Chapter 5 High-tech Brazil: Challenge of Local Innovation Systems

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Nobuaki Hamaguchi

I. Introduction

Brazil constitutes a group of a small number of developing countries exporting technology intensive products. Table 1 includes technology intensive manufactured products such as aircrafts, automobiles, and cellular telephones. The government initiatives in the past shaped the core part of the Brazilian aircraft technology, which was further sophisticated after the deep structural transformation and internationalization in the 1990s. A privatized national company Embraer is the fourth largest aircraft producer competing for the third rank with Bombardier from Canada.

It is to be also noted that even some primary products appearing to be natural resource based actually contain high technology contents. Take soybeans as an example. Soybean exports increase was made possible by expansion of plantation in the vast semi-arid inland area. The national agricultural laboratories of EMBRAPA created biologically modified seeds and developed the method of optimum application of calcium to transform acid soil arable. Consider also the case of petroleum. Since most of crude oil reserves in Brazil are found in a deep sea, exploration projects require highly sophisticated search technology. Petrobras, a national oil company, spent R$1.5 billion during 1995-2001 for research and development. (Petrobras, Relatório de Gestão 2002, p.23)

On the other hand, in some cases high technology products may actually have little local technology contents. Automobile industry in Brazil developed by foreign technology and local parts suppliers were also grown together. Yet, in the climate of the liberalization in the 1990s multinational auto parts firms largely acquired competent local suppliers and others were replaced by imports. In these events, local technological capability was considerably lost while increasing the dependence on foreign technologies. Cellular telephone equipment exports have become significant only recently. Since the import

substitution of telecommunication equipment and informatics failed to establish electronic component industry, increasing exports of cellular telephones contain least local technological contents, provoking large volume of imports of parts and components at the same time. Exports of foreign technology dependent products like automobiles and cellular telephones have been especially helped by devaluation of the real in recent years which encouraged multinational enterprises to utilize their production in Brazil as the export base to neighboring countries. Their competitiveness also depends on tax incentives offered in specific locations. These kinds of exports will not construct a solid basis of the export structure because multinational companies can easily switch their export platform from one country to another.

In the era of the globalized economy, a semi-industrialized country like Brazil should facing a challenge to increase own technological capability. Although there is no doubt to say that the national R&D efforts have already made significant contribution to widening exports variety, much more local R&D is required to have more solid and diversified export structure.

Currently, the R&D expenditure in 2000 represented only 1.4% of GDP and 60% of them comes from the public sector (Figure 1). This contrasts to the case of OECD countries where private enterprises' expenditures account for 65-75% of the total R&D (OECD, Main Science and Technology Indicators). The government is eager to stimulate private R&D and introduced at the federal level such measures as *Fundos Setoriais* (Sector Funds) managed by the FINEP – a science and technology development fund under the Ministry of Science and Technology. Given that the financial constraint is the highest obstacle for private R&D, the funds has financing for R&D activities of private companies allocated to designated sectors as well as co-research projects with universities. In addition PDTI/PDTA (Program for Industrial/Agricultural Technology Development) established by Law 8661/93 and modified by Law 9532/97 provides tax incentive for R&D. Most of beneficiaries of this program are large firms, including local subsidiaries of multinational firms. The new Informatics Law (8248/91 and renewed by Lei 10176/01) in turn provides tax incentives to R&D expenditures in area related to informatics technology.

At local level incipient attempts are being made to help newly established technology based firms to grow by nursing in incubators. According to the survey by National Association of Promoters of Advanced Technology Enterprises – ANPROTEC, there are currently 183 incubators in operation in Brazil, increasing from 12 in 1992. Out of them 147 are located in Southeast and South Region and 57% are considered as technology based ones. 47% are privately owned non-profit seeking and 42% are controlled by federal and local governments. 67% of them incubate less than 10 firms. A half (49%) of incubated firms are of electronics-information technology – telecommunication complex and only 4% are of biotechnology. 47% of entrepreneurs own undergraduate degree and 21% received graduate education. Many of these firms are originated from university research.

It should be recalled that scientific production is intensely concentrated regionally. Table 2 indicates that almost 70-80% of graduate students in biology and engineering are located in Southeast region while other 15% are in South. Naturally, technology based industrialization tend to agglomerate in these regions.

While the federal level effort to ease the bottleneck of finance is considered vital, our argument here is to stress importance of taking geographical dimension of innovation. Namely we emphasize that in practice new ideas of production tend to emerge interaction of related agents and the facility of interaction has much to do with the distance among them. Several scholars like Cassiolato & Lastre (2000) have developed a compelling argument justifying the concept of the local innovation system (LIS) in the Brazilian context, as an analog to the national innovation system idealized by Nelson (1996) and others. According to them the local system will capture production linkage among firms and involvement of related agents other than firms themselves such as universities and other scientific research institutions, workers, local government, and civil societies, promoted by shorter inter agent distances.

