INTECH

Institute for New Technologies

Discussion Paper Series

#9503

Telecommunication Industry in Brazil: Public-Private Relationship and Technology Development

Maria-Ines Bastos

April 1995

United Nations University, Institute for New Technologies, Keizer Karelplein 19, 6211 TC Maastricht, The Netherlands
Tel: (31) (43) 350 6300, Fax: (31) (43) 350 6399, e-mail: postmaster@intech.unu.edu, URL: http://www.intech.unu.edu

1. Introduction

Access to telecommunications services is becoming one of the minimum necessary conditions for participation in domestic and international markets. The design and availability of public telecommunication network are therefore a fundamental element that shapes the prospects of economic agents and the possibilities of stronger social integration. Insufficient coverage and deficient telecommunication infrastructure in developing countries make their prospects of quicker integration in the world market not very promising. The necessary investments in telecommunication networks are extremely high for many of these countries. For some of the middle-income countries, the new digital and satellite technologies may open up the possibility to leapfrog the dependence on electromechanical technology.

The 1980s witnessed the major shift in the telecommunication network from analogue to digital switching and transmission. Computer-supported electronic processing of digital signals created the intelligent telecommunication network. Together with this technology change there was also a policy shift. The trust in a monopolized public and private organization of telecom services supply has shifted to faith in competition as a superior way of organizing the telecom service market (Mansell 1993). The information economy is being built upon the intelligent telecommunication network. Liberalisation of telecom services markets is expected to eliminate obstacles to a worldwide development of intelligent telecommunication networks and speed up the process of constitution of a global information economy. This process is likely to generate a large demand for digital telecommunication equipment, a welcome prospect for internationally competitive telecom industries with currently sluggish rates of growth. It is also likely to provoke significant redistribution of market power within and beyond the traditional telecom equipment industry.

There are not many developing countries with a domestic production of telecommunication equipment, including those with digital technology. Brazil is one, not the most successful, but still being counted among those with a diversified and relatively modern telecom industry. Such an accomplishment is a result of public-private cooperation that not only produced an industrial segment with its corresponding domestic production capacity in a high-tech field, but also stimulated domestic research and development activities. These production and research capacities are presently being challenged by international competition in the opened Brazilian market and by the prospect of drastic institutional change in the supply of public telecom service.

This paper offers a brief overview of the Brazilian telecom industry and pinpoints the major policy directives responsible for the industry's technology modernisation. Comparison with the international market and other developing countries' markets give perspective to the discussion. This is done in Section 2. The institutional and policy components of the establishment and modernisation of the telecom industry in Brazil are discussed in Section 3. Section 4 brings the description of Brazilian telecom industry. The strategy of technology development for the telecom equipment industry is presented in Section 5. Finaly, Section 6 summarises the main conclusions of the paper.

2. The world market of telecommunications equipment

The telecom *equipment* market and the telecom *service* market are the two component segments of the telecommunications market that is itself part of the information and communication technology (ICT) market. Telecom equipment is a category that includes a variety of machinery. *Switching equipment* refer to telephonic and telegraphic switching apparatus including telephone exchange equipment. *Facsimile machines* are among the most popular modern telecom equipment. *Data and text terminal equipment* comprise teleprinters, telex machines, modems and multiplayers. *Transmission equipment* is a category that designates carrier systems, carrier, multiplexors, speech input equipment, telegraph, radio transceivers, microwave systems, and apparatus for signal conditioning of satellites. *Telephone sets* include pay phones and subscriber premise equipment, intercoms, telephone answering machines, but exclude mobile telephones that are sometimes classified in the "Communications" category.

The world market of telecom *equipment* is currently worth between US$ 100 billion (EITO 1995:350) and US$ 120 billion (ITU 1994: 1). Telecom industry accounts for a 11 percent share of the world ICT market (EITO 1995) and 20 percent of the world telecommunications market (ITU 1994). Telecom *services* account for the largest share of the world telecom market, 42 percent according to EITO in 1994 or 75 percent according to ITU in 1992. Forecasts for 1996 are of a world telecom market 13 percent bigger, but still very much concentrated between Europe, the USA and Japan that will share, between them, 77 percent of the total (EITO 1995)

