equity participation being required by the recipient as a form of guarantee.

Exports of capital goods present several interesting contrasts with the other types of technology exports as well as significant differences among the countries. Though other technology exports go primarily to developing countries, more than half of Korea's and Mexico's capital goods exports go to developed countries. It thus seems that the advantage behind a large part of capital goods exports from these two countries is cost competitiveness in embodiment activity (but see below regarding Mexico). Korea's capital goods exports are produced by local firms. Nearly half are ships and structural elements -- these categories comprise less than ten percent of the other countries' exports. Both involve many of the embodiment skills common to construction. There are elements of adapted technology in Korea's other capital goods exports, but the bulk of its capital goods exports consist largely of embodiment activity.

Most capital goods exported from Argentina, Brazil, and Mexico come from subsidiaries of multinational firms. A large share of Mexico's capital goods exports are made as compensatory exports by multinational firms under

26/ For more on the motivation and the advantages of DFI from developing countries, see Kumar and McLeod (1981) and Wells (1983).

special performance requirements imposed by the government, and consist of components for the North American market (which receive almost 60% of Mexico's capital goods exports). Argentina and Brazil are used more as platforms from which to export to other developing countries, especially those in Latin America -- probably reflecting the infuence of the LAFTA regional preferences. Nevertheless, capital goods exports from these countries also include some cases of adapted or locally designed capital goods. In India most of the capital goods exporters are local firms. They export a wide range of simple or older vintage capital goods, which -- not surprisingly -- go primarily to other developing countries. Much of the advantage behind India's exports, may therefore be related to the appropriateness of the technology.

It is difficult to identify the factors behind the competitive advantage in licensing, consulting and technical services (LCTS). In all the countries, but perhaps more so in India (which has the lowest wages for scientists and engineers), some measure of cost competitiveness in technical services appears to be involved. However, many disembodied technology exports appear to be based on the appropriateness of previous engineering experience in the local economy to project or production engineering tasks in other developing countries. This often reflects specific experience in having undertaken these tasks for local projects involving characteristics similar to what is required abroad. 27/ Overall it is clear that very little of the five countries' LCTS exports are based on major technical breakthroughs. But as noted above, Mexico has exports of proprietary technology based on technical breakthroughs in steel, petrochemicals, and textiles.

27/ In many Indian and Mexican cases this type of export consists of helping the purchaser negotiate with established technology and equipment suppliers from developed countries.

4. Revealed comparative advantage by country

As indicated in section 2, there are large differences among the five countries in the volumes of their participation in the five categories of technology exports, as well as in their overall participation in this trade. To assess the relative strength of the countries in each category, some method of normalization is required. The method used here is to take the ratio of i) a country's share in all five countries' exports of a particular category; to ii) the country's share in all five countries' exports of technology -- in effect, to use a "revealed" comparative advantage (RCA) ratio for technology exports based on the five country sample. 28/ Table 4 presents the pertinent information.

In addition to having the largest total volume of technology exports among the five countries, Korea has the largest shares of construction and project exports. However, its RCA is clearly in construction exports. This suggests that its comparative advantage is more in embodiment activity than in technological knowledge or technical services. An important element of its competitiveness in construction and project exports appears to be superior project management and organizational skills. As noted by Westphal, et al (1984, pp. 57-8), "The technology factor that underlies most of Korea's... [technology exports] is much the same as that which underlies most of its other manufactured exports..." -- namely proficiency in production.

In absolute, if not in relative terms, Korea also has significant capability to provide technical engineering services and capital goods for both internal and export markets. Indeed, though it is the smallest country,

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28/ See Balassa (1965) for the concept of revealed comparative advantage.

Table 4: Analysis of Revealed Comparative Advantage of the Five Countries' Technology Exports

	Argentina	Brazil	India	Korea	Mexico	Category subtotal
A. Percentage of grand total						
Construction	.76	5.29	7.44	54.28	1.22	68.99
Licensing, consulting & technical services (LCTS)	.07	.44	.62	.58	.06	1.78
DFI in manufacturing	.06	.02	.12	.08	.03	.31
Project exports	.23	2.04	2.29	3.17	.05	7.79
Capital goods	2.43	7.25	2.24	7.12	2.11	21.14
Country totals	3.55	15.03	12.71	65.24	3.47	100.00
B. Revealed comparative advantage *						
Construction	.31	.51	.85	1.21	.51	
Licensing, consulting & technical services (LCTS)	1.17	1.65	2.73	.50	1.02	
DFI in manufacturing	5.07	.53	2.99	.41	2.65	
Project exports	.83	1.75	2.32	.62	.19	
Capital goods	3.24	2.28	.83	.52	2.88	