The concept of a LIS coincides with a cluster, which is a spatial concept of agglomeration of industries in particular location. We consider LIS as a subset of a cluster, differentiating from other kind of cluster by its very nature of orientation toward creation of products and production methods that are new to the industry. In contrast, a non-LIS

type cluster is based on technologies either already locally standardized or adapted from outside. Following Nelson (1996), information on technology is a public good in such places. Firms do not compete trying to be differentiated from each other, but they collaborate to use the shared technology in most efficient way. Thus, the centripetal force of agglomeration is the frequency of interaction among firms. This type of cluster can be modeled in consistency with neoclassical perfect competition model: i.e., $Q=A(N)f(\ .\ )$, where Q is the sector output, A is an increasing function of the size of local firms N capturing Marshallian externalities, and $f(\ )$ is a constant-to-return production function.

In contrast, firms in LIS seek competitive advantage by enlarging technological differentiation to capture monopolistic rent, following the pattern of the Schumpeterian competition. Such differentiation can be made by incorporating innovative scientific research results. Unless such knowledge flows can be generated inside the firms, private interactions with universities or research institutes are imperative. Even when R&D is internalized, firms should rely on supply of highly educated human resource produced by universities. Thus, firms are attracted by accessibility to universities and research institutions.

Such distinctions lead to different policy implication to local authorities. In the case of non-LIS cluster, local governments are required to support institutions for sharing local knowledge such as local vocational training center, formation of chambers and cooperatives, and arrangement of subcontracting works. For LIS cluster promotion of interaction between local academic institution and firms are most welcome, including joint research, matching of university researches and firm business interest, and spin-off of university researchers establishing their own companies.

This paper consists of three case studies of the LIS type clusters representing different scenarios of industrial policy. The first story is about the case of telecommunication equipment in Campinas of São Paulo State. There, original national technology was developed under the government initiatives but as the result of disorganized privatization and market opening resulted in hollowing out of the major part of the previous efforts leaving only small niches of business. However, the intensified competition has made the

locational advantage of the region revaluated to become one of the most interesting places for technology-based multinational firms because of its strong academic and research base. The second example relates to the most successful case of aircraft industry in São Jose dos Campos of São Paulo State. The initial strong government initiative played a decisive role in formation of sound technological basis and then with privatization the industry made successful transition to local private ownership with strategic alliance with foreign capitals. The third case deals with emerging biotechnology industry in Belo Horizonte of Minas Gerais State. Apart from the previous two cases, there was no government initiative even at the initial stage of its development. Still, three have been some important development led by spin-off of university researchers. Firms are born small and struggle to grow bigger on the basis of their technological competitive edge. Although local arrangements are being organized in systematic way and there is strong local political will to support, firm growth tend to be constrained by limited access to financing. Such constraints may lead to convince them to sell off the developed technologies to multinational firms.

II. Campinas – Telecom Equipment

Brazilian telecommunication industry was restructured by the Telecommunication Law of 1962 that put the national telecommunication system under the coordination of a federal agency. Telebras was then created as the holding company of state level local telephone service companies and the long-distance call operator Embratel. Telebrás exerted monopolistic power in procurement of equipments as a tool of industrial policy[7]. Initially telecommunication equipments were supplied only by local subsidiaries of multinational firms such as Ericsson, NEC, and Equitel/Siemens. Telebras promoted competition of the three firms by utilizing its monopsonic procurement power inducing them to bring the latest technology to Brazil.

[7] The procurement policy was guided by the following principles: (i) diversification of suppliers in order to avoid monopolization or excessive fragmentation of the market; (ii) organization of purchases in clusters according to kind of equipment and geographical area they will be used in order to rationalize 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 (Bastos, 1995: p.9).

Later, Telebras gradually established an industrial policy to absorb foreign technology and substitute a part of market share by national brand. It started an ambitious project targeting the development of the pulse code modulation component in 1973 recruiting professors of University of São Paulo. This endeavor was pursued more systematically after the Telebrás' creation of a research and development center CPqD (Centro de Pesquisa e Desenvolvimento) in 1976. Activities of CPqD broadly varied from electronic switching, digital transmission, optical communication, data and text communication, and satellite communications.

The location of CPqD was chosen in Campinas, located at 100 km to the north of the state capital. The location choice was influenced by the existence of São Paulo State University of Campinas (Unicamp) founded n 1966, taking Massachusetts Institute of Technology as a model to create the center of excellency in research and graduate programs especially in hard sciences. In the related area of electronics, and information and telecommunication technology, Unicamp embodied the Faculty of Electric Engineering and Computation (FEEC), and the Institute of Physics (know as Instituto de Física Greb Wataghin – IFGW) which developed intense interaction with CPqD. Moreover, Campinas has a Cathoric University (PUCCAMP), University of São Francisco (USF) and Campinas Technical School (COTUCA), a vocational education unit of Unicamp, offering specializing course in electronics and telecommunication.

According to Dahlman and Frischtak (1993), in 1988 CPqD was the largest and most sophisticated applications laboratory in Latin America. It employed 400 professionals directly engaged in R&D with about US$ 60 million of allocated budget. Yet, for CPqD's too broad activities without particular focus, the resource was not enough. Coupled with lost opportunities to take advantage of cheaper international technologies, government R&D efforts were considered slow and not very effective (Dahlman and Frischtak 1993: pp.437).

