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Technological evaluation of biotechnology capability in Amazon institutions

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Abstract

The innovation cycle in Amazon countries is considered regarding the exploration of biodiversity biotechnological products, a system of technological evaluation and prospecting as initial activities in the innovation cycle is proposed. In this paper, it is assumed that biotechnology may be considered as a distinctive sector of National Innovation Systems in all Amazon countries and an important technology system to be explored. There are 304 biotechnology firms in Brazil, but only one in the Northern region, where the Brazilian Amazon lies. Many of these firms work with Amazon products. The data, however, indicate that the region itself is not prepared for the burden of exploring its own biodiversity and carrying out bio-prospecting to a high level. Data from other countries indicate that the innovative activity is not growing and that Latin America as a whole is unprepared for the commercialisation of its biodiversity derived goods. In this paper we will examine the innovation cycle and where Technological evaluation and prospecting may help foster the activity in the region.

I. Introduction

Technological evaluation and prospecting are initial activities in the innovation cycle. In this paper, it is assumed that biotechnology may be considered as a distinctive sector of National Innovation Systems in all Amazon countries and an important Technology System to be explored. There is no definite indication that this may be an accurate presumption. In Brazil, there has been a survey of all biotechnology firms ordered by the Ministry of Science and Technology and carried out by BioMinas (Mascarenhas 2001). They found 304 firms, but only 1 in the Northern region, where the Brazilian Amazon lies. That does not mean that many of these other firms are not working with Amazon products —in fact, there is evidence that they are. But it does mean that the region itself is not prepared for the burden of exploring its own biodiversity and carrying out bio-prospecting to a high level.

Data from other countries indicate that the innovative activity is not growing —at least not in every country— and that Latin America as a whole is unprepared for the commercialisation of its biodiversity derived goods. Besides that, inventive activity throughout Latin America is still concentrated in Public Research Institutions (PRIs).

In this paper we will examine the innovation cycle and where Technological evaluation and prospecting may help foster the activity in the region.

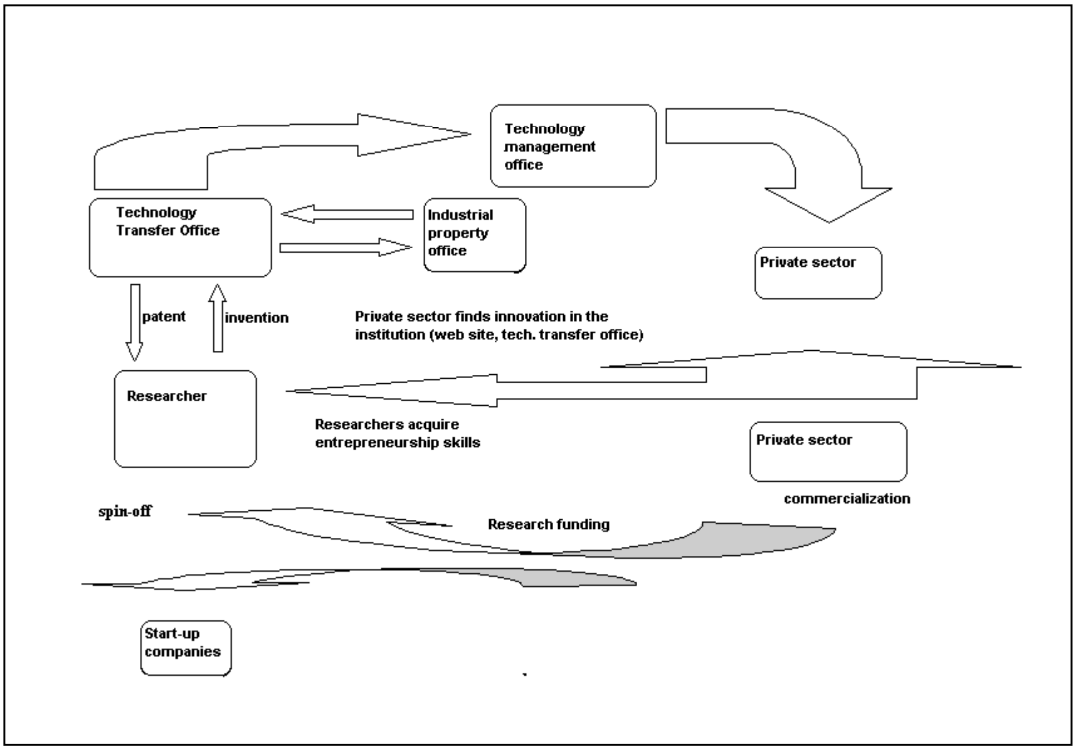
II. The innovation cycle; step-by-step evaluation and management