TABLE 1: MAJOR REGIONAL ICT MARKETS BY PRODUCT. AVERAGE ANNUAL GROWTH IN VALUE (%) -- 1993-1995

	WORLD	USA	JAPAN	WESTERN EUROPE	EASTERN EUROPE	REST OF WORLD
IT	7.6	7.6	7.5	5.5	13.5	12.7
Telecom	4.8	2.0	8.3	6.4	9.2	3.7
equipment	2.3	2.7	3.0	- 4.0	8.8	6.6
services	5.5	1.9	9.6	8.4	9.5	2.7
ICT	6.1	5.2	7.9	6.0	10.8	6.2

Source: EITO (1995: 353), Table 8

Growth rates of telecom services are consistently higher than that of telecom equipment in Japan, Western and Eastern Europe. In the developed world, the telecom industry is the less dynamic segment of the ICT market, showing even a significant decline in Western Europe markets. Eastern Europe ICT market has grown at the highest rates. The impressive 8.8 percent annual growth of its telecom equipment market is certainly explained by the demand of its booming telecom service market. Telecom equipment producers in the Asian NICs seem to have become competitive internationally and to have captured considerable share of the world market. The USA, largest world producer of telecom equipment, has recently shown very modest rates of growth of both telecom services and equipment. This may be in great part due to the slower pace of modernization of the telecom network and consequent disincentive for higher levels of innovation, efficiency and competitiveness in the USA telecom industry. The launching of the information infrastructure program by the Clinton-Gore administration, popularised by the media coverage of "information super-highway," is expected to stimulate recovery of the American telecom equipment industry. Liberalisation of foreign markets is also strategic in this process. In this respect, the USA government is currently pursuing a multilateral telecom services market-opening agreement within the General Agreement on Trade in Services (GATS) negotiations due to be concluded by April 1996. The American negotiators are pressuring for the acceptance of the following market-opening points: (i) foreign firms must be allowed to operate as resellers and facilities-based operators; (ii) foreign firms must have access to the public network; (iii) foreign ownership must not be restricted by quantitative limits or mandatory joint ventures; (iv) countries must not allow their telecom service providers to use profits gained from other ventures to subsidise telecom services ventures; (v) customers must have access to foreign and domestic telecom services providers; and (vi) foreign firms must be allowed to use equipment compatible but differing from the national standard to interconnect with the public network (Olbeter 1995:61-62). American and European views on liberalisation of telecom markets converge in many

respects (Bangeman 1994). Controversy develops around timetables and deadlines for implementation of practical measures and may get heated on the issue of interoperability and the establishment of European standards.

It is in the emerging economies, including Eastern Europe and middle income developing countries, where the market of telecom equipment is growing at higher rates, twice or more as big as world averages. Considering the strong association between telecommunication services and income levels and the significant role the state has had everywhere in the expansion of public telecom services, the potential market represented by some of these emerging economies is not likely to materialise soon or without vital institutional change. Table 2 gives some basic indicators for the major telecom equipment markets including the emerging economies.

Brazil, together with Russia, India and China, constitutes a potential large market for telecom equipment. Brazil would have to double its teledensity to approach the Russian average and to increase it fivefold to reach the present average in South Korea. The attainment of such goals will probably mobilise Brazilian efforts for many years if there is no significant improvement in the 6.5 percent average annual growth rate of main telephone lines since 1983. Brazilian achievements so far are not impressive when contrasted to the average teledensity of 13.5 lines per 100 inhabitants in the group of upper middle income countries where Brazil is included (ITU 1994:A-5).

TABLE 2: BASIC INDICATORS FOR MAJOR TELECOM EQUIPMENT MARKETS (1993)

Countries	Population (million)	GDP per capita (US$)	TV sets per 1000 inhabitants	Telephone lines per 1000 inhabitants	Digital telephone lines (%)(1)	Telecom equipment market (US$m)	Telecom equip. production (US$m)
USA	258	24,681	2,050	561	59.7	20,654	19,230
JAPAN	124.5	34,200	610	471	60.0	12,739	17,396
GERMANY	80.7 (1)	21,200	559	439	12.0	6,331	7,220
FRANCE	57.4 (1)	23,086 (1)	510	515	83.2	3,764	4,661
S-KOREA	44	7,466	207	365	93.0	1,267	1,831
TAIWAN	20.8	10,400	383	371	58.0	738	1,342
CHINA (1)	1,140 (2)	1,300 *	22	7	38.0	1,691	1,230
BRAZIL	152	3,000	703	70	22.0	1,330	1,250
RUSSIA (2)	148.8	1,550 (1)	316	111	-	630	540
INDIA	892	290	33	8	-	615	574