CPqD established a joint-venture with a national private group Procom a manufacturing firm producing the locally developed commuation equipment Trópico. An early models were put into practice in the 1980s but due to its limited capacity they were installed only in rural area. After the introduction of high capacity model Trópico RA in 1991, Telebras

preferentially procured it and by the mid 1990s, Trópico already divided almost equal market share with other multinationals. (Szapiro, 2000) Today Trópico model commutation equipment is produced by Promom and also licensed to a French multinational Alcatel.

CPqD was transformed into a private foundation following the privatization of Telebras in 1998 and its role of the integrator was lost. Yet, there is no doubt about that the presence of CPqD was a critical mass leading to a formation of the current local productive arrangement for technology based manufacturing in Campinas.

First, the frequent interaction with CPqD marked strong characteristics in research and education orientation in local universities. In Unicamp, FEEC (http://www.fee.unicamp.br/FEEC-nova/index2.htm) has over 100 professors in its eleven departments and its graduate program of has about 550 students in the field of industrial automation, biomedical, computer science, and application of electronics to microelectronics e optictronics, energy, telecommunication, and telemetric. They produce more than 60 master degrees and 40 doctor degrees annually. Their program is nationally renown as the only one that is given the highest grade of CAPES, the higher education evaluation office of the Ministry of Education. Institute of Physics (http://www.ifi.unicamp.br/), with 94 professors and 186 graduate students and 458 undergraduate students, confers 25 to 25 master and doctoral degrees annually. Their graduate program also receives the highest grade of CAPES.

Secondly, many local firms in the related business were born. Since 1973, IFGW has worked with CPqD for the development of optic telecommunication technology, leading to foundation of Xtal, the largest optic fiber producer in the domestic market. Another case of spin-off was AsGa, founded by ex-director of IFGW aiming at production of optic-electronic component for electric/optic signal converter. IFGW is recently implementing joint R&D projects in the advanced optic fiber technology with companies such as Ericsson which established a research center in Campinas. From CPqD itself, one of its former researcher (and a graduate of IFGW, too) founded OptoLink, a producer

of optic amplifiers and connectors. The following is a partial list of Campinas-based local companies.

Brazilian firms
Art Craft Produtos Ópticos Ltda. New materials/ Optics
Bioluz- Equipamentos e Serviços Ltda. New materials/ Optics
Carel Indústria Óptica Ltda. New materials/ Optics
Fausto Becca
Fiber Work- Tecnologia de Comunicações Ópticas New materials/ Optics
Fybercom
Ideal Brasil
LR Telecom
Nalitel Telecomunicac. e Teleinformatica
Neger Telecom
Montmartre Produtos Ópticos Ltda. New materials/ Optics
Optolink
Darumatec Digital telephonic assistance systems
Consórcio Tess Telecomunicações Telecommunications
Emerson Electric do Brazil Ltda.
AsGa Microeletrônica S.A. New materials/ Optics
Redein Telecommunications
Promon - Trópico Sistemas e Telecom. S.A. Telecommunications
Celtec / Celplan Ltda.

The Brazilian government reformed the Law of Informatics in 1991. While the old law aimed to import-substitution by practically prohibiting imports of electronics parts, the new law changed aims to stimulate innovation in information technology related area by giving a firm tax reduction when it invest no less than 5% of its revenue in research and development. Since 2.3% out of this can be spent for contracting research institution or university, demand for interaction with CPqD and Unicamp was stimulated. Thus, telecommunication equipment producer such as Promon and Zetax were concentrated in Campinas looking for proximity to CPqD.

Thirdly, availability of skilled labor attracted a number of multinational firms of informatics and telecommunication equipment industry[8].

Telecommunication technology related foreign enterprises in located in Campinas area.

Compaq do Brasil (Computing)	USA
DEC (Computing)	USA

[8] Other than telecommunication technology related, there are increasing localization of automobile industry in Campinas and its surroundings, such as Toyota, Honda, Mercedez-Bentz.

IBM (Computing Research Center)	USA
Hewlett- Packard Brasil S/A (Computing/ Bank automation)	USA
Texas Instrumentos Eletrônicos do Brasil (Computing/ Electronic components)	USA
Avex Electronics do Brasil (Computing/ Goods manufacture)	USA
SCI Systems-Advanced Electronics Technologies (Computing/ Goods manufacture)	USA
GE Plastics (Blades and Cover)	USA
FiberCore Inc/Xtal Fibras Ópticas S.A (New materials/ Optic Fibers)	USA
Motorola do Brasil Ltda. (Telecommunications/ mobile telephony and pagers)	USA
Nortel Comércio e Serviços Ltda. (System integration and data communication)	Canada
Fibercore Inc. (Telecommunication)	USA
Lucent Technol Network Systems Brasil S/A (Telecommunication)	USA
Alcatel Telecommunicacoes (Telecommunication)	France

The concentration of high technology firms has also very much to do with the deregulation process. Pricvatization of the telecommunication service abolished the monopsonic procurement power entitled to Telebás. Newly installed telecommunication companies found the telecommunication infrastructure severely under-invested and operated under obsolete technology. Such regulatory framework change created expectation for huge demand for equipment with the state-of-art technology. This paved the way to entry of foreign companies such as Alcatel, Lucent, Nortel and Cisco Systems. Most of them established local production because of tariff reduction in the early 1990s and the new law of informatics of 1991 liberalized imports of equipment and electronic parts. Newly entered multinational firms do not engage in R&D but provoked large inflow of imports of parts. Trade deficit of the sector reached to US$ 2 billions annually in 1996-2001. (Oliva, 2002)