* Revealed comparative advantage (RCA) is measured by the ratio (X_{ij}/X_{wj}) / (X_{it}/X_{wt}) , where i = country; j = type of technology export; w = exports of the relevant category for all five countries; and t = all technology exports. The greater the RCA ratio of country in a particular category, the greater its revealed comparative advantage in that category.

Korea is the second largest exporter of LCTS and of capital goods. As previously indicated, some of Korea's exports, particularly in manufacturing project exports and DFI, appear to transfer idiosyncratic manufacturing technologies created through experience-based adaptive engineering. And there is evidence that Korea's participation in construction and in project exports is changing over time toward increasingly more complex and sophisticated activities.

Korea's participation in foreign projects with firms from developed countries appears to be an important vehicle for acquiring additional capabilities and new technologies. Many of the large exporters often undertake projects for foreign customers in areas in where they have not yet acquired sufficient capabilities in the local market. They overcome their lack of previous experience by relying on foreign technology suppliers in the critical areas where their own capabilities may be lacking. They use foreign project experience to assimilate new capabilities so that they can supply a wider range of elements in subsequent local and foreign projects. 29/ Thus, while Korea's exports exploit its existing comparative advantage in embodiment activity, they are also dynamically changing its comparative advantage (See Westphal, et al. 1984). We will return to examine more closely the interaction between trade and the development of local technological capability in the next section.

Although construction exports also account for the largest share of India's technology exports, India's comparative advantage appears to be in DFI, LCTS, and project exports. This is interesting, because on the basis of

29/ Good examples are shipbuilding, construction, and various project exports such as cement and desalination plants.

its low wages and abundant labor, one might have expected India to have a strong advantage in construction exports. Instead, India's comparatively strong performance is in exports that involve considerable technical services. In particular, India has the largest volume of LCTS, manufacturing DFI, and manufacturing project exports, all of which include many technological elements as opposed to just embodiment activity. 30/

India's revealed comparative advantage in categories that involve more technical services than embodiment activity may be explained, in part, by various characteristics of the Indian economic environment. Compared to the four other countries, India has practiced the most restrictive policies towards inflows of foreign technology — whether in the form of DFI, licenses, patents, consulting, and technical services, or capital goods (see the next section). It has also had the strongest government action to promote the development of local consulting and engineering services and of local research facilities, giving it the largest local R & D infrastructure. Moreover, India has a relatively well developed technical base, with the largest absolute stock of scientists and engineers among the five countries. But it has a highly regulated economy with many infrastructural constraints that stifle the effective deployment of its high technical capabilities. For example, the growth of some of the most efficient firms is constrained by controls on capacity expansion and maximum size. More generally, poor quality of local inputs, high local content requirements, difficulties in obtaining imported inputs, unreliable local delivery schedules, power shortages, and transportation bottlenecks reduce its international competitiveness in product

30 Note that India's project exports are about equally split between manufacturing and social overhead projects, while more than 80 percent of Korea's are in social overhead sectors.

exports. This is one of the reasons why India appears to do relatively better in technology exports than in product exports compared to the other four countries (see table 1). 31/

Among the Latin American countries, Brazil is the only one with large volumes of technology exports. One of the most striking characteristics of Brazil's export composition is the very high share of capital goods -- the highest among the five countries. Brazil has had the longest and most consistent strategy toward the development of the capital goods sector, certainly among the Latin American countries. In addition, Brazil has the greatest reliance on DFI and foreign licenses as channels for the acquisition of foreign technology (see the next section). This reliance has been particularly strong in the capital goods sector. Brazil's advantage in capital goods thus largely reflects foreign product and process knowledge as well as foreign management combined with local embodiment activity. Its much better performance in capital goods (and to a degree in project exports) than in construction is also in part the result of stronger fiscal and financial incentives for capital goods exports than for other exports.