Source: Yearbook of World Electronics Data 1993, 1994, 1995; ITU (1994:A-10/12)
(1) 1992
(2) 1991
* based on purchasing power parity

There are governmental plans to increase the Brazilian telecommunications network by 25 million terminals by the year 2000. An estimated investment of US$ 47 billion would be necessary in order to attain this goal. If the objective involves more than to increase the basic telecom services to include also data communication and cellular telephony, the necessary investment jumps to US$ 55 billion. There are some analysts who think these estimates are unrealistic because they were based on average costs per terminal much lower than current costs of terminals supplied by the domestic industry (Pessini 1993:Table 2.7). Liberalisation of the Brazilian telecom *service* market is expected to generate the resources needed for improving the telecom infrastructure. New investments in telecom services will stimulate domestic production, generate a push for reduction in prices in the domestic market, as well as increase imports of cheaper equipment.

Less than one-fifth of the Brazilian telecommmunications network was digital in 1992. Switching from analogue to digital is a more difficult task for countries with a strong development of their infrastructure than for those that are only recently investing in their telecom network. In this respect, Brazil is not among those developing countries that have explored in full the advantage of expanding their telecom network with the contribution of new digital technology, as South Korea, Taiwan, and even mainland China. Russia and India are still to introduce digital central switching in their telecom network. The chances for Brazil to take advantage of the benefits of the new technologies in telecommunication depend most of all on the levels of investment it can sustain. Brazil managed to create the way to access efficient communication for the diffusion of new technology. It has also attained reasonable levels of cognitive and network externalities. These are, according to Antonelli (1991), two out of the three basic conditions for a quick technological change in telecom service among developing countries. The necessary condition still missing in Brazil is strong growth rates with consequent high levels of investment. The transition from electromechanical to electronic switching in developed countries has been less affected by investment levels thant by the sheer size and durability of their installed base.

Companies originated in the developed world, particularly the USA, Japan, France, Germany, Canada, Sweden and England hold the largest share of the world production of telecom *equipment*. These companies usually have the majority of their activities in their home countries. Some of them, however, have been pushed by many reasons to invest in foreign markets. One very common reason is the need to be in close contact with the service provider. Pressures from the demanding country for increased domestic content have also been an important incentive for investment in foreign markets. Finally, the push for investing abroad has also affected some of

these companies that served small markets in their home countries. AT&T's and Northern's affiliates outside the USA were estimated to account for less than 10 percent and 6 percent of the companies billings respectively. NEC's, Fujitsu's, and Hitachi's foreign affiliate shares of their companies' sales were around 25 percent and Ericsson's 36 percent (Pouillot and Dartois 1991).

3. Institutional and policy conditions of the modernization of Brazilian telecom industry

The Institutional Foundations

The present structure of the Brazilian telecom industry was shaped by the institutional restructuring of the telecom services and governmental regulations of the purchase of equipment by the operators of public telecom service. Subsidiaries of Ericsson, Siemens, Standard Electric and Philips have been active in the Brazilian market since the 1950s, mostly in the assembly of imported parts and components. The shift in their production strategies and the emergence of locally-owned companies were a direct result of Brazilian economic development, institutional change in the telecom services sector, and policy restrictions on telecom equipment imports together with requirements of domestic component.

The single most relevant change affecting the future of the Brazilian telecom industry was the mid-1960s institutional restructuring of the telecom services that started with the Telecommunication Law of 1962. This law defined the general policy for the sector and outlined the measures for the development of a whole telecom system. It also initiated the policy process that resulted in the regulatory framework that has been in force since then and is presently being revised. Three major institutions were created on the basis of this law: a federal agency for the formulation of a telecom policy, a public company to operate long-distance telecom services, and a telecommunication fund to support the establishment of the Brazilian telecom system.

Telephony, telex, telegraphy, international services - all of which had been hitherto provided by over 800 telecommunication-concession firms - were restructured, the federal government obtaining the exclusive authority for the development and operation of public telecom services. It is this state monopoly of telecom services one of the central issues being now discussed in the process of constitutional reform in Brazil.