Although regulatory framework change has led to expansion of the market and promoted internationalization of the telecommunication equipment industry, the sector increased dependence on foreign technology and autonomy of local innovation was lost[9]. De Souza et.al (2001) considers that the new institutional framework contributed to attract foreign investment and new technology but reduced the degree of internalization of technology in the local production chain, contributing the significant part of the trade deficit, and reduce

[9] De Souza et.al (2001) reports that CPqD's difficulty after the privatization having to survive with small projects rather than long-term strategic ones like Tropico and training service to local enterprises which end up inducing outflow of personnel to such companies.

the chance of spillover. Porto et.al.(2000) also pointed out that the structural change in the 1990s provoked profound "dismantling" of the telecommunication equipment agglomeration.

The regulatory reform gave profound impact on the local firms as well. CPqD was reestablished as a private consulting firm and lost the characteristics of the integrator of the local innovation system. Several firms were acquired by foreign enterprises. An American firm Fiber Core recently acquired Xtal (Xtal Fiber Core Brasil as it is now called). Zetax was acquired by Lucent together with Batik of Minas Gerais in 1999. As for the companies remaining in the market, Promon established manufacturing plant in Manaus, away from Campinas, seeking for tax incentive in the Free Zone. Promon recently accepted a minority participation of Cisco Systems which still does not have its own local production unit in Brazil. AsGa, one of CPqD spin-offs, could not compete in the electronic component market and sought to survive by switching specialization to produce equipment such as optic modem with imported parts.

Although Campinas area is sometimes dubbed Brazilian Silicon Valley because of the high concentration of high technology based big names, Cassiolato et.al (2001) remarked that operations of these companies do not necessarily represent high technological intensity. The new Informatic Law certainly give incentive to local R&D but since R&D is too broadly defined by the Ministry of Science and Technology to include workers training, international trips, adaptation of foreign products (so-called nationalization), and technical services, the current tax incentive scheme tend to distort toward such lower intensity "R&D". Furthermore, while technology-based firms were attracted to Campinas area by the technological spillover of CPqD in the past, these new coming multinational firms are attracted only by opportunities to hire well-educated workers than the technological dynamics that the region can offer through interaction of research and production. Thus, as Diniz and Razavi (1999) worries, "Campinas will increase its role as an assembly platform with weak supply links to national and local industries." Such scenario may depend on Brazilian market prospectives. Companies such as Nortel and Motorola have announced an intention to establish research and development units in Campinas integrated in their global innovation network.

III. São Jose dos Campos

São Jose dos Campos is also 100 Km away from the São Paulo State capital, yet to the east along the Dutra Highway connecting São Paulo and Rio de Janeiro. Not only the distance but the city also shares similar characteristics to Campinas. Local innovation system of São José dos Campos is also based on establishment of MIT-modeled research center in 1945 – Centro Tecnológico Aeroespacial (Aerospace Technology Center), which was later complemented by establishment of a higher education institution Instituto Tecnológico de Aernáutica (ITA) in 1950 and a special research institute Aerospace Research Institute (Instituto de Pesquisas Espaciais, INPE) in 1961. During the 1950s and 1960s, ITA became the most prestigious engineering school in Brazil (Diniz and Razavi, 1999: p.114)

State owned aircraft company Embraer was in turn founded in 1969. Embraer was created with the research and management personnel from the Research and Development Institute (IPD) of CTA. The blue pints of Embraer's first products like Ipanema (for agricultural works)and Bandeirante (for civil market) were also developed by CTA. Embraer initially counted on technical support from foreign companies such as licensing agreement with an Italian firm Aeromacchi for the production of military aircraft Xavante and general engineering support from Piper Aircraft Company of the USA. In the 1980s, Embraer launched AMX project to produce subsonic military aircrafts in cooperation with a joint project with Italian Aeritalia and Aermacchi. Such experience of technology learning from foreign companies were crucial for formation of development strategy of Embraer[10].

While other import-substitution industries focused on increasing the degree of nationalization, Embraer pursued completely different strategy. The company did not intended to deepen vertical integration but made long-term parts supply contract with foreign suppliers. Instead, Embraer concentrated its effort in design and final assembly. Bernardes (2000) quotes Dagnino (1994) that "if the aircraft industry organization had insisted in nationalization of parts, the production costs could have been even prohibitive

[10] These technical cooperation programs enabled substantial technology transfer to Embraer including training of the personnel in the advanced production facilities in overseas. (Cassiolato & Lastres, 2002: p.17)

and Embraer's market entry could have been substantially delayed (because of the small scale, instable market condition, less reliable quality and underdeveloped technology)." Only the production of fuselages was internalized because it was considered as the key technological area that cannot be learned from overseas. (Bernardes 2000: p.17) In other words, Embraer has identified itself as a final assembler with technological autonomy based on the capability to systemically integrate available advanced technology of the world. Government agencies like National Bank for Economic and Social Development (BNDES) and Banco do Brasil offered buyers credit to streamline the sales. The result was spectacular. The bimotor turboprop airplane Bandeirante one third of the US market of commuter line aircrafts with 10-20 passenger seats in the 1980s. In the military market, Tucano model training airplane was widely sold to British and French air forces.