Brazil also shows a revealed comparative advantage in LCTS. This largely reflects consulting and technical service contracts for more than $200 million for services to the Nigerian telecommunications sector. These exports are based on foreign technology originally assimilated for use in Brazil. Thus Brazil's revealed comparative advantage in LCTS is somewhat specialized in the telecommunications sector, perhaps because it has the largest telecommunication sector among the developing countries. But Brazil has also developed considerable engineering capability in various industrial sectors

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31/ See Lall (1983, 1984a) for development of this argument.

including chemicals and steel.

Most notable in the case of Argentina's exports is its strong revealed comparative advantage in DFI -- the RCA ratio here is the highest for any category among the five countries. Argentina's strong advantage in DFI can be explained by the lack of political stability in Argentina, which has induced many Argentine industrialists to seek more stable foreign environments in which to exploit the technological capabilities that they have developed at home. Argentina's capital goods exports and its LCTS exports reflect the relatively high levels of human capital and industrial infrastructure that Argentina had already reached a generation ago -- indeed, Argentina is the country in the group with the longest industrial tradition. But though many of its industries used to be far ahead of those in other countries, they now lag considerably behind. Early efforts to strengthen a wide range of domestic technological capabilities were abandoned to focus on few activities (such as nuclear energy) to which extensive support continues to be given. And much of Argentina's early advantage in terms of qualified manpower (see the next section), has been lost -- at least temporarily -- through emigration during the politically difficult years of the last decade. Like Brazil's, Argentina's capital goods exports owe much to the important role of foreign multinationals and to the LAFTA regional preferences. In turn, its relatively poor performance in project exports may, in part, be due to the narrower definition of project exports used in Argentina as compared with the Asian countries. The poor performance in construction exports is probably related to the fact that Argentina has the highest labor costs among the five countries.

Contrary to what one would expect, Mexico appears to have a revealed comparative advantage in capital goods. In fact, Mexico has the least developed capital goods sector among the five countries. Most of its capital goods exports are from multinational firms. Some of these exports are made under special compensatory export arrangements imposed by the government in exchange for the right to produce for the protected local market. Mexico's very poor performance in project exports is attributable to its underdeveloped capital goods industry, which is one of the constraints most often cited by Mexican firms as limiting their technology exports. Mexico's relatively poor performance in construction exports appears to be related to the fact that its participation in foreign markets is mostly to offset the fluctuations of the six-year internal economic cycle linked to the length of the Mexican presidential term. It also reflects the increasing overvaluation of the Mexican peso from the late 1970s until the major devaluations of 1982.

The most striking aspect of Mexico's technology exports is not apparent from the tables presented. It is Mexico's exports based on local product and process innovations in steel, petrochemicals, pulp and paper, and textiles. 32/ Beyond noting the influence of cultural and educational factors deriving from close ties to and proximity with the U.S. (see Kamenetsky, 1976.), we are not yet sure how to account for what the apparently greater incidence of innovation based exports in the case of Mexico.

32/ See Dahlman and Cortes (1984) for short case studies on some of these innovation based exports.

5. Trade, strategy, and technological development

Our analysis of technology exports suggests various differences in technological capabilities among the five countries. These are related to different country strategies toward the import and export of elements of technology. After examining differences toward technology imports, this section summarizes lessons about the interaction between trade in the elements of technology and technological development -- lessons learned from firm-level studies of technology exporters -- and draws some conclusions about country strategies.

5.1. Technology imports

Table 5 shows the relative importance of aggregrate technology inflows into each of the countries. 33/ The inflows reveal some important differences in strategies between the Asian and the Latin American countries and between India and Korea. The three Latin American countries have relied more heavily on DFI and on imports of disembodied technology (as indicated by payments for licenses, royalties, and technical services) than have India or Korea. However, Korea has relied the most heavily on imports of embodied technology in the form of capital goods, while India has relied the least on such imports. The pattern for capital goods imports in Argentina and Brazil is more similar to India's; that in Mexico, to Korea's. These differences are in part related to the level of maturation of each country's capital goods sector. India, Argentina, and Brazil have older and more developed capital goods sectors; Mexico the least developed. Korea has used extensive capital goods imports to rapidly build up its modern and efficient industrial base,

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33/ Because of the different sizes of the economies, each flow has been normalized using a relevant macro-economic variable.