The central telecom policy agency in charge of planning, coordinating, supervising, controlling and regulating postal and telecom services, the Ministry of Communication(MINICOM), was created in 1967. MINICOM has the constitutionally established monopoly authority over the use of telecommunication services. It is presently helped in its planning activities by GEATIC, an interministerial advisory group that also mediates the relationship between government and industry.

The Brazilian Telecommunication Company (EMBRATEL) was created in the mid-1960s as the agency directly responsible for operating long-distance telecom services at national and international levels. Since the mid-1970s it is also in charge of data communication and telex services. The telecom service articulated by EMBRATEL consists in a complex network serving, since the early 1980s, every capital city, major urban areas and many rural areas. Traditional telephone lines have been supported by high-capacity microwave systems and a domestic satellite communications system operating through four communication satellites, Brasilsat A1, A2, B1 and the B2, recently put into orbit. This system is however still far from satisfying population's needs.

The National Telecommunication Fund (FNT), supported by financial resources generated by a surtax of up to 30 percent on telecom service rates, was earmarked for the implementation of the Brazilian telecom system. This fund was abolished in the early 1980s.

Another important institutional change of the early 1970s was the amalgamation of the many existing local telephone companies in order to rationalise the country's telephone services. This was done by the creation of TELEBRAS as the holding company of a large telecommunication corporation including EMBRATEL and the current 29 telecommunications services operating companies at state level. TELEBRAS became responsible for the planning, budgeting and also for the research and development activities for the whole corporation. The R&D Centre (CPqD) was created in 1976 and constitutes one of the most successful cases of state intervention for industrial technology development in Brazil. More about CPqD and the university research stimulated by TELEBRAS will be discussed later in this paper.

The Brazilian Policy for Telecommunications Equipment

Government procurement in a monopsony market, as is the case of the market of equipment for public telecom services, can be used as a powerful instrument of industrial policy. In Brazil, purchase of telecom equipment by the operators of public telecommunications service was the major inducing factor of private investments in new industries or in the modernization of existing ones.

Government procurement of telecom equipment in Brazil has been guided, since the early 1970s, by the following principles: (i) diversification of suppliers in order to avoid monopolization or excessive fragmentation of the market; (ii) organisation of purchases in clusters according to kind of equipment and geographical area they will be used in order to rationalise operation and maintenance; and (iii) planning the expansion of services within a five-year interval with the specification of the equipment to be ordered to allow the industry to organize production accordingly. The industrial policy that was established on the basis of these principles had as its first objectives to achieve increasing degrees of local content, to internalise the production of the most updated equipment, to stimulate domestic absorption of imported technology and of technological development, to propitiate the development of an industry with participation of local capital to which the production of equipment designed locally would be commissioned.

Technological development was a central target of the industrial policy. There were two kinds of incentives for product improvement. One was the technical specification of the equipment the industry was asked to supply. Such specification followed TELEBRAS plans of gradual substitution of digital switching for electromechanical. The other was the transfer to private companies, particularly those under control of local capital, of CPqD and academic research results. Funding of CPqD and other telecom-related research activities comes from 1 to 1.5 percent of TELEBRAS operating revenue. TELEBRAS average investments in R&D during the 1977-1984 period was around US$24 million, most of which directed to CPqD (Hobday 1990:119). CPqD has searched abroad for technology, developed and adapted systems locally in association with university research teams. Various indicators of technological progress - patents, product and process development, human resources and technology transfer - show that CPqD accumulated a significant capacity in digital telecom (Hobday 1990:146). The strategy of technology development for the telecom equipment industry in Brazil will be discussed in more detail in Section 5.

4. The telecom equipment industry in Brazil

Some of the products of the Brazilian telecom industry (for example, electromechanical switching equipment for public network and electric cables) is not digital nor has electronic components. In spite of that, the digitalisation of telecommunication and the growing electronic component of telecom equipment is a general trend also in Brazil. Table 3 shows the composition of the Brazilian electronic industrial manufacture and the share of the segment of telecom equipment.

The manufacture of most of the telecom equipment in Brazil achieved more than 90 percent of domestic component in early 1980s. Even those products that incorporate more sophisticated technology, such as SPC switching, analogic microwave radio transceivers, and electronic teleprinters, were produced in Brazil with more than 80 percent domestic content in 1983. The equipment with the smallest domestic component at that time was digital microwave radio transceivers which production depended on direct importation of around 25 percent of its parts and components (Pessini 1993:Table 2.3). The interpretation of such accomplishment has to take into account that a significant share of domestic component represents simply assembly of imported parts.

