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ON SEMI-INDUSTRIALIZED COUNTRIES AND THE ACQUISITION OF TECHNOLOGICAL CAPABILITIES

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"ON SEMI-INDUSTRIALIZED COUNTRIES AND THE ACQUISITION OF TECHNOLOGICAL CAPABILITIES"

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Abstract: The last decades have witnessed a breaking down of the hitherto quasi-monopoly in industrial and technological development by highly industrialized countries. Man-made changes in comparative advantage due to rapid accumulation of human capital, development of technical institutions, and public policies in support of enterprise development and innovation, have led to the emergence of advanced technical capabilities in a number of semi-industrialized countries. Study of selected instances of their technological achievement show that they cannot be adequately interpreted as necessarily requiring the working of a well integrated national innovation system. They seem to be instead, path, or process, dependent, and determined by the circumstantial convergence of requisite skills, appropriate institutions and supportive public policies.

Key words: Industrialization, technology, semi-industrialized countries, innovations.

JEL classification: O14, O31, O32, O33, O38, L60, L63.

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by Simón Teitel

Highly industrialized countries in North America, Europe, and Asia have the potential to succeed in undertaking practically any kind of technological development and eventually bringing to market the results of their R&D[1]. At the other end of the development spectrum is the vast majority of developing countries that are generally incapable of comparable innovation feats. But sufficient evidence is also available about specific instances of successful technological development in selected Asian and Latin-American countries that are somewhere in between, and that we call "semi-industrialized".

I. Is There Sharing of Room at the Top?

Our first step will be to identify a group of semi-industrialized countries that exhibit certain economic, industrial, and technological performance features similar to those observed in highly industrialized countries. For this purpose, we initially pre-selected the top countries in terms of the dollar value of their manufacturing value added. Of course, any such ranking implies the need for an arbitrary cut-off point, and we chose to restrict the sample to the top 25 countries, which, de facto, also implied a value of manufacturing value added of around 30 billion dollars.

[1] Yet a caveat is in order since, for example, as highly developed a country as Japan failed in its attempts to set up an internationally efficient aircraft industry.

Table 1. Ranking by Manufacturing Value Added and Other Industrialization and Economic Indicators

Rank	Country	Mf.VA $	Mf.VA/cap$	GDP $	GDP/cap $
1	USA	1,432,800	5,301	10,065	35,227
2	Japan	895,425	7,083	4,141	32,601
3	Germany	481,315	5,866	1,846	22,422
4	China	355,540	287	1,159	911
5	France	280,223	4,762	1,310	22,129
6	U.K.	246,789	4,179	1,424	24,219
7	Italy	235,087	4,082	1,089	18,788
8	Brazil	151,274	912	502	2,915
9	Canada	105,725	3,489	694	22,343
10	Spain	103,186	2,621	582	14,150
11	S. Korea	97,866	2,108	422	8,917
12	Russia	97,357	663	310	2,141
13	Mexico	81,912	855	618	6,214
14	Taiwan	73,183	3,351	281	12,621
15	India	63,860	65	417	462
16	Nether.	62,061	3,953	380	23,701
17	Switzer.	59,084	8,315	247	34,171
18	Argentina	53,293	1,475	269	7,166
19	Sweden	46,874	5,295	210	23,591
20	Australia	46,658	2,488	369	19,019
21	Belgium	45,366	4,446	230	22,323
22	Turkey	44,106	695	148	2,230
23	Austria	41,935	5,191	188	23,186
24	Thailand	35,771	584	115	1,874
25	Poland	30,129	779	176	4,561

Notes: Manufacturing value added (Mf.VA) in millions of US dollars for 1998.
Manufacturing value added per capita, (Mf. VA/cap) in US dollars, for 1998.
Gross domestic product (GDP) in US dollars for 2001.
Gross domestic product per capita (GDP/cap) for 2001.

Sources: Manufacturing value added and manufacturing value added per capita from UNIDO, Industrial Development Report, 2002/2003, Table A2.14.

GDP and GDP per capita from UNDP, Human Development Report, 2003, Table 12, except for Taiwan, Statistical Yearbook of the Republic of China, 2002, Table 93.

This choice restricts the group to the most highly industrialized countries in Europe, North America, and Oceania, plus Japan, some European countries in transition, as well as a few developing countries in Asia and Latin America, to the exclusion, for instance, of all Sub-Saharan Africa countries[2].

Examination of Table 1 shows that when countries are ranked by the value of their manufacturing value added, two developing countries are among the top ten: China, in 4th place, and Brazil in 8th place. With Russia included among the industrialized countries, the top 25 countries by dollar value of their manufacturing value added comprise 15 industrialized countries, and 10 developing countries, that we shall call semi-industrialized.

The 15 industrialized countries are responsible for 81% of the total dollar value of manufacturing value added by all these countries, and the developing, or semi-industrialized, ten countries, for the remaining 19%. With respect to geographical, or regional, distribution, there are five Asian countries, (China, India, Korea, Taiwan, and Thailand), three, Latin American countries, (Argentina, Brazil, and Mexico), one Middle Eastern-European country (Turkey), and one Eastern European economy in transition (Poland)[3].

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[2] If a lower cut-off point, say of 20-25 billion dollars in manufacturing value added, were adopted, South Africa would be the only Sub-Saharan Africa country making the cut.

[3] Poland has been recently accepted in the European Union.

Table 2. Ranking by Manufacturing Value Added Per Capita, 1998, and Population Data for Same Year.

Ranking	Country	Mf. Value Added per Cap.	Population
1	Switzerland	8,315	7.1
2	Japan	7,083	126.4
3	Ireland	7,043	3.7
4	Singapore	6,178	3.2
5	Germany	5,866	82.0
6	Finland	5,557	5.1
7	USA	5,301	270.3
8	Sweden	5,295	8.8
9	Austria	5,191	8.1
10	Denmark	4,776	5.3
11	France	4,762	58.8
12	Belgium	4,446	10.2
13	United Kingdom	4,179	59.0
14	Italy	4,082	57.6
15	Netherlands	3,953	15.7
16	Norway	3,803	4.4
17	Canada	3,489	30.3
18	Taiwan	3,351	21.8
19	Portugal	2,631	10.0
20	Spain	2,621	39.4
21	New Zealand	2,611	3.8
22	Israel	2,599	6.0
23	Australia	2,488	18.7
24	Slovenia	2,365	2.0
25	Korea, Republic of	2,108	46.4
26	Czech Republic	1,612	10.3
27	Bahrain	1,577	0.6
28	Argentina	1,475	36.1
29	Hong Kong	1,411	6.7
30	Uruguay	1,125	3.3
31	Hungary	947	10.1
32	Malaysia	937	22.2

33	Greece	927	10.5
34	Brazil	912	165.9
35	Mexico	855	95.8
36	Poland	779	38.7
37	Chile	749	14.8
38	Mauritius	739	1.1
39	Turkey	695	63.4
40	Russian Federation	663	146.9

Notes: Manufacturing value added per capita in US dollars. Population in millions.

Source: UNIDO, Industrial Development Report, 2002/2003, Table A2-14.

The rankings by manufacturing value added per capita show some semi-industrialized countries mingling with the highly industrialized countries in the top positions; to wit: Singapore, in fourth place, Taiwan in 18th place, Korea in 25th place, Argentina in 28th place, Hong-Kong in 29th, and Uruguay in 30th.

Due to indivisibilities, critical mass requirements, and economies of scale, prevalent in many industrial and technological activities, a number of countries tilt towards exports to compensate for small size domestic markets, and, consequently, values of manufacturing value added per capita are likely to be higher in countries with small population but significant industrial development. Thus it is not surprising that both industrialized and developing countries include a number of small population countries which are among the top ranked in terms of manufacturing value added per capita. Among highly industrialized countries this is true for number 1, Switzerland, (7.1 million population), number 3, Ireland, (3.7 millions), number 6, Finland, (5.1 millions), number 8, Sweden, (8.8 millions), number 9, Austria, (8.1 millions), number 10, Denmark (5.3 million), and number 16, Norway, (4.4 million). Among semi-industrialized countries we similarly have, number 4, Singapore, (3.2 million), number 29, Hong Kong, (6.7 million), and number 30, Uruguay, (3.3 million).