Changes in local innovation system

The overall deterioration of the macroeconomic scenario in the 1990s affected the government science and technology projects. In the same way as what happened to CPqD in Campinas, CTA suffered reduction of resources and drain of knowledgeable people. Embraer itself experienced substantial structural changes in the 1990s. Its employment was cut half from the peak level of 12,000 at the end of 1980s to about 6,000 in 1994 when Embraer was privatized. Embraer was acquired by a financial consortium of an investment bank (Bozano Simonsen group) and public enterprise pension funds. During the state ownership period, the management board used to be consisted with members promoted internally but after the privatization the management board was replaced with external professional persons. Employment was further reduced to less than 4,000.

After the privatization, productive arrangement changed substantially. Based on the original strategy of focusing design and system integrating assembly, Embraer sought risk sharing partners who take full responsibility in manufacturing of sub-systems with own investment sharing the commercial risk of the final product. There the competitiveness of product design capability of Embraer was tested and such tenders attracted many internationally known enterprises. On the other hand, through cooperation with global partnership Embraer acquired higher technological standard. The first case was the risk sharing contract with United Technologies – Sikorsky in

development of a civil helicopter where the latter develop and produce the fuel system, fuel tank, and landing train. Through this project, Embraer had first access to the design technique through virtual technology utilizing computer aided three-dimensional interactive application, which turned to be technical standard of Embraer (Goldstein, 2002: p.108).

Embraer started development project of medium-size (50 passenger seats) jet airplane (ERJ-145) in 1989 and the jet aircrafts but the project was stopped because of the lack of finance, even though the quality of its design was of high quality. The project became viable thanks to the participation of four foreign companies (Gamesa, ENAer, SONACA, and C&D Interiors) as risk sharing partners which carried out construction of subsystems such as wing, subsections of fuselage, and interior[11]. Embraer adapted the concurring engineering with real time connection via CAD/CAM with several project teams. This brought substantial saving of cost both in time and money[12] (Cassiolato 2002: p.41).

The regional jet market expanded in the US and Europe prompted exceptional growth of exports of Embraer. The ERJ –145 jet aircraft was well accepted by the market because it was lighter, quieter, cheaper, and more fuel saving. Compacter variations ERJ-140 and ERJ-135 were derived from the same platform of ERJ-145 to attend differentiated needs of customers. It should be also remarked that even after the privatization, Embraer continued receiving substantial financial assistance for R&D activities from government agencies (FINEP and BNDES), tax incentive in the framework of PDTI, and credit and interest subsidies (PROEX) to buyers[13].

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[11] The Spanish company Gamesa was responsible for the production of the wings, engine nacelles, fairings of the wing/fuselage junction and the doors of the main landing gear. Sonaca, headquartered in Belgium, committed itself with the production of the luggage, service and main doors located in the fuselage, besides a front and a rear section of the fuselage and the two motor pylons. The Chilean company ENAer produced the airplane wings and rudder controls. The interior of the passenger cabin and luggage compartment was developed and manufactured by C&D Interiors - one of the largest companies of the world in its specialty. (Cassiolato et.al. 2002, Box III)

[12] Embraer established a Virtual Reality Center with the cooperation of Silicon Graphics Inc. in 2000 with the investment of US$ 2.6 million.

[13] Canada filed a complaint to WTO that PROEX is a sort of export subsidy not allowed by WTO agreement and Embraer is threatening Bombardier with unfair competition. The trade dispute was enlarged to NAFTA's ban on

Taking the same steps, Embraer initiated a new project for larger (70 passenger seats) airplane – ERJ-170 – in 1998. Risk sharing partners in this project include General Electric, Gamesa, Hamilton Standard, Latécoère, Kawasaki Heavy Industry, Gamesa, Sonoca, C&D Aerospace, Parker, and Liebherr.[14] According to Cassiolato et.al. (2002) up to 2001, about 95% of the suppliers were located abroad (p.48). Embraer is trying to induce its partners and suppliers to establish production in Brazil but so far only Sonaca established in São José dos Campos an affiliate Sobraer. ELEB (Embraer Lebherr) is in São José dos Campos. Recently, Kawasaki announced to establish a plant in Gavião Peixoto

With the internationalization of partnerships, local factors for innovation is weakened. Although CTA performed fundamental role in creating Embraer, the latter do not depend on CTA's research. ITA is still considered as one of the most prestigious engineering school, but its graduate program is not given the highest grade. It is also said that ITA cannot supply specialists at the same speed as Embraer requires (Forbes Brasil, 25/10/2002: p.33). Embraer created own master program "Program of Specialization in Engineering" in partnership with ITA and Unicamp. .