Electronic components are among those of difficult internalisation in Brazil. There were not many favourable conditions for the development of such industrial segment domestically. The consumer electronics industry has everywhere represented a dynamic factor in the development of an industrial segment of electronic components.

TABLE 3: SHARE OF THE TELECOM EQUIPMENT PRODUCTION IN THE TOTAL ELECTRONICS PRODUCTION IN BRAZIL (1980/1986/1993)

	1980	1986	1993
Telecom equipment (US$million current)	712	1,050	1,250 *
Total industrial electronics production (US$million current)	3,922	6,847	12,791
Telecom share (%)	18.1	15.3	9.7

Source: Bastos (1994:50) for the years 1980 and 1986; the Yearbook of World Electronics Data 1995 for the year 1993

* exclusive of communication equipment such as radio communications transmission and reception apparatus, transceivers, mobile radio telephones, other communication and military equipment that wereclassified as telecom equipment by the source of data for 1980 and 1986.

In Brazil, the consumer electronics industry that has been located in the Free Zone of Manaus benefited from imported components and did not generate demand for local products. Market size, the large investment requirements, and the competition of imported cheaper and more advanced product did not stimulate domestic production of components.

TABLE 4: TELECOM EQUIPMENT INDUSTRY IN BRAZIL - PRODUCTS, PRODUCTION CAPACITY AND ANNUAL PRODUCTION (1977/80/83/86/89)

Equipment	Companies	Production capacity	1977	1980	1983	1986	1989
Electromechanical central switching (public network)	5	390,560 terminals	795,400	505,100	470,099	376,819	353,960
SPC central switching (public network)	8	1,341,432 terminals	-	-	110,600	385,964	1,004,632
Electromechanical PBX	6	93,200 terminals	127,600	197,800	93,418	113,019	45,080
Automated PBX	9	483,514 terminals	-	-	35,838	106,842	362,386
Packet switching (public network)	7	35,000 gates	-	-	-	-	2,400
FDM multiplexing system	8	145,640 channels	49,980	26,400	39,526	37,382	137,524
PCM multiplexing system	4	342,300 channels	30,500	29,300	54,134	44,652	157,864
Multiplexing telegraph system	1	44,160 channels	3,024	4,322	15,640	21,528	35,398
Multiplexing data system	6	4,078 systems	-	-	-	-	2,846
SHF radio transceivers (high capacity)	3	2,200 transcept.	388	353	445	266	1,995
VHF multichannel radio transceivers (6 to 120 channels)	5	3,240 transcept.	622	590	1,082	2,839	2,492
VHF/UHF radio transceivers (monochannel duplex)	4	9,600 transcept.	884	2,373	2,140	8,230	8,640
HF/VHF/UHF simplex radio transceivers (stationary/mobile/ portable)	23	80,006 transcept.	17,000	21,290	18,357	36,161	50,056
Key-systems	8	314,500 apparatus	112,000	157,400	110,023	174,147	215,634
Pay telephone	4	125,800 sets	9,990	14,620	24,789	55,411	60,000
Customer premise equipment	8	2,243,200 sets	886,570	1,388,940	921,085	1,101,136	902,805
Telex	7	27,710 units	5,200	11,720	7,000	6,712	13,996
Facsimile	3	4,750 units	-	-	120	358	8,000
Modem	15	135,922 units	-	-	5,820	40,898	87,722
Cables	17	32,800 tons	14,000	10,000	9,000	15,500	13,650
Optic cables	7	30,000 Km.	-	-	-	8,000	30,000
Subscriber carrier (mono- and multichannel)	2	23,200 carrier	5,500	22,976	9,290	7,700	2,200
Voice amplifier	5	105,500 units	9,370	43,050	2,450	10,351	8,110

Source: GEATIC, in Pessini (1993: Table 2.2)

The stable market for telecom equipment, made predictable by the plans of expansion of telecom public services, together with requirements of domestic content, stimulated the development of a diversified equipment industry. Table 4 shows the structure of the telecom equipment industry in Brazil.