II. Developing Countries Ranking at the Top in Selected Industrial, Trade and Technology Indicators.

After a number of preliminary inquiries (See, UNIDO 2002/2003, Statistical Annex), a set of indicators was selected to search for the presence of developing countries among top ranking industrialized countries. Those indicators cover manufacturing production, trade in manufactures, as well as technology acquisition and related human capital formation. They are listed and briefly described below.

Table 3. Selected Indicators to Identify Semi-Industrialized Countries

Manufacturing Production	International Trade	Technology Acquisition
-Manufacturing Value Added (MVA)	- Manufactured Exports (MFXs)	-Tertiary Technical Enrolment (TEnr)
-Manufacturing Value Added per capita (MVAcap)	- Manufactured Exports per capita (MFXscap)	-Licensing payments per capita (TLic)
-Technological composition of manufacturing value added (TMVA)	-Technological composition of manufactured exports (TMFXs)	-Enterprise R&D per capita (R&Dcap)

The first two MVA indicators take into account the manufacturing production performance of both, large and small countries, while the third one assesses the "quality" or composition of the MVA. Similar considerations hold for having two quantity, or value, of exports of manufactures indicators, plus one indicator to account for quality, i.e. technological complexity, or difficulty, within a certain volume, or value, of manufactured exports. Technical tertiary enrolment, as a share of total population, attempts to quantify the educational, or human capital formation, effort made by countries to acquire the scientific and technical knowledge required by the new technologies used in production. Licensing payments per capita, tries to measure the financial effort made to pay for new technical knowledge, and enterprise R&D per capita, is supposed to measure the internal effort made to develop and adapt technologies used in production.

Table 4. Developing Countries Rankings in Selected Industrial and Technology Indicators

#	Count	MVA	MVAcp	MfXs	MFXcp	TMVA	TMfX	TEnr	TLic	R&Dcp	#Ind	Avrk
1	Argen	18	28	--	--	--	--	34	29	31	5	28
2	Bahra	--	--	--	--	--	--	27	--	--	1	27
3	Brazi	8	34	23	--	13	31	--	33	27	7	24.1
4	Chile	--	--	--	--	--	--	13	--	--	1	13
5	China	4	--	7	--	24	29	--	--	--	4	15.5
6	Colom	--	--	--	--	--	--	28	--	--	1	28
7	CRica	--	--	--	32	--	32	--	--	35	3	33
8	Egypt	32	--	--	--	--	--	--	34	--	2	33
9	HKong	--	29	32	18	19	28	31	4	--	7	23
10	India	15	--	29	--	12	--	--	--	--	3	18.7
11	Indon	29	--	27	--	--	--	--	--	--	2	28
12	Jamai	--	--	--	--	--	--	--	30	--	1	30
13	Korea	11	25	11	22	9	10	1	19	13	9	13.4
14	Malay	31	32	18	20	11	6	--	6	34	8	19.7
15	Mauri	--	--	--	29	--	--	--	--	--	1	29
16	Mexic	13	35	13	31	--	4	--	--	--	5	19.2
17	Panam	--	--	--	--	--	--	24	35	--	2	29.5
18	Phili	--	--	26	--	--	2	26	--	--	3	18
19	SArab	--	--	--	35	15	--	--	--	--	2	25
20	SAfri	30	--	--	--	33	34	29	--	--	4	31.5
21	Singa	33	4	14	1	1	3	33	14	2	9	11.7
22	Taiwa	14	18	12	12	14	11	5	16	20	9	13.5
23	Thail	24	--	21	34	--	25	--	28	--	5	26.4
24	Urugu	--	30	--	--	--	--	--	--	--	1	30

As shown in Table 4 above, a total of 24 countries made the cut-off rank of 35 in one or more of the above indicators[4]. Perusal of the table and the number of indicators in which each country qualifies, as well as of the last column, with the average rank for each country,

4 Thirty five represents a varying proportion of the total number of countries reporting data for each indicator. These numbers vary between 87 for the first seven indicators, to 65, and 60, respectively, for the last two.

indicates that performance according to the selected criteria is quite lopsided. The countries included can be broken down in four geographical groupings: East Asia, with ten countries, Latin America and the Caribbean with nine countries, Africa, with three countries, and the Middle East, or Arabic Peninsula, with two countries.

A number of countries just meet the cut-off requirement only for one indicator. In Latin America there are four such cases: Chile and Colombia, in Technical Enrolment where they occupy ranks 13 and 28 respectively; Jamaica in Licensing Payments, in rank 30; and Uruguay, in Manufacturing Value Added per capita, also in rank 30. In Africa, Mauritius qualifies in Manufacturing Exports per capita, in rank 29, and, in other areas, Bahrain in Technical Enrolment, in rank 27.

It is easy to dismiss the above group of six countries as not being really representative of strength in the three areas covered by the rankings, i.e. Manufacturing Value Added, Trade in Manufactures, and Technology Acquisition. We shall similarly argue to justify the exclusion of all other countries that qualified in less than five indicators (i.e. in less than one half, or more, of the total number of nine indicators). Thus for example, in East Asia, China qualifies in MVA and MfXs, as well as in the Technological Composition of both MVA and MFXs, but not in the per capita MVA and MFXs, neither in any of the Technology Acquisition indicators. India also qualifies in the MVA and MFXs indicators as well as in the Technological Composition of MVA, but not in any of the other indicators, including those representing Technology Acquisition effort. Indonesia's performance is similar to India's, but it does not qualify in the Technological Composition of MVA. Finally, the Philippines, qualifies in MFXs, and their Technological Composition, plus in Technical Enrolment, but it misses all representation with respect to MVA (its value, its value per capita, and its Technological Composition).

In conclusion, in East Asia we have three country candidates that qualify in all nine indicators: Korea, Singapore and Taiwan; additionally, Malaysia that does so in eight, Hong Kong in seven, and Thailand in five.

In Latin America, besides all the countries qualifying in only one indicator already eliminated, we have Costa Rica, that qualifies in three, MFXs per capita, Technological Composition of MFXs, and R&D per capita, and Panama, only in two: Technical Enrolment and Licensing Payments, i.e. it fails to qualify in all MVA and MFXs indicators. Thus the Latin American group of pre-candidates includes: Brazil with seven, and Argentina and Mexico with five indicators each.

In Africa, Egypt only qualifies in MVA and Licensing Payments, while South Africa does so in MVA and its Technological Composition, the Technological Composition of MFXs, and in Technical Enrolment. In other areas, Saudi Arabia only qualifies in MFXs per capita, and in the Technological Composition of MVA. Thus no pre-candidates can be selected from these two groups of countries.

We may now ask: is the performance of pre-selected developing countries in these indicators competitive with that of industrialized countries? What are their best results, or, better yet, which ones look like areas of potential comparative advantage?

In the search for extraordinary achievement among developing countries, we below we go over each of the indicators and look for countries placing among the top ten in the world.

MVA: Thirteen countries qualified, with an average rank of 20.15. China, in fourth place, and Brazil in eight, took top places.

MVAcap: Nine countries qualified with an average rank score of 26.11. Singapore took fourth place world-wide.

MFXs: Twelve countries qualified with an average rank of 19.42. China occupies the seventh place in the world.

MFXscap: Ten countries qualified with an average rank score of 23.4. Singapore took first place in the world.

TMVA: Ten countries qualified with an average rank of 15.1. Singapore took first place in the world, and Korea the ninth.

TMFXs: Twelve countries qualified, and their average rank score is 17.92. Philippines is in 2nd place, Singapore in third, Mexico in fourth, and Malaysia in sixth.

TEnr: Eleven countries qualified and their average rank score is 22.82. Korea is in first place and Taiwan in fifth, globally.