Table 5: Comparative Indicators of Inflows of Foreign Technology

A. Stock of direct foreign investments as percent of gross national product (GNP) and percent of gross domestic investment (GDI) stock 1/

	Argentina		Brazil		India		Korea		Mexico	
	% GNP	% GDI Stock	% GNP	% GDI Stock	% GNP	% GDI Stock	% GNP	% GDI Stock	% GNP	% GDI Stock
1967	10.6	7.4	11.8	9.1	3.1	2.3	1.6	1.7	7.3	6.2
1977-79	4.8	2.6	6.6	4.2	2.1	1.1	3.1	2.4	5.6	3.3

B. Payments for disembodied technology as percent of gross national product (GNP) and as percent of gross domestic investment (GDI)

	Argentina		Brazil		India		Korea		Mexico	
	% GNP	% GDI	% GNP	% GDI	% GNP	% GDI	% GNP	% GDI	% GNP	% GDI
1973-75	.10	.90	.20	.77	.04	.18	.10	.40	.20	.80
1979	na	na	.40	1.70	.08	.36	.20	.40	.30	.90

C. Imports of capital goods as percent of gross domestic investment (GDI) and ratio of exports of capital goods (X) over imports (M) of capital goods 2/

	Argentina		Brazil		India		Korea		Mexico	
	% GDI	X/M	% GDI	X/M	% GDI	X/M	% GDI	X/M	% GDI	X/M
1965	5.3	6.8	4.6	11.0	10.3	1.5	13.0	5.1	14.5	1.9
1970	4.5	12.2	9.4	9.2	4.6	15.5	22.8	4.5	12.6	8.7
1975-79	7.5	34.8	9.3	29.7	5.4	27.8	27.3	33.0	11.7	10.0

1/ The stock measure of GDI is obtained by summing GDI in current U.S. dollars from 1960 to the year for which the foreign investment stock is reported.

2/ Same definition of capital goods as in table 1.

Sources: Project files summarizing data from diverse international sources, World Bank Research Project Ref. No. 672-48. Details available upon request from the authors.

including its own capital goods sector (particularly in the later half of the 1970's). 34/

Although all countries obtain elements of foreign technology indirectly through such means as sending students abroad and through imitation and copying, it appears that such indirect transfers have been more important in Korea than elsewhere. A key source of this type of transfer in Korea has been product design technology and technical assistance in process technology and management received "free of charge" from foreign buyers of Korea's exports. 35/ Such informal transfers received through trade contacts have been particularly important because of Korea's much more export oriented economy (see table 1).

Table 6 presents comparative data on human capital formation and R & D activity that provides some insights into how effectively the countries have been able to assimilate technology from abroad. Because of its very large population, India has the largest absolute number of people trained above the secondary level as well as the largest stock of scientists and engineers in the population. However, relative to its size, Korea stands out in having the highest ratios of: secondary school enrollment; postsecondary students enrolled abroad; engineering students in post-secondary education; scientists and engineers per million population; and scientists and engineers in R & D per million population. Even more remarkable is the rapid growth in most of

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34/ Note that even though Korea has the highest ratio of imports of capital goods to GDI, its ratio of capital goods exports to capital goods imports has increased the fastest, and is in fact the second highest, reflecting its rapid development and high degree of specialization.

35/ See the sample survey results of Korean exporters and the case studies reported in Westphal, Kim and Dahlman (1984).

Table 6: Comparative Indicators of Human Capital and of Local R & D Resource Allocation

	Argentina	Brazil	India	Korea	Mexico
Secondary students as percent of secondary age population					
1960	26	13	19	27	11
1970	37	31	28	41	15
1978	46	17	30	68	37
Post-secondary students as percent of eligible post secondary population					
1960	9	1	2	4	2
1970	11	4	5	6	5
1978	18	10	9	9	9
Engineering students as a percent of post-secondary students					
1960	15	19	5	30	10
1970	10	12	5	20	na
1978	14	12	na	26	14
Post secondary students abroad as % of all post-secondary students					
1970	1.0	1.0	1.0	2.0	1.0
1975-77	0.3	0.7	0.3	1.7	1.0
Scientists and engineers per million population					
Late 1960's	12,786	5,648	1,885	6,939	6,596
Late 1970's	16,525	5,850	2,989	21,965	6,910
Scientists and engineers in R & D per million population					
1970	274	na	na	169	78
1974	323	75	58	291	101
1978	313	208	87	398	na
Expenditures on R & D as percent of GNP					
1973	0.30	0.39	0.40	0.30	0.20
1978	0.40	0.62	0.60	0.67	na

Sources: Project files summarizing data from diverse international sources, World Bank Resource Project Ref. No. 672-48. Details available upon request from the authors.

these ratios in the last two decades in Korea, reflecting very high investments in technical human capital formation.