Here we go from bottom up: let us examine the process of innovation in the first place and then consider the context in which it develops. The innovation cycle from a Public Research Institution (PRI) to industry depends on sound technology management intervention.

Figure 1 illustrates the functioning of the cycle. A research result is disclosed as an invention to the technology transfer office at the university. More or less pro-active offices will depend on the innovativeness awareness of the institution researchers. The office then has a number of attributions: first, it has to make sure the invention is innovative and must have anteriority search skills to check the state of the art, originality and industrial applicability. The next step is to decide, with the researchers, which route to take: whether the invention will be patented, proposed as partnership to a commercial partner through a business plan, attract resources for a start-up company, etc. This will depend on the invention's maturity and the researcher's subjective decisions. If the choice is to patent the invention before a commercial partner is involved, the technology transfer office must choose among a database of specialized offices the best one for that invention in particular. Once a patent is applied for, a commercial partner may be searched.

In any event, patent or no patent, business plan or start-up company, the process reaches technology management stage. This may be done by the technology transfer office itself or may involve third parties, since there are a number of firms specialized in technology management.

Figure 1
THE INNOVATION CYCLE FROM PUBLIC RESEARCH INSTITUTIONS (PRIs) TO INDUSTRY



Source: Author's elaboration.

In the technology management stage a commercial partner or partners are involved. At this point special agreements must be devised as to patent assignees, royalty sharing, legal responsibility, etc. Legal departments usually back up technology transfer offices in universities for this purpose.

Once involved, the commercial partner participation may vary from financing the development of the research, providing infrastructure to commercialising a mature innovation.

The commercial partner participation feeds back into the innovation cycle through many different routes.

Let us examine a concrete example: Four universities and one institute from Mexico, Argentina and Chile are part of the International Cooperative Biodiversity Groups (ICBG) program. This is an American government supported program granted to the University of Arizona. The program provides the funding for the "Bioactive Agents from Dry land Biodiversity of Latin America" project. In addition to the "source countries" in Latin America and the "host country", represented by the University of Arizona, the project involves three commercial partners. The project organized traditional information with the involvement of local communities, who participated in exchange for techniques they needed to cultivate their plants. The team created a data bank to organize all the information and they produced 6,900 extract samples from collected plants. Most of them have already been subjected to primary and secondary assays. They developed cheaper biological activity screening procedures in order to provide alternatives for the source-countries. They determined the chemical structure of selected compounds, together with many other research and training activities.

The contract includes protection mechanisms against possible pitfalls in the relations with the commercial partners. Among them are confidentiality of all information about the plants and source-country monopoly in the collection and manipulation of plant material. The eventual patents will be registered by the program and preferentially offered to the commercial partners for licensing. The eventual royalties will be divided among inventors, collectors and conservation activities in source-countries. The commercial partners have also agreed with other forms of payment, such as high power computers and publication funds for the host-country institution, and specimen collections and microbiological training for the source-countries. Publications are always collaborative (Timmermann, 1999). In this example, long before royalties are shared, there are benefits to all participants in the research.

It must be clear that the final objective of technological management in a PRI is not detaining a large number of patents. The objective is to aggregate value to the research result's intellectual property (Thursby & Thursby 2000). The objective is to take part in the innovation route. An entrepreneurial attitude is instrumental in responding to the market's demand.

In the case of Amazon institutions, there would be no difficulty in matching researchers with commercial partners, whether to commercialise mature inventions or to follow a business plan and develop research, promising co-assignee arrangements and beneficial relations. Many are products that certain commercial partners would try to obtain through less legal measures and in this case the PRI would be providing the means for an orthodox, perfectly legal cooperative arrangements. This is the case of certain products from Amazon oleaginous flora, ready for patenting. Through cosmetic corporations' point of view, they are ready for product formulation. A good commercial partnership may lead to long-term collaborations, with the commercial partner financing more research in the institution.