There are still small number (around 40) of locally-owned suppliers and producer service providers depending on subcontracting of Embraer. Many of them were setup by former Embraer employees. A SERCO (Engineering Service Cooperative) setup in 1995 by former engineers of Embraer as a non-profit organization. The associated firms offer specialized services to Embraer and its risk sharing partners. Owing to the recent boom of aircraft exports, employment level of Embraer is the highest since the beginning of 1990s.A part of the ex-employees are retuning to Embraer's workplace. This existence of a pool of specialized labor has given Embraer a certain flexibility enabling its rapid growth. Availability of highly qualified engineers, in turn, has given agglomeration effect

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Brazilian beef imports. Although it was justified on the basis of the suspect of foot and mouth disease, Brazil recognized it as retaliation. The dispute was settled by WTO in favor of Brazil.

[14] GE is responsible for supplying turbines. It then holds 99.6% stake of Celma, a suuplier of motors, accessories and parts, located in Petrópolis-RJ. GE also took over Honeywell who supplies most avionics. Gamesa supplies rear fuselage. Kawasaki, from Japan, is developing the central part of the wing. Liebherr established a joint venture with Embraer for the supply of the landing gear.

to technology-based multinational firms in transport equipment and electronic sectors like General Motors, Volkswagen, Ericsson, Panasonic, Philips, and Kodak located in São Jose dos Campos and its vicinity.

IV. Belo Horizonte

Unlike the previous two cities, Belo Horizonte is not a specialized industrial city. It is the state capital of the third largest economy in Brazil, Minas Gerais. So, like other state capitals, Belo Horizonte has highly diversified economic structure with high proportion of service activity. Secondly, Belo Horizonte cannot be seen as a *technopolis* as the previous two because technology-based activity is not really representative. The state is known for its agricultural richness and as the name of the state – the land of all mines – speaks, industrialization of the state was led by metal and machine industry. Hence, in terms of the share in the total industrial production, heavy industries, such as the automobile production complex of Fiat in the outskirt of the city, are still predominant. In this sense, the city economy is more resource based than being technology based. Thirdly, Belo Horizonte did not host a large-scale mission-oriented research institution like CPqD in Campinas and CTA in São Jose dos Campos, through which abundant amount of financial resource was devoted intensively.

Still, there is noticeable development of biotechnology industry[15] in Belo Horizonte. The fundamental vehicle has been the cumulated knowledge in UFMG (Minas Gerais Federal University) from which some entrepreneurial spin-off created competitive firms supported by local institutional arrangement. According to FIEMG (2000), UFMG counts on 161 professors and researchers with PhD degree in the area of biology. The non-profit organization Fundação Biominas serves as the administrative tool to gather newly created firms in its incubator.

The first spin-off from UFMG was Biobras born by biochemist Marcos Luís dos Mares Guia who also founded Institute of Biology of UFMG. The company started production of enzymes in 1976, then engaged in production of insulin as the joint venture with Eli

[15] Another difference from the cases in Campinas and São Jose dos Campos is that the biotechnology is relatively new industry and it was never be a target of import substitution industrialization.

Lilly (USA) in the early 1980s and dominated the domestic market in a few years. The company was sold to Novo Nordisk for US$ 22 million in 2002, still holding some patents to establish a new enterprise Biom, specialized in development of synthetic insulin.

The 2001 survey by Biominas Foundation identified 304 biotechnology firms creating about 28,000 qualified jobs among which 89 firms (29%) are located in Minas Gerais, being only second to São Paulo which accounted for 129 (42%). (Biominas, 2002) In this, biotechnology firms in São Paulo are suppliers to multinational firms while those in Minas Genrais are independent and locally-owned concentrating in human health products. In Belo Horizonte alone, there are 58 firms with total sales revenue of US$ 417 million and 4,273 workplaces in 2000, engaging mainly in development of medical diagnostic kits (18 firms) and pharmaceuticals (11 firms). (FIEMG 2000)
Yet, some analysts are still skeptical whether the biotechnology industry in Minas Gerais is as big as to be called "a cluster".[16] They also cast a doubt that the even that size is exaggerated, given the fact that Biobrás and Vallée (a leading firm in veterinary products such as vaccine for aftose fever originated in Uberlândia, located at 550 km west to Belo Horizonte) has predominant weight in this subset, representing 42% of the total sales revenue. Firms do not show any particular locational pattern in the city neither being agglomerated in particular streets or districts, nor concentrated nearby the university. So it is even doubtful whether they are having any technological interaction among themselves. In particular, production units of the above mentioned two firms are located in Montes Claros in the northern part of Minas Gerais to receive incentives for northeastern regional development of the federal government.

Another key component of the biotechnology LSI in Belo Horizonte is Biominas Foundation. Biominas was funded in 1990 as the non-profit organization for incubating new biotechnology firms. It is located in the northern suburb of Belo Horizonte on the land conceded by the Minas Gerais State Technology Center (CETEC). It is currently incubating 10 companies and 8 companies are already graduated[17]. The incubator is

[16] Interview at CEDEPLAR and Faculty of Economics of Minas Gerais Federal University on December 5, 2002.