The shift from analogue to digital equipment is observed here, in relation to switching apparatus for public network as well as in private branch exchanges (PBX). The production of electromechanical central switching is gradually being phased out while the production of the electronic substitute (the SPCcentral switching) has grown tenfold in six years. In general, industries producing most of the digital equipment (SPC central switching, automated PBX, packet switching, multiplexing data system, and modem) were operating with excess capacity in 1989. One exception is the production of facsimile that can more easily mobilise production capacity of companies producing other electronic equipment. The other exception is the optic cables industry that was already producing at full capacity in 1989. Prospects of increasing exports to Mercosul[1] countries and new investments in the expansion of telecom services in Brazil will generate a prompt response by the domestic industry that still has a comfortable margin to expand production without major investments in the short term. Other industries will have to make major investments to increase their production capacity and face the challenge of international competition in the local market.

TABLE 5: LARGEST TELECOMMUNICATION EQUIPMENT FIRMS IN BRAZIL (1991)

MAIN PRODUCT	COMPANIES	AS % OF COMPANY SALES
Central switching apparatus (public network)	7	100
Transmission equipment	3	100
Cables	6	26
Data terminal equipment	11	94
PBX	3	100
Facsimile equipment	3	7
Pay telephone	1	100
Radio transceiver	3	100
Components	10	44
Customer premise equipment	1	100
Other	2	16
TOTAL	50	49

Source: Anuario Telecom 92/93, extracted from Pessini (1993: Table 2.3)

[1] Mercosul countries are: Argentina, Brazil, Paraguay, and Uruguay

Recent analysis has concluded that the Brazilian industry of telecom equipment is not internationally price-competitive. It has neither significant export achievements. However, it has been able to supply domestic demand for increasingly sophisticated equipment, particularly that of the telecom service public operators.

International price-competitiveness was not a policy objective for this industrial segment that developed under the protection of a strategy of import substitution. International competitiveness has become a target of governmental efforts since very recently. Only telephone sets (public and subscriber) made in Brazil were price-competitive in the early 1980s. The price of Brazilian made technology-intensive equipment, as digital radio transceivers, was twice as high as international prices (Pessini 1993:Table 2.4). Prices of the majority of domestically-manufactured telecom equipment however were between 50 to 80 percent higher than international prices. This price differential does not seem excessive considering the modest size of the market and the dependence on imported high-tech components.

TABLE 6: SHARE OF 10 LARGEST FIRMS IN THE SALES OF TELECOM EQUIPMENT OF THE LARGEST INDUSTRIES IN BRAZIL (1991)

COMPANY	MAIN PRODUCT	% OF TELECOM SALES OF LARGEST 50 COMPANIES
Ericsson	Central switching (public network)	14.6
Equitel (Siemens)	Central switching (public network)	13.7
NEC	Central switching (public network)	11.4
Elebra Multitel	Transmission	8.7
Sesa Rio	Central switching (public network)	4.5
Promom Eletronica	Data switching terminal	3.1
Matec	PBX	3.0
Telemulti	Transmission	2.6
Splice	Transmission	2.4
SAT	PBX	1.8
10 largest firms		65.8
50 largest firms		100.0

Source: Anuario Telecom 92/93, extracted from Pessini (1993: Table 2.3)

Production of telecom equipment in Brazil is a highly specialised industrial activity. Information of the 50 largest telecom companies presented in Table 5 shows that most of the companies in the telecom industry segment are specialised, with the obvious exception of firms producing

components and cables. Production of facsimile equipment is also made jointly with other electronic goods.

Production of equipment destined to public telecommunication services is as concentrated in Brazil as everywhere else. The three largest producers of central switch for public networks, which are also the three largest firms in the whole sector, have 40 percent share of the market. The 10 largest telecom companies have a 60 percent share of the market. The strategy of some of these companies has been, since the mid 1980s, to explore economies of scope by establishing association with other sister companies acting in the segments of data-processing equipment, consumer electronics, or components. This has been the case of Elebra, Multitel, and the ABC, SID and Itau holding groups.

The Brazilian telecom industry is oriented towards the domestic market. Its exports are small, around US$30 million in average during the 1977-86 period, representing in average a 3.8 percent share of the total production (Moreira 1989:84). In 1992, Brazilian exports of telecom equipment were worth US$35 million, or 3 percent of production. Imports were in average US$108 million in the 1977-86 period, when the apparent consumption was in average US$866 million. Imports of telecom equipment contributed, therefore, in average 12.4 percent to the Brazilian apparent consumption of telecom equipment in that period.