It thus appears that Korea's capacity to assimilate and make very effective use of imported technology owes much to its strong base of technical human capital and the high educational level of its population in comparison with the other countries. Another salient feature revealed by the table is that Korea also has the highest expenditures on R & D among the five countries. Although there are well known problems in the measurement and interpretation of R & D statistics, other data confirms that Korea has been rapidly increasing its expenditures on local R & D in order to keep abreast of new technology and to have the capacity to assimilate more advanced technology.

5.2 Technological development at the firm level

Studies of the acquisition of technological capability at the firm level yield various insights into the relationship between trade in the elements of technology and technological development that have interesting policy implications. Several of the "lessons" have to do with efficiently utilizing foreign technology. To give the lessons concrete expression, we will first present summaries of case studies representative of the main types of technology exporting firms. These summaries illustrate some principal lessons that come from case studies of successful firms -- be they technology exporters or not.

a. A Mexican producer of glass products

This firm acquired glassmaking technology through a licensing and technical assistance contract with a U.S. firm which provided the process technology and the design for the first production line. A Mexican team that had received considerable training from the foreigners was set up to adapt the technology to the smaller local market and to increase its productivity. Working with a local capital goods producer, they expanded the product line and considerably improved the productivity of the originally imported process. Some of these improvements were licensed by the Mexicans to another U.S. producer for use by its affiliates in other developing countries. The productivity of the adapted process was also the basis for exporting a turnkey plant to Brazil. The codification of the technology required for that export and the experience of setting up the foreign plant helped the Mexicans to establish a larger plant in Mexico on their own. Various adaptations developed at the Brazilian plant (including energy savings motivated by higher energy prices there) were later introduced in the Mexican plants. The positive experience with the technoloy export eventually contributed to the establishment of an R & D center by the firm in Mexico.

b. A Korean construction firm that diversified into shipbuilding

The largest Korean construction firm, which started as a small subcontractor building barracks for the U.S. army in Korea and grew by undertaking larger and increasingly more sophisticated construction projects locally and abroad (often in association with foreign companies) was urged by the government to diversify into shipbuilding. On the basis of its reputation as a very efficient construction company, its first contract was to build a 260,000 ton supertanker for a foreign client; the largest ship ever built in Korea until then had been 12,000 tons. It hired local Korean shipbuilders, bought the design for the ship and technical assistance for establishing its shipyard from British firms, sent many of engineers abroad for training, and successfully finished the ship and the shipyard at the same time. It then got a contract to produce six ships for a large Japanese shipbuilder facing excess demand. The contract involved receiving technical assistance, design and production manuals, and training of its engineers. The shipbuilder has since gone on to produce ships for many countries and to buy and license technology from many suppliers to meet new and constantly changing needs. It also hired a Japanese professor who was instrumental in designing a production system emphasizing the interpenetration between production and design, and developing a mass production type of shipbuilding process which has given the firm a great cost advantage. Furthermore, although it initially imported all components, it now produces its own ship engines under foreign licenses and has diversified into offshore structures and industrial machinery.

c. An Indian consulting engineering company:

This firm was started by an Indian engineer with training and work experience in the U.S. It was established at a time when India was launching large capacity expansion in steel and there were no local consultancy and design firms. Its first three years of work were for a large privately owned Indian steel firm. Initially its sources of technology were previous staff experience and on-the-job learning, but subsequently these sources expanded to include project sponsors, foreign process technology suppliers, foreign and local capital goods suppliers, specialized training in India and abroad, its own technical effort, feedback from clients, and contacts with local R & D institutes. Like most engineering firms in other countries, the main obstacle to its development has been lack of a market large enough to provide the repetitive build-up of experience. To overcome the limited size of the local market it has diversified from steel into other areas and also has started selling services abroad. It has offices in Europe, Latin America, and the Middle East to get access to foreign markets and has undertaken numerous foreign projects. Besides giving the firm a larger market for its capability, foreign projects have had the added benefit of exposing the firm to new technologies and equipment, which have been useful for future local and foreign projects.