TLic: Eleven countries qualified with an average rank score of 22.54. Hong Kong is in fourth place and Malaysia in sixth, world-wide.

R&Dcap: Only seven countries qualified with an average rank score of 23.14. Singapore took second place in the world.

Table 5 summarizes the above information. Indicators in which semi-industrialized countries show apparent comparative advantage are: TMVA with a 15.1 average rank, and two countries among the top 10; TMFXs with an average score of 17.92 and four countries among the top 10 in the world; and MFXs, with an average rank of 19.42, and only one country among the top 10.

Clearly, developing countries seem to be at a greater relative disadvantage in technology acquisition than in manufacturing production or trade in manufactures.

Table 5. Top Qualifying Developing Countries According to Nine Indicators

Indicator	# of Qualifying Countries	Countries in Top 10 Places	Average Rank
MVA	13	2: China, 4th, Brazil, 8th	20.15
MVA cap	9	1: Singapore, 4th	26.11
TMVA	10	2: Singapore, 1st, Korea, 9th	15.1
MFXs	12	1: China, 7th	19.42
MFXs cap	10	1: Singapore, 1st	23.4
TMFXs	12	4: Philippines, 2nd, Singapore, 3rd, Mexico, 4th, Malaysia, 6th	17.92
TEnr	11	2: Korea, 1st, Taiwan, 5th	22.82
TLic	11	2: Hong-Kong, 4th, Malaysia, 6th	22.54
R&D cap	7	1: Singapore, 2nd	23.14

Singapore is the undisputed star, qualifying among the top ten countries in the world in five indicators, with two first places, and one each, second, third and fourth places in the others. China is among the top ten countries in two indicators, Korea and Malaysia also in two, and Brazil, Hong-Kong, Mexico, Philippines and Taiwan in one each.

The pre-selection is thus restricted to East Asian and Latin-American countries. Among the Asian countries, although Singapore seems to be superior in terms of average rank: 11.7, and number of placings among the top ten countries in the world, it must be excluded because of its small population (4.1 millions) which induces its strong export orientation and justifies its low performance in the MVA indicator. Thus Korea and Taiwan, that also qualified in all nine indicators, and have quite low average ranks[5], seem to be the best candidates to represent East Asia.

[5] Meaning of course that they are close to the top performers.

In Latin America, Brazil is the undisputed leader in terms of number of indicators for which it qualified, while Argentina and Mexico share second place with five indicators each. Argentina missed all trade (exports of manufactures) indicators, while Mexico, missed all those pertaining to technology acquisition. Given the purpose of our work, Mexico does not seem to be a good candidate. Argentina and Brazil then remain as candidates for Latin America to join Korea and Taiwan for the case studies part. Table 6 summarizes pertinent information on the four pre-selected countries.

Given the apparent lack of similarity between the two groups of countries and their regions, in terms of both factor endowments and economic policies, it might be hard to accept, prima facie, that we are in the presence of comparable
levels of achievement. We seem to be suggesting that significantly different economic development paradigms can lead to similar results.

Thus the countries in East Asia belong to a group of economies, sometimes called the "Asian Tigers", that following the Japanese example adopted an industrial export-led growth strategy well-suited to their limited domestic markets and sparse natural resource endowments. These countries were responsible for the so-called "East Asian economic growth miracle"[6].

Table 6. Preselected Semi-Industrialized Countries

Country	Population (millions)	GDP per cap. US$	Average Rank
Argentina	37.5	8,174	28/5
Brazil	174.0	4,626	24.1/7
Korea	47.1	13,199	13.4/9
Taiwan	22.3	12,621	13.5/9

Sources and Notes: Population data, UNDP, 2003, for Argentina, Brazil and Korea. Statistical Yearbook of the Republic of China, 2002, for Taiwan. GDP per capita is from World Bank, World Development Indicators. It is in constant 1995 US dollars and for the year 2000. The data for Taiwan is from the same source as population and is in current US dollars for the year 2001.

6 See, Wade, 1990, and World Bank, 1993.

On the other hand, countries in Latin America have been chastised for their inward-orientation behind protective walls that often led to inefficiency and only sporadic growth spurts.

Although the above broad-brush characterization contains some truth, the record of the period 1950-1980 shows about equal average yearly rates of economic growth for both regions of around 5.5% per year. (Teitel, 1992, ch. 12). Moreover, while an implicit dichotomy between supporting import substituting industries and an export oriented strategy is generally assumed, the East Asian countries also went through an import substitution phase, and, in Latin America, many of Argentina's and Brazil's successful export industries were part of a prior import substitution growth push (Teitel and Thoumi, 1984)[7].

[7] It is also worth noting that entering the new millennium, the most outstanding economic performances belong to two large, subcontinental, giants, China and India, with huge populations and large domestic markets, that have recently adopted economic liberalization policies. China's growth strategy is nevertheless strongly dependent on reaching world export markets.

III. Case Studies

Case studies will be drawn from semi-industrialized countries in Asia and Latin America. As mentioned above, those selected are: in Asia: Korea and Taiwan, and in Latin America: Argentina and Brazil.

While examination of specific cases in a few countries hardly qualifies as a representative sample, we are restricting ourselves to countries with a relatively high proportion of value added in manufacturing, substantial diversification in industrial output and exports, plus some significant technological assets and achievements.

A. Argentina. Nuclear Engineering

Argentina's traditional accumulation of human capital and institutional strength in agronomic sciences, best exemplified by the work carried out at the National Institute of Agricultural Technology (INTA), as well as in medicine and the natural sciences, where the country earned three Nobel prizes[8], has more recently been extended to engineering and technology fields, such as nuclear energy and nuclear engineering. In this case, we can observe the confluence of capable and highly trained human resources, the "esprit-de-corps" and leadership of the institutions involved (essentially CNEA), as well as the impact of appropriate support policies influencing results via the allocation of funds to carry out projects with significant risk, but also potential for substantial technological learning.

Argentina's record in the nuclear power field is not an unblemished one. After World War II, a scientific impostor refugee, Dr. Richter, convinced President Juan D. Peron that he had developed a process enabling nuclear energy to be bottled in regular glass bottles for distribution and consumption (sic). The direction of the Comision Nacional de Energia Atomica (CNEA) was subsequently entrusted to the Navy and it also benefited from the services of some very talented and hard-working civilian managers.

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[8] Unique among developing countries, Argentine scientists have earned three Nobel prizes: in medicine and physiology by Houssay in 1925, in chemistry in 1970, by Leloir, and again in medicine and physiology in 1984, by Milstein.

Case Study: INVAP[9]

The sale in June of 2000 of a nuclear reactor worth 180 million dollars to the Australian government, signaled the peak in a series of similar, though smaller, achievements of Argentina's nuclear engineering industry. The projected reactor will be destined to research and the production of radioactive isotopes for medical and industrial applications. INVAP, a public enterprise established in 1976, in Bariloche, by the National Atomic Energy Commission (CNEA) of Argentina and the government of the Province of Rio Negro (where its laboratories and industrial plants are located), won the contract in competition with firms based in Canada, France, Germany and the United States. The project will demand more than a million man/hours spread over a construction time of about 5.5 years. INVAP will be heading a consortium with Australian firms in the fields of architecture, engineering and instrumentation. The civil engineering works will consist of four buildings with about 12,000 square meters of covered space, and the reactor will have a 20% enriched uranium nucleus.

Besides producing radioactive isotopes for medical research and treatment, as well as other industrial applications, a research and teaching center in the use of neutron technologies will be set up for use by Australian science and engineering students. The future installation will also be able to provide materials testing services using neutron activation techniques, as well as irradiation services for agriculture and industry.

As stated above, this is not the first such sale of atomic energy technology from Argentina. Similar, though smaller, nuclear reactors have been sold to Peru, Egypt and Algeria. The process of acquiring mastery of nuclear engineering technology started way back, in 1951, with the creation of the National Atomic Energy Commission, and the vehicle adopted was via the construction of atomic energy power plants. Although these plants were contracted on a turn-key basis, a deliberate process of learning was undertaken both at the design and construction sites, through interaction with the German firm supplying the technology, as well as by sending technical personnel abroad to study and acquire experience in the nuclear field.