5. Diffusion of digital telecommunication through Brazilian R&D

The establishment of a strong base in digital technology was one of the long-term development goals of TELEBRAS. The creation of CPqD and a selective approach to collaboration with domestic research groups have been central elements in this long-term policy. CPqD was to assist TELEBRAS in specifying the local network, to develop systems locally and to help in the strengthening of a locally-owned industrial segment. One strategic aspect of CPqD initial activities was to identify and deploy the existing technology resources, consisting mainly of university teams engaged in electronics-related research which had already been supported by TELEBRAS. These groups received sustained support to pre-competitive basic and applied advanced research with high academic returns. TELEBRAS has adopted these research results as standards or basis for procurement specification. CPqD has been engaged in development activities to scale up research results to be transferred to private companies, and in the training of production engineers of private companies.

Despite the comparatively low levels of investment in R&D, a substantial base in digital telecom was developed. In the early 1980s, CPqD employed around 700 staff with an additional 290 "contracted out" employees (Hobday 1990:120), not much if compared to public R&D centres or research departments of transnational corporations in the developed world. With this staff, however, CPqD conducted a program covering the main telecom equipment areas: digital exchange technology, digital transmission, data communication, optical communication, satellite communication, telecom systems, and components and materials[2]. From its establishment in 1976 to 1984, CPqD registered 183 official patents at the national directory of patents of the Brazilian Institute of Industrial Property. A study of all patents and technologies applied for and received by firms from CPqD in the early 1980s has shown that all products developed were digital semiconductor-based technologies (Hobday 1990: 128). An extensive list of international collaborative technology agreements was established between CPqD and other research institutes, firms, foreign PTTs and UN institutions, covering various areas ithat nclude satellite development, integrated circuit manufacture, exchange equipment, and optic fibre.

TELEBRAS R&D resources have consistently supported three university research groups: the Electric Engineering School (FEE) and the Glebb Wataghin Institute of Physics (IFGW) at the University of Campinas (UNICAMP), and the telecom and microwave research group within the Microelectronic Laboratory (LME) at the University of Sao Paulo (Castro and Balan 1994). Before the creation of CPqD, TELEBRAS had already established three cooperation agreements with FEE. The first, in 1973, targeted the development of the pulse code modulation component to be later used in the Tropico project. The second, in 1974, financed the creation of a laboratory for microelectronics research with telecom applications. The third, in 1975, promoted the constitution of a new research team on purification of silicon for electronic applications. When CPqD was created, a decision was made to locate it in the vicinity of UNICAMP, close to FEE and IFGW and not far from LME.

Presently, FEE is a research institute and graduate school with an academic staff of 91 specialists, 86 percent of whom with Ph.D degrees, 530 graduate and 450 undergraduate students. It is

[2] The "Tropico" project illustrates the kind of R&D activities conducted by CPqD during the 1980s. Exploiting the modularity of digital exchange technology, CPqD started by concentrating on developing small-capacity digital exchanges. Tropico C entailed the development of a line concentrator with a capacity of 100 to 200 terminals. Field tests were carried out in 1982 and in the following year the system was contracted out for manufacture. The Tropico R project developed a small public exchange with a capacity for 1000 terminals. Subsequent projects aimed at a 4000-line and a 10,000-line switching systems (Hobday 1990:123).

composed of eleven departments specialised in the areas of computing engineering, automation, electric machines, electronics, microelectronics and optical-electronics, bio-medical engineering, telecommunication, and energy systems. An assessment of the academic training and research in engineering in 1993 gave "centres of excellence" status to five out of the seven areas of specialisation of FEE, including electronics, microelectronics, automation and telecommunication. The recent liberal treatment of imports of digital telecom consumer products, economic recession and the stagnation of public investments in the telecom network have provoked some excess capacity and reduction of research activities at the FEE and LME. Their research infrastructure and the human resources generated during previous decades constitute precious assets to be preserved.