As seen in these examples, one of the key characteristics of the successful technology exporting firms in all countries is that they complement local technological capabilities with foreign technological elements. Even in India, virtually all technology exporters originally made, and continue to make, extensive use of foreign technological elements. The first lesson then is that successful technological development requires access to foreign elements of technology. The use of foreign technological elements makes it possible to undertake projects that could not have been undertaken, unless at great cost. Complementary use of foreign technological elements permits the earlier establishment of internationally competitive industries than is possible through a more autarchic strategy.

The second lesson is that conscious effort is necessary to assimilate, adapt, and make effective use of the technological elements obtained from abroad. The effort to master foreign technological elements requires a firm to identify where it has a possibility of becoming competitive and to accumulate the human capital needed for developing local capabilities in the selected areas. Imports of foreign technological elements can be used to further build up local capabilities through imitation, apprenticeship, and other forms of learning. The more technologically dynamic firms in all the countries are known for making extensive use of foreign technological elements while investing heavily in local technological effort and technical training, and for using what they learn at each stage to re-evaluate their strategies in the technological area.

A third lesson is that technology exports themselves may facilitate technological development. Many technical services are characterized by extreme economies of scale due to their specialized nature. Exports make it possible to establish capabilities that could not otherwise have been established without tremendous sacrifice of scale economies. Furthermore, since experience is a critical input in acquiring most technological capabilities and in improving product and process technologies, exports also have the advantage of permitting faster accumulation of experience in more diverse circumstances, which can be expected to reduce costs through learning and to deepen existing capabilities. Moreover, exports of technology may also be a way of acquiring new technological capabilities through imitation of and apprenticeship in tasks undertaken by foreign collaborators.

A final lesson emerges from comparing the firm studies across the sample of countries. Considerable technological effort may take place regardless of the trade policy environment. However, there appear to be important differences in the nature and direction of the technological effort that is undertaken. Under a protectionist regime, much of the effort is deployed to overcome policy-induced constraints and to substitute for imports -- raw materials, components, products, and elements of technology -- which often could have been obtained at lower cost from abroad. For example, while some of the technological effort that has been undertaken by firms in Latin America is dictated by market needs and local input supply conditions, much has been undertaken specifically to overcome protectionist policies. These policies have included local content requirements, promotion of technological self-reliance, and restrictions on imports of foreign technological elements. It appears that some of the efforts induced by these policies have been socially wasteful in the sense that they would not have been warranted in a less restrictive regime (see Teitel 1984).

In an export-led economy there is greater pressure to deploy local technological effort to reduce costs, to upgrade quality to meet product specifications at competitive prices, and to keep up with changes in the world technological frontier. The point is not that there is no technological effort to reduce costs and improve quality in protected economies, the point is rather that much of the effort may be diverted to overcome policy induced-constraints unrelated to potential comparative advantage. Moreover, even in countries with more protectionist environments, firms that sell to both domestic and foreign markets appear to undertake more technological effort than those that do not, and to marshall it to meet the stricter cost and quality requirements demanded by the foreign market.

5.3 Country trade strategy and technological development

With the insights obtained from the firm-level case studies we can draw some conclusions about country strategies. As previously stated, Korea has by far the largest volume of technology exports. This is in part due to the government's more explicit strategy toward promoting such exports. 36/ The Korean government appears to promote these exports because they are thought to be an important vehicle for acquiring additional technological capabilities, not only because of the benefits of being able to participate in a larger market, but because of the possibility of using that participation to broaden and deepen Korean capabilities.

36/ See Westphal et al. (1984) and Westphal, Kim, and Dahlman (1984).

Such use of technology exports is in contrast to the experience of the other countries. Their technology exports are usually repetitions of what they have already done in their home markets. In the case of India, for example, as Lall (1983, pp. 28-29) puts it:

> "...its best firms find markets for their accumulated technology in some Third World countries, but these are small (and shrinking) markets: technology exports and technological development can, in other words, co-exist with growing technical backwardness... The export of some of these [technological] capabilities to lesser industrialized countries should not conceal the fact that many of them are too obsolete to be beneficial to the exporting country itself."