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[9] Information from La Nacion, 2000, Martinez Vidal, undated, INVAP web-page, and Capdevila, 2002.

The two first atomic plants for electric generation built in Argentina, Atucha I and Atucha II, went into operation in 1973 and 1983 respectively. From the very beginning, CNEA realized how important the technological learning process associated with such projects could be for the development of local suppliers and the acquisition of domestic technical capabilities. Thus the contract with Siemens A.G. for the construction of Atucha I, included clauses committing it to buy local parts and services for up to DM 100 million. The acquisitions were earmarked for items in civil engineering, assembly, transportation, insurance, and electro-mechanical parts and components.

Given the likelihood that due to lack of prior experience, diseconomies of scale, etc., local supplies would be more expensive, CNEA agreed to assume the cost differences. Additionally, to make local supplies more competitive with those provided from abroad, a special law was enacted to: exempt such supplies from sales taxes, provide a tax rebate, and also exempt them of prior deposit and surcharge requirements in the case of local supplies requiring imported parts. A review conducted some 2 1/2 years after the above promotional measures were enacted, showed that the original list of 71 competitive items had been expanded to include 25 additional ones, and purchases and work orders for DM 16 million had been locally placed. Among the parts and equipment provided were: heat exchangers, ventilation systems, water treatment equipment, electrical transformers from 1,000 to 1,600 KVA, steel tubing for vapor and high pressure water, condensers tubing, electrical cables, valves and pumps, condenser covers, refrigeration tubing, etc. Up to the time of the review, the CNEA had "bought" the local supplies with an implicit average protection of about 24%, when considering the local factory prices with the tax rebates vis a vis foreign FOB prices, and an average of about 4% when considering the supplies placed at the Atucha site.

The extent of local participation has varied significantly with the type of work and skills required. While in civil construction the extent of local participation was up to 90%, for electromechanical components it was about 12%. It has been estimated that local participation reached about 40% of the total cost. More important, perhaps, for local industry than the physical extent, or monetary value, of its participation, was the realization that it could meet strict quality norms, as well as the scheduling requirements, of such a major project in a new technological field. Following the successful experience with Atucha I, the CNEA devised a promotional program for local participation in the provision of additional selected equipment and parts, as well as the acquisition of advanced metallurgical technologies utilized in the construction of nuclear reactors.

CNEA has had an intensive program for upgrading its human capital; hundreds of scientists, engineers and technicians have been sent for training abroad. It has also developed a large cadre of local subcontractors. As mentioned above, the acquired engineering design and construction capabilities in the nuclear power field are now being marketed by a separate firm, INVAP, which employs more than 300 professionals and conducts R&D for CNEA as well as for private industry. Besides its strength in nuclear engineering, INVAP has a significant aerospace program, having built several satellites meeting NASA specifications, and is also active in a number of other industrial applications such as the development of food conservation processes, and the design and construction of industrial waste disposal facilities.

Although further expansion of the nuclear power sector in Argentina might be limited, inter alia, by the discovery of substantial natural gas fields, the development of high quality R&D and engineering capabilities for nuclear peaceful applications is now finding its rewards in successful exports following bidding for large international projects.

B. Brazil. Aeronautical Industry

Areas of relative technological success in Brazil, include, EMBRAPA in agro-technology; CTA in the development of civilian transport jet aircraft (successfully applied by EMBRAER), plus rocket fuel, and gaso-hol based engines; the arms industry (with its exports to Middle East and neighboring countries); segments of the steel industry, well established in major export markets, and the automotive industry, after relocations within MERCOSUR, with successful technological adaptations that find application in neighboring and other developing countries[10]. Mention should also be made of the Brazilian generics pharmaceutical industry, which, similarly to those of India and South Africa, can produce, at low cost and with the required quality standards, the equivalent of many of the patented drugs now used in AIDS treatment programs across the world. In terms of sheer technological and

[10] On the other hand, Mexico, also a large recipient of FDI by major MNCs, has its automotive industry set up mostly to supply the North American market within the NAFTA framework.

entrepreneurial achievement though, EMBRAER clearly takes the place of honor among all above mentioned accomplishments.

Case Study: EMBRAER[11]

Founded as a public enterprise in 1969, EMBRAER's first popular commuter plane, the 19 seat EMB-110, known as the "Bandeirante", was originally introduced in the US in 1978. At that time, from a total production run of 500 planes, about half were exported, with 126 registered in the US by 1983. Since the introduction of the Bandeirante, EMBRAER has produced more than 5,000 aircraft, and a substantial proportion of them have been exported to foreign markets.

The US is the largest market for commuter aircraft with about a 60% share of the total aircraft demand world-wide. USA's plus Canada's demand accounts for about 3/4 of total world demand. Given the dominant size of the US market, its regulations critically affect the production of commuter aircraft. A specially important FAA regulation was the requirement that, for safety reasons, an aircraft seating 20 or more passengers had to have at least one flight attendant. Not surprisingly, a strong demand ensued for aircraft seating 19 passengers. This was the market niche EMBRAER entered with the Bandeirante plane.

The economics of the industry was strongly affected by the Middle East oil crisis of the early 1970s. Relatively low fuel costs had made the relationship between passenger carrying capacity and labor costs (maintenance and operating crews), the critical factor in aircraft selection during the 1960s. From the early 1970s to the early 1980s, fuel costs rose from around 13% to about 50% of direct operating expenses. Thus fuel efficiency in relation to carrying capacity and distance travelled acquired much greater importance. Relatively fuel-inefficient aircraft in use during the 1960s, such as the DC-8 and Boeing 707, were forced out of regular service while smaller, more fuel-efficient aircraft, took their place for medium distance hauls.

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[11] Hess, 1997, EMBRAER website.

The market for commuter aircraft was also substantially boosted in the US by deregulation of the airline industry in 1978. Prior to that, with prices fixed by the government, price discrimination by routes was quite common, with higher prices set on international, or long distance, routes, used to finance lower prices in shorter routes. Deregulation made it less profitable to operate short-haul routes with regular aircraft carrying a reduced number of passengers per plane, and with the increased competition that ensued the airlines could not continue subsidizing their shorter distance routes with higher fares for the international, or longer distance, routes. Smaller commuter airlines stepped in to fill the void left by the larger carriers in catering to destinations with a low number of passengers, and small, but efficient, aircraft were required for that purpose. With the major US aircraft producers (Boeing, MacDonnell Douglas, and Lockheed) not participating, the field was left to smaller international firms such as Fokker/Fairchild, Saab, De Havilland, British Aerospace, Dornier (Germany) and CASA (Spain). This group was joined by EMBRAER which at the time of deregulation in the US was a less than a decade old firm with just one certified commuter plane, the 19 seats turbo-prop Bandeirante.

The Brazilian government supported the development of EMBRAER to ensure that it would not fail as did previous attempts to create an aeronautical industry in the country. Government support was centered around four key areas: protection of the domestic market, help in export promotion, finance, and research and development. Besides an initially high tariff of 50 % (instituted in 1977 and lowered to 20% in 1986) that deterred imports of commuter type aircraft for Brazilian airlines[12], the government also enacted a law of "similars" which prohibited, with some exceptions, the acquisition of foreign planes by the public sector when a domestic substitute was available. These protective policies were effective in shutting out imports of commuter planes into Brazil. Whereas US suppliers sold about 600 planes to Brazil in 1974, and 628 in 1975, they were only able to sell 43 planes during the decade 1976-1985.