[17] One of graduated firms Ferrara Ophthalmics produces ring to reform deformed cornea causing myopia and astigmatism. The company invested R$ 1 million. Among the incubating companies, JHS Laboratorio Quimico develops material of reconstruction of bones by means of powder based on carbonic calcium with the investment of

concentrated on the second floor of the Biominas building where the space is layout for 26 rooms of 45m^2 partitioned with removable walls and common laboratory space. The incubation contract is annually and renewable to four years. One room is rent for R$ 20/m^2, equivalent to US$6, totaling to R$900 (US$270) per room. One firm can occupy up to 4 rooms slots. Each room is equipped with only basic telecommunication cable (telephone and internet) and purified water, whose services are charged by usage. Research equipment and office furniture should be brought by the rentees. Besides the rental of the space, Biominas provides business support including: legal assistance to setup a corporation; search for funding with private and governmental institutions[18]. Biominas also provides seed money based on the loan from Multilateral Investment Fund of the Interamerican Development Bank (MIF-IDB).

In fact, biotechnology firms are not as representative as the telecom equipment means to Campinas and aircraft means to São Jose dos Campos[19], but it is worth visiting the case because it illustrates the case where technology-based industry can be established within the local innovation system framework even without the financial bonanza. Because of the wide possibility of application and potential synergy effect to other business area (like fusion with electronics, creation of new materials, contribution for emission control, etc.), the local business community has high expectation in the potential of emerging biotechnology cluster.[20]

R$ 800 thousand. Another incubating case includes Biocod Produtos & Servicos who competes in the market of genetic identification with its own methodology cheaper than the competitors in the domestic markets who depend on imported kit

[18] For example, Minas Gerais State Fund for Promotion of Research (FAPEMIG) associated with Development Bank of Minas Gerais (BDMG) and SEBRAE-MG implements PROMITEC (Financial Support Prgram for Technology Based Micro and Small Firms). A beneficiary signs a contract for 24 months, renewable once, of the credit line up to R$ 100,000. A beneficiary should be a research based micro and small firms aiming to develop a scientific research aiming at commercial application, either at setup, initial, or second-stage. The credit has up to 18-24 months of the grace period, interest free (monetary correction by the consumer price index (IPC-A) is charged), repayable in up to 24-36 installments. It requires the guarantee by a third party. Matching fund of 10% of the research project by the beneficiary if the project is in the second stage. BDMG also offers a PROINTEC (Program for the Promotion of Technology based Incubators) which supports incubators.

[19] Remember that a biotechnology is still an incipient industry for Brazil as a whole.

[20] The Federation of Industries of Minas Gerais State (FIEMG), in cooperation with McKinsey, elaborated future development vision of the state, in which the biotechnology cluster in Belo Horizonte was given top priority.

With the technological base on UFMG and supporting activity of Biominas, new firms are emerging. In his own sample survey, Fajnzlber (2002) found diversified reactions to his questions on managers' perceptions on their source of competitiveness and obstacles for growth. Quality (product differentiation, qualified personnel, high standard of production facility, precision of product) is most cited as a source of their competitiveness. Most of firms are implementing own R&D and also maintain contact (either formal or informal) with universities and exchange information with other firms. Yet, he found that only a small portion of firms engage in new technology seeking R&D and most of them are simply application of publicly available technologies. Issues of common interest are discussed in the Chamber of Biotechnology Industry and Syndicate of Biotechnology Firms. According to my own visit to these institutions, they discuss mainly about institutional matter such as government regulations.

Each biotechnology firms in Belo Horizonte are still small and faces obstacles for growth. On the other hand, most important obstacles are access to enough demand. Because of creating new products firms are feeling difficulty in creating the market obtaining consumers confidence. Firms competing with multinational firms, like the case of medical laboratory kits, are having difficulty in competing with products with brand name and strong commercialization channel. Most of them do not have access to the foreign markets. Liberalization is seen as both risks and opportunities. Risks are intensified competition with multinationals and chances are greater opportunities for subcontracting and partnerships.

Fonseca et.al (2002) analizes that Brazil has potential in biotechnology in terms of the quality of the talent in universities and research institutions. According to them, major obstacles are of financial nature to support R&D activities. There are two emerging efforts movements. One is private venture capital fund established by big business groups such as Votaorantim and Copersucar to finance new biotechnology firms. Another is government initiatives led by FINEP in the framework of *Fundo Setorial* to finance private R&D and joint research between firm and universities. Since they are still new institutions and we do not have enough information to evaluate. Yet, private venture

fund, which created high-tech bubble in the USA, has never been a corporate finance model in Brazil. Hence it is hard to predict that this will be a major break-thorough of the financial bottleneck. Likewise, the public fund for science and technology cannot be sufficient due to the hard budget constraint imposed by the macroeconomic scenario. As Fonseca et.al (2002) predicts, there are already some examples of successful partnership with big corporations which should be followed by new biotechnology firms.