More generally, Korea has used both imports and exports of elements of technology to accelerate its own technological development and to achieve very rapid industrialization. It appears that the pressure of having to compete and increase market shares overseas is one of the key determinants that motivates Korean firms to assimilate foreign technology more thoroughly and to focus on technological efforts that lead to greater productive efficiency. 37/ India has been more restrictive toward imports of technology and has not made very effective use of exports to broaden its technological capability. It has a broad base of technological capabilities in many sectors. But India's bias toward technological self-reliance has condemned large sectors of industry to technological obsolescence -- there are limits to what developing country enterprises can do on their own without periodic injections of new elements of foreign technology. 38/ The Latin American

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37/ On the relationship between trade orientation and productivity change, see Nishimizu and Robinson (1984).

38/ See Lall (1983 pp. 26-29) for an elaboration of this argument.

countries have not been as restrictive toward proprietary inflows as India or Korea, but they do not appear to have assimilated foreign technology as thoroughly as Korea. Furthermore, like India, they have not made as effective use of exports of technology in furthering their technological development.

These differences among the countries appear to be linked to different policy regimes affecting all kinds of trade, including that in technology. The general lesson is thus that the policy environment plays a very important role in determining the nature and direction, if not the extent, of the local technological effort that is undertaken. There have to be incentives and pressures for technological improvement. There also has to be the possibility of complementing local technological effort with imported elements of technology. Improvement requires more effort than no improvement, so the environment must compensate the right effort and penalize the lack of effort, or the wrong effort. Barriers to trade can lead to misdirected local technological effort to produce inputs, goods, or technological elements that could be obtained more efficiently through trade. Furthermore, as has been argued above, more active participation in trade may help accelerate local technological development.

6. Summary and conclusions

Technology exports reflect important shifts in the global pattern of comparative advantage. The industrially more advanced of the developing countries are now exporting not only manufactured products but also some of the technology, capital goods, and technical services that until quite recently could only be obtained from developed countries. Technology exports from these countries reflect their increasing industrial maturity and the technological experience that they have accumulated in their industrialization. Except for construction and capital goods, which largely involve embodiment activity, the volume of technology exports is comparatively small, but it has reached appreciable levels in recent years. More significantly, all types of technology exports have been growing rapidly and seem likely to continue their rapid growth, particularly once favorable international market conditions are restored.

Most of the exports involving adapted product and process knowledge as well as management and technical services go to other developing countries and are primarily based on technological needs and experiences which are closer to those required by countries that are following in the footsteps of the exporting economies. Exports involving embodiment activity go mainly to developed countries and are largely based on a cost advantage that has been achieved through upgrading skills, management abilities, and technological capabilities.

As indicated in the introduction, technology exports can be accounted for in terms of the influences of resource endowment, government policy, and firm strategy. We have looked for systematic relationships among these and have found that the relationships are quite complex. The combined impact of these influences can be expressed in a general way in the following terms: overall resource endowment, including the stock of human capital, determines potential comparative cost advantage; firm strategy and country policy affect the realization of potential advantages and the relative profitability of exercising them through different means; strategy and policy aspects influence changes in comparative advantage through their effects on human and institutional capital accumulation.

We have found several relationships between trade and local technological development. The tentative lessons include: the importance of appropriately combining foreign technological elements with local technological effort; the importance of conscious effort in assimilating, adapting, and making effective use of foreign technological elements; the possibility that exports of elements of technology may themselves facilitate greater technological development; and the finding that the trade policy environment can affect the nature and direction of local technological effort, if not its extent.

These lessons have to be confirmed and amplified through additional research. It must be recognized that, while there are benefits to greater participation in trade, it is not easy to compete in the world market in newly established activities. Acquiring experience in order to become competitive takes time and effort. This raises questions of how to stimulate initial efforts and how to insure that there is effective learning leading to competitiveness. Here more research needs to be done about the nature of technical change and productivity improvement at the firm level, about the interplay between trade in the elements of technology and local technological development, about the type of environment which most effectively stimulates appropriate technological effort, and about the best strategies at the firm and the country level to foster technological development.

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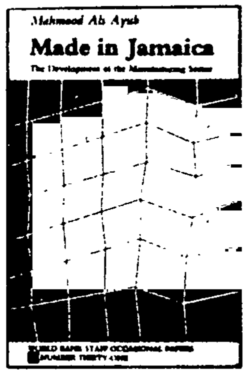

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