TELEBRAS strategy stands in stark contrasts with the way the Brazilian state approached technology development of another segment of the electronic complex, the domestic data-processing industry. Brazilian "informatics" policy did not attach a clear strategy of incorporation of domestic research capability to the protectionist, import substitution industrial policy for the computer segment. The focus was on incentives to R&D at firm level, not to linkages with established research groups. University "brain drain" in favour of some locally-owned companies and the generation of "spin-off" companies created by university researchers were the major effects of the "informatics" policy R&D strategy. The import control policy did not favour the needs of technical equipment for academic research and university laboratories soon became outdated. Around 60 percent of the locally-owned companies affiliated to the Brazilian Computing Society had internal R&D activities in the late 1980s. None of them had established any coperation links with university research groups (Castro and Balán 1994:9-10). When the policy collapsed in the late 1980s, there was not much left in terms of R&D infrastructure. Electronic engineers and other higly specialized technicians employed in the private sector became redundant and are now willing to return to the universities. Some public resources have been directed to stimulate the area of software development and export. Economic recession and the adaptive strategy domestic industry has chosen to face competition of imported electronic products have reduced drastically the employment prospects for qualified researchers and the incentive for younger generations to get academic degrees in computing engineering. To avoid that institutional shifts affecting the markets of telecom services and equipment have similar consequences on Brazilian technology capacity is presently a challenge to policy makers.

6. Summary and conclusions

International diffusion of advanced telecommunications has usually been disconnected with local innovation capacity, which remains concentrated in a few industrialized countries. Brazil, a middle-income developing country, is among the few that developed a domestic production and research capacity in digital telecom equipment.

The present structure of the Brazilian telecom industry was shaped by the institutional restructuring of the telecom services and governmental regulations of the purchase of equipment by the operators of public telecom service. This institutional arrangement of public-private cooperation that promoted digital technology diffusion and Brazilian R&D has presently reached its limit. The reduced investment capacity of the state and the need to expand and diversify the telecom service network in a context of open market, push for another institutional change with a redefinition of the relative weight and the terms of collaboration between the public sector and the domestic telecom industry.

The terms of a multilateral telecom services market-opening agreement that is under GATS negotiation sets the international background for a new institutional configuration. International debate on the best way to promote liberalisation and create a global information infrastructure has still to overcome controversies over topics such as interoperability and regional standards that have direct impact on the telecom equipment industry.

The telecom advanced research infrastructure and human resources available in Brazil constitute precious assets which are presently underutilised. As a part of the domestic system of innovation, they define a Brazilian dynamic comparative advantage in the area. This technological basis is a important economic incentive for firms to expand production capacity and increase their efficiency and competitive levels. To preserve and expand this technology capability for the benefit of a more efficient domestic production and service supply is the present challenge of policy makers in Brazil.

References

Antonelli, C. (1991) *The Diffusion of Advanced Telecommunications in Developing Countries*, Paris, OECD Development Centre

Bangeman, M. (1994) *Europe and the Global Information Society. Recommendation to the European Council*, Brussels

Bastos, M.-I. (1994) *Winning the Battle to Lose the War. Brazilian Electronics Policy Under US Threat of Sanctions*, London, Frank Cass

Castro, M. H. M. and Balán, J. (1994) "Universidade Versus Setor Produtivo: A Perspectiva e a Realidade da Universidade", São Paulo, NUPES/USP, Working Paper 8/94

EITO (1995) *European Information Technology Observatory 95*, Frankfurt

Hobday, M. (1990*) Telecommunications in Developing Countries. The Challenge from Brazil*, London, Routledge

ITU (1994) *World Telecommunication Development Report. World Telecommunication Indicators*, Geneva

Mansell, R. (1993) *The New Telecommunications. A Political Economy of Network Evolution*, London, Thousand Oaks, and New Delhi, SAGE Publications

Moreira, M. M. (1989*) Progresso Técnico e Estrutura de Mercado: O Caso da Indústria de Telequipamentos*, Rio de Janeiro, BNDES

Olbeter, E. R. (1995) "Opening the Global Market for Telecommunications", *Issues in Science and Technology*, Vol. XI, No. 2, Winter 1994-95, pp.57-64

Pessini, J. E. (1993) "Competitividade da Indústria de Equipamentos de Telecomunicações", in IEI/UNICAMP, IEI/UFRJ, FDC and FUNCEX, *Estudo da Competitividade da Indústria Brasileira*, Campinas

Pouillot, D. and Dartois, O. (1991) La Globalisation dans les Telecommunications, OCDE, FAST, Fop 282

SEI (1982) *Transborder Data Flows and Brazil: The Role of Transnational Corporations, Impacts of Transborder Dat Flows and Effects of National Policies*, Brasilia