In fact, Salles-Filho et.al (2001) describes that one of major characteristics of the modern biotechnology market is a contract of cooperation. Biotechnology is highly research intensive and involves high degree of uncertainty in viability toward profitable commercialization. There is a tendency that large enterprises are competing internationally for market share through mergers and acquisitions in seek for greater market power and financial strength. They are extensively diversified both geographically and in product variety. While the degree of global oligopoly has been increasing, they are looking for outsourcing of innovative specialized knowledge while minimizing the internalization of R&D cost to sustain technological competitive edge in the diversified activities. In the technological frontier, therefore, so-called new biotechnology enterprises (NBEs) have opportunities of partnership with the big enterprises, mainly financial, to advance their research at their own risk. When the research will reach a concrete result NBEs will let the development for commercialization to the global firms because they cannot compete with the latter due to a scale economy. Thus, NBEs and global firms can play complementary role with each other.

Biotechnology firms in Brazil can amplify potential of growth by pursuing such strategic alliances with big enterprises. The sales of Biobrás to Novo Nordisk can be understood as one of the leading examples[21]. The ex-president of Nordisk and current president of Biom says, “In the technology based industry, a success may not mean to hold a firm for ever, but one can actually make success by transforming from one promising business to another.” (*Cluster*, Abril/Junho 2002: p.32)

[21] When Biobrás started commercialization of human insulin, Novo Nordisk and Eli Lilly (USA) sold their product below the international price to ruin the new entry. Since Brazil levied antidumping surcharge, Novo Nordisk started domestic production and still tried to undercut the price of Biobrás.

V. Conclusions

Our examination of three cases of high technology based localized industrialization in Brazil leads us to the following tentative conclusions:

Technology based industry depends on the capability of the local research institutions. Such necessity makes the firms necessary to be located at the knowledge center. Interactions with industries also sharpen the capability of universities and deepen their expertise.

Well-targeted public investments in R&D many have lasting result. Creating a core technology in designing a creative product is an essential part.

Materializing the research result requires uninterrupted (but not necessarily so big) *seed money*. Government programs, private venture capital, or partnerships with large corporations can be such sources. Because of financial constraint of the government and underdeveloped capital market, the third option turned to be frequently used.

Brazilian technology based-firms face obstacles for growth. Relatively successful companies are being acquired by foreign firms before entering the growth phase due to the limited capability of investment. Because of competition with large multinational firms.

Technologically autonomous and competitive firm can grow through strategic partnership with other companies – including multinationals, effectively reducing the financial risk and amplifying opportunities for learning.

Our findings imply that once we will lose the local dynamics of technological learning between industry and universities, the industry will be a set of subcontracting and simple assembly of imported parts. The financial problem continues to be a bottleneck of growth of technology-based firms. Here, the legacy of underdeveloped financial market during the uncertain macroeconomy for many years still cast a dark shadow.

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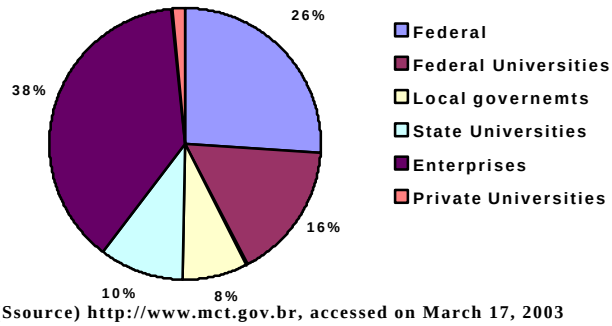
Table 1: Brazilian top 10 export items in 2002 at 8 digits NCM level (US dollars million)

1. Soybeans in grain	3,029
2. Soybean refuse from extraction of oil	2,197
3. Iron ore, not concentrated	2,021
4. Aircrafts weighted 2000KG<=5000KG	1,826
5. Petroleum crude oil	1,691
6. Automobile with engine 1500<CM3<=3000 for no more than 6 passengers	1,486
7. Coffee crude, not roasted, beans	1,195
8. Sugar from sugar cane, not refined	1,111
9. Wood paste for paper fabrication	1,109
10. Cellular telephone	1,071

(Source) MDIC, Aliceweb, http://alicewwb.desenvolvimento.gov.br, accessed on March 7,2003.

Figure 1: Brazil: R&D expenditures by entities, 2000



(Ssource) http://www.mct.gov.br, accessed on March 17, 2003

Table 2. Regional distribution of the creation of knowledgeable people

	Biology				Engineering			
	Registered Students		Title given in the year		Registered Students		Title given in the year	
	MASTER	DOCTOR	MASTER	DOCTOR	MASTER	DOCTOR	MASTER	DOCTOR
North	4%	3%	4%	4%	1%	0%	1%	0%
Northeast	10%	6%	9%	4%	9%	5%	9%	3%
Southeast	67%	75%	64%	77%	71%	80%	68%	85%
Rio de Janerio	17%	19%	18%	20%	20%	25%	18%	26%
Minas Gerais	8%	7%	8%	6%	11%	6%	10%	5%
São Paulo	40%	49%	36%	51%	38%	48%	38%	54%
South	14%	13%	17%	13%	15%	13%	18%	12%
Rio Grande do Sul	7%	8%	10%	5%	6%	6%	8%	5%
Paraná	5%	4%	6%	7%	3%	1%	3%	1%
Central-West	5%	4%	6%	3%	4%	1%	4%	0%
Brazil	4,081	4,238	1,554	779	9,675	5,395	2,651	765

(Source) CAPES homepage http://www.capes.gov.br