A patent is, thus, a strategic document: if well written, it gives the owner the opportunity of exploring wide slices of the market. This is why the technology transfer office must have a well-documented database of industrial property offices. It also must be a multidisciplinary team: otherwise, it may be hard to follow-up on the invention's fate. It might be also unable to analyse the invention, conduct market studies and anteriority searches. Most of these activities involve the inventor.

Since technology transfer responsibilities are heavy and many, it may be beneficial for Amazon institutions to work in networks of technology management.

Amazon institutions frequently work in cooperation with small high technology businesses and traditional communities. These detain unprotected knowledge. Therefore, participating in the innovative cycle for an Amazon institution might require additional efforts directed at the protection of their first partners. It is quite different from the average tasks conducted by technology transfer offices in other regions.

Such "first partnerships" may require mobilizing government resources to support these other actors and special agreements that protect their rights when a commercial partner is found for the invention.

Working with small high technology businesses, usually with scarce resources for intellectual property protection, and with traditional communities require a great deal of effort on the part of the research institution. It implies a real cultural change.

Therefore, it is clear that it is not enough to be sitting on the "green gold". It will only be converted into capital if value is aggregated to its intellectual property. Otherwise, it remains an extractive economy as it has been for the last centuries (Bunker, 1984), with the difference of being bio-molecular (and extracted by foreign countries).

III. Latin America as a collection of immature innovation systems

But innovation is much more that this series of events involving inventors, technology offices and industrial property firms. They involve a net of institutions that establish the technological dynamics of a country. To understand innovation, it is important to understand, then, the economic, social, political and regional factors at play: the National System of Innovation. More than that, it is important to understand how the various institutions —universities, industry, research centres, and investors— interact. Latin American countries have immature innovation systems (Dosi, 1982; Nelson & Winter, 1977; Rosenberg, 1976; Albuquerque, 2000, 2001, and Patel e Pavitt 1994). Each one of these authors adopted a different point of view in analysing National Innovation Systems and their maturity. The taxonomy adopted here is similar to that adopted by Albuquerque (2000, 2001) in the studies where he compares "catching up countries" (the New Industrializing Economies such as Korea) with others such as Brazil, Mexico and India.

Freeman (1997) compared the Soviet Union and Eastern European countries, as well as Latin American countries, with successful catching up countries and concluded that countries, which fail to invest in innovation, may fall into an underdevelopment trap. The appropriations necessary to foster innovation, however, are much higher than what these immature countries are able or willing to commit.

In reviewing the modern literature about National Systems of Innovation, Archibugi & Michie (1997) have thus listed the crucial aspects that define and explain them:

a) Education and training:

Education is still largely of national scope and will define whether a country is capable of developing certain industrial sectors or not. The participation in the educational system in each level is predictive of future labour and the distribution of higher education students by discipline is of great importance. The importance of such a factor go to the point of making it an important government policy if the country is willing to develop certain industrial fields. Training is also very important and there are several ways of acquiring capability. Costa Rica, for example, has adopted a policy to protect its bio-diversity and acquire biotechnological capability at the same time. The Instituto Nacional de Biodiversidade (INBio) is responsible for the application of this policy. The INBio was created in 1989 as a non-profit private institution. INBio has a library of chemical substances of potential commercial interest. The institution basically brokers the commercial exploitation of the country's biotic richness. All income beyond costs is to be used to protect and manage the country's natural resources. In October 1991, Merck Pharmaceutical celebrated an agreement with INBio according to which it would pay one million dollars for the opportunity to screen INBio's samples. It is foreseen that royalties will be paid for every product directly or indirectly derived from INBio, with no time limit.

b) Science and technology capabilities:

That has to do with Research and Development (R&D) management in a nation. Countries such as Latin American ones, where the bulk of R&D is still developed in academic environments, do not have a good prospective for innovativeness.

c) Industrial Structure:

Since firms are the main agents of technological innovation, it is of uttermost importance to know the industrial strengths and weaknesses of a country. They will condition the nature of innovativeness in the country. Biotechnology is a tricky issue, since most of the firms that carry out biotechnological research are large trans-national corporations. Biotechnological firms and the pharmaceutical market in Latin America are still weak and small.

d) S&T strengths and weaknesses:

Each country has some specialization in a different field. Some countries are highly specialized in a few niches of excellence. Amazon countries have the opportunity of using their privileged access to Amazon biodiversity to follow this path. Brazil, for example, is undeniably capable of biotechnological self-sufficiency. It has the greatest area of the Amazon rain forest. It lacks the rest of the innovation cycle components, though.

e) Interactions within the innovation system:

This refers to the ability to coordinate the actions of the many parts of the innovation system. This is probably one of the weakest points of Amazon countries, where an industrial development policy is hardly tightly connected with an S&T policy and these, in turn, with the educational system.

f) Absorption from abroad:

This refers to international cooperation and coordination. However, there is no technology transfer without an endogenous policy to acquire that knowledge. The INBio example is an effort to do both. Multinational corporations may have an important role here. They are in a position to transfer specialized equipment and skills to new locations in spite of the fact that they tend to locate in their "national strongholds" (Freeman, 1997). With generic technologies such as biotechnology is, the chances of radical innovations increase with bio-prospecting. Totally new substances may reveal themselves in a matter of months. Trans-national corporations, as licensees and developers, might be able to shift their locations.

With such generic technologies, inward investment is significant in determining the destiny of a country's technological window. There is a widening gap between highly industrialized countries and the rest of the "under-developed" world. The explanation for why they differ so much may be a clue as to how to close this gap: institutional differences in the mode of importing, improving, developing and diffusing new technologies, products and processes (Freeman, 1997). Bell and Pavitt (1997) stress the role of different growth paths and economies with different initial income levels. Whatever the origins, local, national policies for catching up remain instrumental in overcoming such development shortcomings (Freeman, 1997).

This becomes all the more important when we consider the distinction between production capacity and technological capabilities. Amazon countries may have technological capability but they definitely lack the production capacity in biotechnology and the pharmaceutical field in general. Production capacity refers to the resources used to produce industrial goods at given levels of efficiency, while technological capability is related to the resources needed to generate and manage industrial change, including skills, knowledge and experience (Bell & Pavitt, 1997). According to Bell & Pavitt (1997), there are two reasons for concentrating policy attention on technological capability: first, intangible resources are increasingly important; second, there is a trend towards specialization in the knowledge resources used by industry. Again we loop back into the exploration of differential niches, these being those related to biodiversity biotechnology derived goods.

Developing countries are, generally, still crawling in the whole technology transfer discussion and way behind in adopting measures to either defend themselves or to take part in the fiery biotechnological commercial war. In 1998, ISNAR conducted a study about agricultural biotechnology developed in the national agricultural research systems of four countries: Mexico, Kenya, Indonesia and Zimbabwe (Falconi, 1999). Only a few institutions in each of these countries use sophisticated techniques. Biotechnological research still represents a small part of agricultural research there. Almost all biotechnological research is public. Almost all funding comes from the government. Investment in biotechnology has grown in the four countries. Nevertheless, growth is not balanced: the number of researchers has grown more than financial resources, making research efforts hardly sustainable.

The recipes to boost up a National Innovation System to maturity are many and economists disagree on the solutions. One of the main problems faced by an immature country is its low innovativeness level as measured by the number of patents (used as innovation "proxy") and high level of commodity exports instead of industrialized goods.

When we consider biotechnology we are considering a national technology system that interacts and is part of the national innovation system. Focusing on a technology system may have more global implications, but one must never lose sight that it takes place within national innovation systems.

In their long review of the world pharmaceutical innovation, B. Achilladelis & N. Antonakis (2001) have shown how science and technology act as catalysts upon each other, in the hard technological development at the heart of the expansion of markets and industrial sectors. For long years, the technological management paradigm was that everything followed the "science-technology push" and "market pull" (Schmookler, 1976; Mowerey and Rosenberg, 1979, and Walsh, 1984) system. These would be the main forces underlying technological innovation. In the project in which the authors participated, seven other forces were identified: (i) external technological advances; (ii) raw materials (such as biodiversity, for example); (iii) market demands;

(iv) competition; (v) social needs; (vi) government legislation, and (vii) company's market, technological and scientific specialization.