The policy of helping to project the firm abroad was not only successful in penetrating key international markets, but was also instrumental in gaining access to important

[12] The level of real protection against imports was considerably higher than the nominal tariffs since other duties and tariffs, not specific to the aircraft industry, simultaneously applied.

technologies and partnerships which in turn brought new customers and markets. As regards finance, besides supporting specific projects via FINEP programs, the government offered special tax incentives for private investors in EMBRAER who were required, in return, to leave part of their earnings in the firm for R&D purposes. Finally, but perhaps most importantly, EMBRAER had access to state-supported aeronautical engineering and aerospace R&D institutes (CTA and INPE) which were responsible, together with EMBRAER's technical personnel, for the designs of its new planes. EMBRAER was charged a small fee for the use of these facilities, but the arrangement was very convenient since the institutes were located close to EMBRAER's physical plant. The design for the Bandeirante originated in CTA, and was successfully transferred to EMBRAER following its creation in 1969.

Besides design, the technologies required to stay abreast in the aircraft industry include: avionics, advanced metallurgy and metalworking materials, and assembly techniques. To obtain the technological assets it required EMBRAER resorted to licensing, international partnerships, subcontracting agreements, and local R&D. Licensing: EMBRAER signed an agreement in 1975 with Piper Aircraft to produce various Piper plane models for the domestic market. During the period 1975-1985, an EMBRAER subsidiary produced 1,800 Piper airplanes. Manufacturing techniques were also transferred, and, by the 1980s, about 70% of the Piper aircraft parts were manufactured locally. Similar arrangements were also made for military aircraft. Through a license agreement with the Italian firm Aermacchi, EMBRAER produced the twin-seat light attack plane EMB-326 Xavante derived from the Italian model MB 326. Production of the Xavante was licensed in 1970, and in 1981, when the production line was closed, EMBRAER had produced 166 planes. Besides being used by the Brazilian armed forces, the Xavante was exported to Argentina, Paraguay and Togo. International Partnerships: The manufacture with two Italian firms, Aeritalia and Aermacchi, of the AMX light attack aircraft is worth mentioning among the partnerships with manufacturers in industrialized countries. Each company produced part of the plane with EMBRAER being in charge of some of the most complex parts, including the wings, electrical system and pylons and external tanks. The AMX is already in service in Italy and Brazil, and a number of military forces have expressed interest in its design. Subcontracting agreements: EMBRAER has done extensive manufacturing work in subassemblies for large airliners (beyond the size of those it produces). Thus it has manufactured the outboard flaps for the McDonnell Douglas MD-11, (made of carbon fiber composite), and has also produced nose-wheel doors and other components for the Boeing 747. In 1976, in exchange for the purchase of Northrop F-5E fighters, the Brazilian government required production offsets including the production of tail assemblies by EMBRAER. Metal-bonding technologies were transferred with that agreement. Domestic R&D: The above not withstanding, the most important technology source for EMBRAER has been domestic R&D. The state-supported aeronautical research institutes have been the source of many technological advances incorporated in EMBRAER's aircraft. Moreover, it can be argued that collaboration with foreign manufacturers was possible precisely because of EMBRAER's previous success with planes of its own design[13]. Thus by entering into strategic partnerships, EMBRAER was able to gain important new customers and access to cutting-edge technologies, and by having a high quality indigenous design group it brought a valuable asset to the bargaining table.

Probably the main lesson to be derived from EMBRAER's experience has to do with the strategic advantage it enjoyed because of its own design and technological capabilities. An important difference with other developing countries firms manufacturing high-technology goods, is that they generally rely on foreign MNCs for their technologies rather than manufacture according to their own designs, as did EMBRAER in a majority of cases. These capabilities were also key assets when negotiating joint ventures, licensing, and subcontracting agreements. Very important also, specially in the initial stages, was the protection granted in the domestic market which enabled the firm not only to plan ahead with a fair degree of certainty about the viability of its projects, but also permitted the attainment of economies of scale in production, plus the revenue to undertake significant R&D investments. It was also important to count with facilitated access not only to the domestic civilian, but also to the military, market, ensuring that it had a significant market outlet, should one of the two segments be doing poorly. Similarly, EMBRAER exhibited strong performance both domestically and abroad, which allowed it to continue with its development projects even when the Brazilian economy was doing poorly.

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[13] According to Mowery, 1987, the Piper licensing agreement only took place after EMBRAER's success with the Bandeirante, and, similarly, the agreement with Italian firms for the production of the AMX military trainer plane, was signed because EMBRAER had already shown the capacity to produce its own version of a military training plane.

In sum, by fielding high quality products capable to compete with those of major subsidized firms from industrialized countries, EMBRAER was able to capture a large share of the US market, the world's largest for commuter aircraft. In 1994 EMBRAER's stock was auctioned to private investors[14], and today it is listed in the New York Stock Exchange. It has become the fourth largest producer of civilian aircraft in the world and was Brazil's largest exporter in 2001, and the second largest in 2002.

C. Korea. Digital Telephony Switching

Korea attained spectacular industrial development in a little over two decades in the process becoming a top producer in world markets of textiles, plywood, steel products, shipbuilding, etc. Korea developed large conglomerates ("chaebols"), such as Daewoo, Goldstar, and Samsung, in major manufacturing fields, as well as firms such as Posco which runs Pohang, the largest steel mill in the world. An initial reluctance to allow FDI in many sectors has been followed, more recently, by a willingness to engage in cooperative efforts with major MNCs to obtain new technologies in emerging fields. The development of digital switching equipment based on its own R&D, and carried out by a government sponsored consortium, clearly constitutes the most important technological achievement attained by Korea so far.

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[14] The privatization path followed by EMBRAER in 1994, goes against an international trend towards greater involvement of the public sector in the industry. The Airbus consortium, for example, now competing strongly with Boeing and other US firms, receives subsidies, protection, and capital investments from the governments of European participating firms. Moreover, most consortium participating firms are nationalized. Saab, besides being the sole manufacturer of military aircraft for the Swedish Air Force, also receives public financial support for R&D. Finally, Canadair and De Havilland Canada (DHC), were both nationalized to maintain a military aircraft industry in Canada,.

Case Study: The TDX Switching Project[15]

This major R&D effort was carried out jointly by the Korean government and private industry, and was instrumental in the country's completion of its automated nation-wide telephone network by 1987.

By adopting digital technologies Korea bypassed the existing, and still prevalent, analogue technologies and did so successfully and in record time. While the government also promoted R&D efforts in mini-computers and dynamic random access memory (DRAM) chips, its biggest success, and the one program that has had a major domestic and international payoff, has been the development of the digital electronic telephone switching system, applied to its own automated telephone system since the mid 1980s. When originally conceived, this project was the largest R&D project ever attempted in the country. Besides the management of large human and financial resources, it demanded close coordination among public R&D laboratories, private sector manufacturers, as well as Korea Telecom, destined to be the first, and main, customer of the system.

Korea had the advantage of not having invested heavily in the infrastructure required for electro-mechanical switching systems, since integrating them with the new electronic (digital) switching exchanges is more expensive, and technically difficult, than building a new electronic switching system from scratch. It was also a fortunate coincidence that the cost of installing digital switching had been falling during the 1980s, and by the time Korea launched its program, it was already significantly lower than the cost of installing analogue switching[16]. On the other hand, it could be argued that digital switching technologies were more difficult, or complex, to develop and implement, because substantial expertise in electronics, semi-conductors, and software were required. Paradoxically, this same feature also made it attractive to Korean planners since once a qualified R&D team was assembled, it could be

[15] Based on Norman, 1997, UNDP, WIDE.
[16] See Antonelli, 1991, for a discussion of the diffusion of advanced telecommunications technologies in developing countries.

available to develop other cutting-edge technologies in semi-conductors, computers and telecommunications.

In 1973, the Korean Institute for Science and Technology (KIST), with GTE's assistance, developed new switching technology on a small scale, and, in 1981, presidential advisors recommended improving industrial, rather than consumer, electronics, and to focus on switching technologies. The TDX-1 pilot project was then launched. The project was started in the Telecommunications Research Institute (KTRI), established in 1977 under the aegis of the Ministry of Science and Technology, and later transferred to the new Electronics and Telecommunications Research Institute (ETRI) subordinate to the Ministry of Communications. This reorganization reflected, at least in part, that the primary customer of TDX equipment was destined to be Korea Telecom also dependent of the same ministry.

Once it become known that Korea Telecom was going to invest in an electronic switching system, "chaebols" Goldstar and Samsung decided to participate and so did a smaller firm, Otelco. All had been assembling digital switching equipment, albeit on a small scale. Korea Telecom joined in the development of the TDX system and international partners were also involved. Goldstar had an agreement with ATT, Samsung with BTM of Belgium, and Otelco with Ericsson.

The project required a great deal of coordination to maintain product and engineering quality control, since, prior to the joint R&D project, each manufacturer had been producing its own individual models of digital switching devices. Planning of future development of the telephone network was also involved since analogue switches had to be replaced in urban areas where they were already in place, while at the same time expanding the new telephone network to rural areas. The project nevertheless grew rapidly with R&D personnel at ETRI expanding from 20 staff in 1981 to 100 in 1982 and 250 in 1983. All of them, except for some high level managerial personnel, were locally trained. Some key technology was licensed from Ericsson and some ETRI staff travelled to Sweden for technical training. By 1984 the project had produced the first prototype of the TDX-1 system, and its TDX-1A version, with 10,000 lines, was operational by 1986. A modified version, with digital switches for lower density use in rural areas, called TDX-1B, was then developed. 23,000 lines were installed in

1986 using the new switches, and by the late 1980s the system was already being exported to other countries. The TDX-10, a large scale, high-density system, for use in urban areas, was developed and installed during the 1990s.

By the early 1990s, Korea was approaching self-sufficiency in the design and production of some digital switching equipment, and had been exporting parts of the TDX system since 1985. It was estimated that by 1993, locally designed switches had already been installed in 55% of the local market, and the number of lines supplied with TDX technology had increased from some 24,000 lines in 1985 to 1.3 million lines in 1990, and more than 10 million lines by 1997. It has been estimated that the total cost of the project was 115 million dollars, and implementation spanned the period 1982-1995. From 1991 when the first export order was shipped, to 1997, more than 3.5 million TDX exchange lines have been exported to 23 countries.

D. Taiwan. Computers, parts and components.

Taiwan also followed a strategy strongly based in exports to compensate for its limited market. It was also reluctant to import technologies as part of a FDI package, but, as distinguished from Korea, did not stress large scale undertakings and enterprises preferring instead a development based on SMEs, at least in the initial phases of its industrial growth following the attainment of autonomy from Mainland China. While initially emphasizing labor intensive exports such as textiles, it found itself pretty soon with the need to diversify into more skill and capital intensive industries. To accomplish this while retaining the emphasis in SMEs and the reluctance to allow major FDI, the government sponsored R&D consortia and a science and technology park.

Nevertheless, the case study we focus on reflects the practically autonomous development of a by now very large enterprise in the computer field which received little or no benefits from the government, and grew phenomenally while retaining its independence from both foreign investors and public intervention.

Case Study: ACER[17]

Originally called Multitech International Company, ACER was established in 1976 by 11 US-trained engineers, with very little capital, to produce computer components. It has now grown to become one of the main international producers of computers, and their parts, including sophisticated components such as monitors and mother-boards, as well as advanced lap-top models. The trajectory followed by ACER has been quite spectacular, particularly for an enterprise in a developing country, since in less than 30 years it has grown from being a subcontractor of original equipment manufacturing (OEM) for foreign corporations, to become a large own-brand manufacturer (OBM), and more recently moving into "on demand" business in competition with IBM.

Some members of the initial group had Silicon Valley experience which helped them to sell their services to companies such as Intel and IBM. For ACER the period spent producing OEM for others was an important learning experience as it assimilated product and process technologies being transferred by its contractors. Thus ACER did not need initially to spend time and money establishing sales or distribution networks, or on consumer-oriented advertising to promote own-brand preference. Through its OEM relationships ACER learned all aspects of computer manufacturing, including those pertaining to input/output attachments, as well as other consumer electronic products, becoming, in a relatively short time, one of the world's largest manufacturers of personal computers (PCs), monitors, keyboards, fax machines, and printers. These outside orders also provided financing and helped to improve capacity utilization.

During the period 1981-1986, ACER devoted resources to in-house R&D for the development of a line of its own products, and to promote recognition of its own brand-name. Because of its lack of experience and own-brand recognition, ACER followed a "periphery to the core" marketing strategy that focused on entering smaller, emerging markets, before taking on the US and European markets. During this period, ACER also succeeded in its R&D efforts by developing, in 1982, Taiwan's first 8-bit home computer, and in 1986 it launched the world's second 32 bit PC, after Compaq, but well ahead of IBM. ACER 80386

[17] Based on Ross, 1997, ACER web-page.

computers were widely praised for their price and technology, and helped turn the company into a leading computer producer. Thus 1986 can be considered a turning point in the development of ACER's capabilities beyond OEM. Its computer sales grew from some 50 million dollars in 1983 to about 550 million dollars in 1988, and about 60% of its sales were by then of products with its own brand. Its output of 400,000 PCs represented approximately six percent of the total world market.

By 1988, the ACER group employed some 4,000 people, of which 500, or 12.5%, were devoted to R&D. The group had expanded operations overseas and included subsidiaries in US, Europe, Japan and Hong-Kong. Off-shore manufacturing facilities were also established in China and Malaysia. Because it was now heavily engaged in OBM, a network of some 100 distributors was used to sell ACER PCs in some 70 different countries.

During the early 1990s ACER lost money in its OBM sales because of lack of brand awareness and limited market share. It then decided to place greater reliance on OEM and ODM. It also realized that heavy marketing and distribution expenditures during the late 1980s and early 1990s, had diverted funds from R&D and production. Its renewed OEM strategy was instrumental in obtaining a large contract to supply APPLE with its popular notebook, the Power-book 145. Similarly, for the first time, IBM agreed to market ACER fully-assembled PCs to be sold under its brand name. This strategy of selling products of its own design and manufacture both under its own name and that of others, allowed ACER to maintain a level of operating capacity and profits that facilitated the financing of its R&D activities. By the end of 1996 more than 60& of the value of its sales was from own-brand name products, and success in its OBM activities remained its overriding objective.

Pari-passu with its commercial development, ACER retained and expanded its innovating capacity. In 1989 it formed a joint venture with Texas Instruments to develop DRAM chips, and in 1991 it invented a Chip Up technology for upgrading from 386 to 486 technology. The derived line of PCs with upgradable technology become so popular that in 1993 ACER licensed its Chip Up technology to Intel. Thus in a mere 17 years, ACER accomplished the feat of selling its own, newly developed technology, to Intel which had been one of its original subcontracting clients. In 1993, ACER introduced another chip-related innovation by launching a PC with a reduced instruction-set chip (RISC), running on Microsoft's NT Windows operating system. The above chip innovations contributed to ACER's global image as a leader in chip technology recognized by major firms in the industry such as National Semiconductor, Texas Instrument, NEC, etc., that paid to license ACER's chip designs.

The ACER group is currently among the largest computer manufacturers and vendors in the world. Although the firm, like other Taiwanese start up technology firms, profited, in general, from Taiwan's improved technological infrastructure and established export channels, it was not a firm located in the Hsin-Chi Science Park, benefitting from participation in government sponsored research consortia, or receiving technical assistance from public R&D institutes. Rather, it was a latecomer that thanks to its well-qualified engineering manpower and the learning obtained by doing subcontracting work, was able to enter the market at a level of expertise close to the technology frontier set by its multinational corporation clients.

IV. OVERVIEW

Table 7 below summarizes the experience of the four case studies, and then we briefly describe for each one, the main product or process innovation, the entrepreneurial origins of the enterprise, its technology and skill sources, main institutions and policies that affected its performance, and the ownership structure adopted,

Table 7. Overview of Case Studies

Case-Country	Product Innovation	Entrepren. Sources	Technology Sources	Skills and Sources	Institut.	Policies	Ownership Structure
INVAP Argentina	Nuclear Reactors	Navy/CNEA	CNEA/MNC construct.	Phys./eng. for.train.	CNEA CONICET	Nuc.power unpa.proc.	Govern. Aut.
EMBRAER Brazil	Regional Aircraft	Defense	CTA/R&D, jointvent.	Aer.eng. mats.elec.	CTA,FINEP BNDE	Prot.Xpro. Dereg.US	G/Private public
TDX Korea	Digit.Tel. Switches	Public consortia	R&D, ETRI Ericsson	Elec.eng. softwa.	ETRI/TELE Kconsortia	Digi.R&D cons.Xpro.	G/Private Temp/arra
ACER Taiwan	Computers Chips	Private expat.	Subcontr. R&D	Elect.eng. softw.exp.	Gral.S&T infrastr.	OEM,ODM, OBM, Xpro.	Private, public

A. Innovations

All four cases involve products and/or processes normally categorized as requiring the mastery of technologies that are "complex", "advanced", "high", or "cutting-edge". All four cases also involve design, R&D, and engineering and construction skills. Thus from the viewpoint of technological development they are normally to be found in advanced, innovating, industrialized countries. All cases, to different degrees, have seen their technological prowess validated internationally by exports, licenses, etc. Thus they have met stringent competitive standards.

B. Entrepreneurial sources

Three of the four cases received significant doses of public entrepreneurship. Elements of the armed forces played an important initial role in promoting nuclear power in

Argentina as well as in the acquisition of an aeronautical capability in Brazil. Interestingly enough, Argentina also tried hard to develop its aircraft design and manufacturing capabilities, but did not attain Brazil's level of achievement with EMBRAER. Correspondingly, Brazil also tried to develop a local nuclear power industry without success until recently[18].

In Korea's case, the government's entrepreneurial intervention, which was decisive, entailed, first, the determination to "go digital" thereby largely leapfrogging electro-mechanical technologies then in use in telephony switching, plus the decision to set up an R&D consortium involving facilities in public R&D institutes as well as private manufacturing, and the main eventual public customer of the equipment to be designed locally. There was no public entrepreneurial intervention in the case of ACER which was the creation of a group of young technical expatriates. Moreover, as will be seen later, ACER did not benefit from important public interventions such as the establishment of a science park, and the various R&D consortia sponsored by the government to help SMEs (Mathews, 2001).

C. Technology sources

CNEA was the initial source of technical knowledge for all local engineers and physicists in the atomic power field in Argentina, as well as the mother institution of INVAP. When construction of the first atomic power plants took place, local personnel learned from the unpacking of the foreign technology, as well as from the procurement they participated in, and which was expressly promoted for learning purposes by the CNEA with the support of the national government.

CTA, a public research and design facility, provided the design for the first successful plane built by EMBRAER, the Bandeirante. Design for other planes was also done in house and EMBRAER also benefitted from advanced materials and other technologies acquired by doing subcontracting work and from licensing and joint venture agreements with foreign aircraft builders. These arrangements were in part made possible because of its engineering capabilities and the successes attained with its own designs.

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[18] Because of its dependence on imported oil, and in spite of the relative success of the gas-hol program, Brazil is now committed to a significant nuclear energy program.

While some initial, minor scale, switch manufacturing was carried out domestically with help from abroad, the TDX project was carried out by a local, government-sponsored consortium formed by ETRI, the public R&D institute assigned for this purpose, the principal manufacturers, as well as Korea Telecom, the main potential purchaser of the equipment to be designed and eventually manufactured. Some technical know-how was also obtained from abroad, and the manufacturers engaged in technical alliances and joint ventures with major international firms.

ACER did not benefit from science and technology institutions, such as the science park and R&D consortia, created by the Taiwanese government to help SMEs overcome size-derived obstacles. It acquired its manufacturing technology from sub-contractual work (OME) for major international producers of computers and related equipment, moving then to the design of its own equipment which it managed to sell both under its own name and those of well established foreign firms. Finally, ACER ventured successfully into the redesign and design of chips, and even managed to license its own technology abroad to some of the same manufacturers that originally contracted with it to produce equipment for them.

D. Skills and their sources

Following their basic training at major Argentine public universities, physicists, chemists, and engineers employed by CNEA learned about nuclear power technology in house. Many were also sent abroad for post-graduate studies sponsored by CONICET. Their more applied skills were acquired by working in CNEA and INVAP as a result of the construction of the first nuclear power plants in Argentina, and the design and building of nuclear power research reactors, first for themselves, and later on for export contracts.

Basic training in aeronautical engineering was provided in major public Brazilian universities, and aircraft design skills were initially transferred from CTA which had adjacent facilities to EMBRAER's plant. Knowledge of advanced materials and manufacturing techniques was acquired by working in subcontracts for major international aircraft builders. Specialized training abroad was also involved.

Electronic and electrical engineering degrees were granted in Korean universities, but applied skills involved in designing and manufacturing digital switches for telephony also required computer and software specialized skills that were learned by working with major international firms, and by sending staff to be trained abroad.

The core of ACER's skilled personnel in electrical and computer engineering was the original group of technically trained, and experienced abroad, expatriates that started the firm to do subcontracting work for major MNCs in the computer field. Chip design skills were acquired by "reverse" engineering and own R&D, with some technologies transferred to ACER by the firms for whom it was manufacturing OEM.

E. Institutions

Undoubtedly, the key institution in developing the nuclear power field in Argentina has been CNEA. CONICET played an important role with its support of R&D projects and specialized training abroad.

For EMBRAER, the most important institutions have been the CTA from which it obtained the design for its first successful commuter plane, as well as FINEP for its financial support of R&D projects, and, indirectly, the BNDE.

The Korean government, through the Ministry of Telecommunications, played a critical role in the development of the TDX switching system by promoting the project and sponsoring the local R&D consortium that included the ETRI as well as Korea Telecom, plus the interested manufacturers.

ACER only benefitted from general science and technology and export infrastructure in the country, but made no use of the science park, or research consortia promoted by the government of Taiwan.

F. Policies

The most important policy decision preceding the development of a nuclear engineering capability in Argentina was undoubtedly the original interest of the armed forces, going back to the early 1950s, and which lead to the creation of an autonomous atomic energy agency, the CNEA. It further included the policy decisions to provide it with relative autonomy within the government, and with the necessary funding out of the federal budget. A subsidiary policy of importance, derived from the relative independence and technical prestige enjoyed by the CNEA, was its ability to push technological unpacking and domestic preferential procurement in the tenders for the construction of the first atomic power plants in Argentina. R&D appropriations for the CNEA have been reduced recently, in part, because energy policy in the country is becoming more reliant on natural gas.

For EMBRAER undoubtedly the initial protection of the Brazilian commuter plane market gave the firm the necessary assurance to plan, invest, and even do R&D to develop new aircraft. Of importance have also been the export promotion policies that permitted the firm to gain a foothold in major foreign markets. External policy developments, particularly in the US, significantly affected EMBRAER's success. First was the regulation that EMBRAER benefitted of with its Bandeirante plane, to have to include at least one flight attendant when 20 or more passengers were flying, and which obviously stimulated the development of 19 seat planes. Second, and equally important for EMBRAER, was the deregulation of the US aviation industry in 1978, which provided a strong boost to the commuter aviation industry and to the production of smaller, regional, aircraft.

The policy decision "to go digital" was undoubtedly crucial for the development of the TDX system. Instrumental were also the government interventions in sponsoring the R&D consortium and in involving the consumers (Korea Telecom) and producers (major "chaebols" with international partners) of the future equipment. Export promotion policies have also been important to facilitate expansion of productive capacity beyond the needs for the domestic market.

ACER was not the direct beneficiary of any policies aimed at stimulating its activities. It did benefit, however, from general export promotion policies. Of determining importance were its own internal strategic decisions as to how to balance the original OEM work with its ODM and OBM capabilities. Similarly critical was its decision to carry out own R&D which led to significant chip developments, and strengthened the company's position among its international clientele.

G. Ownership structure

INVAP is a joint venture between the federal government and the province of Rio Negro in the south-west of the country. The firm was segregated from CNEA and absorbed part of its R&D and technical personnel. It acts as an autonomous enterprise with total independence in its technical, operational and financial activities.

EMBRAER started as a joint venture, with a large public sector majority share, and a tiny private participation. It went private in 1994 with a public stock offering, and the firm is now listed in the NYSE.

The development of the TDX system only required temporary consortium type arrangements between the Ministry of Telecommunications and the various Korean public and private participating entities. Once the research and development work had been completed, these special arrangements were terminated.

ACER is a wholly private firm which has recently made a public stock offering.

V. Concluding Remarks

It might be tempting to characterize the case studies we presented as just individual instances, or exceptions, that merely confirm the rule that significant technological developments only take place in advanced, highly industrialized countries, because they require the workings of well integrated national innovation systems.

In his overall review of the country cases included in Nelson, 1993[19], the editor noted the important role of government defense expenditures in promoting technological development and the acquisition of new technological capabilities in various countries. Also of importance seems to have been the role played by education; institutions and policies, such as the promotion of competition, and exports, were also required. He also noted that there seems to have been little or no evidence of well thought-out, and structured, industrial policy, but rather cases of infant industry protection plus some R&D subsidies. The promotion of "high-tech" industries constituted a special case in most countries, and "market failure" seems to have been the preferred justification for government intervention. In a number of countries, innovation systems, narrowly considered, tended to be sectorial and not "national" in scope.

While Taiwan established a number of publicly guided research consortia to compensate for diseconomies scale, Korea did so only to spearhead R&D deemed critical for the development of telecommunications technology, even though the firms involved were all of large size. Korea resisted direct foreign investment, encouraging instead the development of large national firms, while Taiwan, although also restricting the role of FDI, insisted on basing its industrial and technological development in SMEs. Thus, no clear picture emerges from the summary review undertaken by Nelson.

In our case studies, the results clearly point to the confluence of several key factors, but not necessarily to the workings of an integrated national innovation system. Skills, institutions, and policies played critical roles in all of them, with strong doses of public

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[19] The book edited by Nelson includes national studies for nine advanced and five developing countries that do not share a common theme or outline. The only attempt at classification is by grouping the advanced countries according to size.

entrepreneurship in all cases except Taiwan's. The emphasis on own, indigenous, technological development, as opposed to obtaining technical knowledge through foreign investment, is also an across the board finding. Clearly, resorting to the acquisition of autonomous technological capabilities would not have been an option without the availability of significant cadres of highly skilled technical manpower, at times complemented by training abroad as well as licensing or partnership agreements.

The cases we studied also indicate the importance of historical developments and individual decisions that played a critical role in assuring the success of particular undertakings. The support of the military was crucial for the development of nuclear energy in Argentina, and the aeronautical industry in Brazil. But EMBRAER also benefitted, to an important extent, from changes in policy regulations in the major market it wanted to tackle, the USA. The development of digital switching technology in Korea required major public entrepreneurship, while, on the other hand, ACER in Taiwan, is a strong example of private undertaking with little or no governmental support.

While all the above mentioned individual, or particular, decisions were of critical importance, and there is no clear evidence that an integrated innovation system was required, it can be argued that they only led to fruitful results because of the levels of industrialization, skill development, and technological accomplishment, previously attained in the countries studied.

BIBLIOGRAPHY

Antonelli, C., 1991. The Diffusion of Advanced Telecommunications in Developing Countries, Paris: OECD.

Capdevila, F., 2002. "INVAP: Made in Argentina", ARGENTIME, No. 17, SIDUS.

Centre National de la Recherche Scientifique (CNRS), 1973. L'Acquisition des Techniques par les Pays-Non Initiateurs, Paris.

Comision Nacional de Energia Atomica, undated. "Participacion de la Industria Industria Nacional en el Proyecto Atucha", draft signed by C. Martinez Vidal, director, OAS Multinational Metallurgy Program.

Federal Reserve Bank of Dallas, 1999. The New Paradigm. Annual Report 1999.

Hess, E. M., 1997. "Embraer: Third World Success in a First World Industry", draft term paper for Course INAF 321, "Science and Technology in International Affairs", School of Foreign Service, Georgetown University, May 1997.

Lall, S., 1996. Learning from the Asian Tigers. Studies in Technology and Industrial Policy, Macmillan Press Ltd-St. Martin's Press, Inc.

La Nacion, 2000. "Exporta el Pais Tecnologia Nuclear", Buenos Aires, June 2000.

Mathews J.A., 2001. "The Origins and Dynamics of Taiwan's R&D Consortia",Research Policy, 1315, pp. 1-20.

Mowery, D.C., 1987. Alliance Politics and Economics: Multinational Joint Ventures in Commercial Aircraft, Cambridge: Ballinger Pulbishing Co.

Nelson, R.R., 1993. (edit.) National Innovation Systems. A Comparative Analysis, New

York-Oxford: Oxford University Press.

Norman, C., 1997. "Information Technology in South Korea", draft term paper for Course INAF 321: "Science, Technology and International Affairs", School of Foreign Service, Georgetown University, May 1997.

Organization for Economic Cooperation and Development (OECD), 1996. Reviews of National Science and Technology Policy: Republic of Korea, Paris: OECD.

____, 2001. Brazil, Economic Surveys, June, Paris.

____ **and The World Bank Institute**, 2000. Korea and the Knowledge-based Economy. Making the Transition, Paris.

Ross, N., 1997. "Developing Information Technology Industries in Taiwan: The Success of ACER Industries", draft term paper for Course INAF 321: "Science Technology and International Affairs", School of Foreign Service, Georgetown University, May 1997.

Soifer, R.J., 1984. "Argentina", World Development, Volume 12, Number 5/6, Special Issue, pp. 625-644.

Teitel, S. 1978. "On the Concept of Appropriate Technology for Less-Industrialized Countries", Technological Forecasting and Social Change, Vol. 11, pp. 349-69

________, 1981. "Towards an Understanding of Technical Change in Semi-Industrialized Countries", Research Policy, vol. 10, pp. 127-47. (Reproduced in revised version as chapter 9 in Teitel, 1993).

________, 1987. "Towards Conceptualization of Technological Development as an Evolutionary Process", chapter 11, in J.H. Dunning and M. Usui, (eds), Structural Change, Economic Interdependence and World Development, Vol. 4, International Economics Association, The Macmillan Press, Ltd.

________, 1992. (editor), Towards a New Development Strategy for Latin America, Inter-American Development Bank, Washington DC, distributed by Johns Hopkins University Press.

________, 1993. Industrial and Technological Development, Inter-American Development Bank, Washington DC., distributed by Johns Hopkins University Press.

Teitel, S. and F. Sercovich, 1984. "Latin America", World Development, Volume 12, Number 5/6, Special Issue, pp. 645-660.

Teitel, S. and F. Thoumi, 1986. "From Import Substitution to Exports. The Manufacturing Exports Experience of Argentina and Brazil", Economic Development and Cultural Change, Vol. 34, Number 3 (April), pp. 455-490.

UNESCO, Science and Technology Yearbook, various issues.

UNIDO, 2002/2003, Industrial Development Report, Vienna.

United Nations Development Program (UNDP), Human Development Report, various issues

____, "Switch is on: Korea", WIDE Innovative Experiences. Special Unit for Technical Cooperation among Developing Countries, Website, downloaded 6/1/2004.

US Department of Commerce, 1997. Korea's Strategy for Leadership in Research and Development, Office of Technology Policy.

Wade, R., 1990. Governing the Market: Economic Theory and the Role of Government in

East Asian Industrialization, Princeton: Princeton University Press.

Westphal, L., 1982. "Fostering Technology Mastery by Means of Selective Infant-Industry Protection", in M.Syrquin and S. Teitel (edits.), Trade, Stability, Technology and Equity in Latin America, Academic Press, pp. 255-279.

World Bank, World Development Report, various issues.

__________, 1993. The East Asian Miracle, Oxford: Oxford University Press.