One of the most important findings in this study is that in each of the five pharmaceutical innovation steps in which corporative participation increases and academic inputs decreases, PRIs role as sources of inventions has never decreased. The origins of original work remain in these institutions. R&D is what grew very much in industry, increasingly expensive. These activities created straighter synergisms between academic and industrial organizations.

Other studies about technological policy point towards the same conclusions: universities and research institutes remain as inventiveness centres (Godin & Gingras 2000).

IV. How to handle innovation sitting on the green gold

It is clear that there is an unexplored technological richness in and around Amazon institutions that is dangerously coveted. Decision-makers are faced with difficult questions relative to granting protection to this fragile region. The main issues to address here are:

1) Understand what the market needs
2) Map the technological richness
3) Maintain an entrepreneurial and cautious culture among researchers
4) Pro-active activities to seek commercial partnerships and the establishment of an entrepreneurial environment
5) Networking
6) Examining small businesses in the region
7) Examining technologies
8) Technology management

A. What does the market need and what is viable?

Much more important than pouring money into an abstract technological system is considering its interaction with the market. That is where product development and improvement takes place.

According to Murashige (1997), the average American Biotechnology Company expends about 10 times more per employee per year in conducting research than the United States average.

Industry leading companies spend much more. The five leading firms she listed —Biogen, Genetics Institute, Genentech, Immunex and Amgen— apply for many patents every year. Murashige concludes then that the availability of patents encourages research. Otherwise, the five big ones would not have spent US$7.7 billion on research in 1995.

This is the market for pure biotechnology products and they may be expanded if we consider the leading pharmaceutical companies as well, such as Ciba-Geigy, Roche, Merck, Hoechst, Bayer, Lilly, Parke Davis, Pfizer, Upjohn, Bristol, Sandoz, Squibb, Beecham and others.

This is a multi-billionaire market worldwide and even in Latin American countries it is significant: Brazil, a small player in the pharmaceutical market, had an average 12 billion dollar share.

Globalisation makes it hard to plan for technology transfer without taking into account the global market. Governments and businesses have to consider foreign competitors and possible partners. Governments have to consider the factors associated with inward investment, especially in areas such as biotechnology in the Amazon: foreign investment might upgrade their productive capacity but might and will increase their dependency (Archibugi & Michie 1997).

According to Aquilladelis & Antonakis (2001), we are on the fifth generation of technological trajectories (1980-1993), where radical innovations tend to concentrate on synthetic antibacterial, cardiovascular/anti-hypertension, central nervous system drugs, anti-gastric ulcer drugs, biotechnology drugs and anti-viral drugs.

The Ministry of Science and Technology in Brazil has ordered from the BioMinas a report about the growing biotechnology market (Mascarenhas 20001). They have found 304 companies, many of them small high technology businesses still incubated in University incubators.

Criteria for assessing firms' abilities to launch new products were established in a 1989 joint study by the Small business Development Centre of New York State and the Research Foundation of State of University of New York. They ended up with a seven key informational predictors ranked as follows (Muir 1997):

1) Percent of sales from products introduced in the last 5 years;
2) Number of new products, or innovations to existing products in the last 5 years;
3) Number of new product of process technologies licensed in or acquired in the last 5 years;
4) Percent of sales used for new products development
5) Return on investment
6) Number of employees in engineering and/or R&D
7) Average age of manufacturing equipment and processes

Using modified versions of this list and looking for advances in the fifth generation of technological trajectories might be a good way of assessing the market in the region.

Understanding how the market works means assessing the participants (or competitors), their level of participation and what share of this market may be profitably explored by them.

It is easy enough to understand what the market wants: one web search on recent big pharmaceuticals will show the large amount of such drugs as Aquilladelis and Antonakis (2001) have listed. Understanding what is viable is different: the search for last generation's contribution to the market led to an overemphasis in computerized synthesis and robotized screening. This first euphoria has given way to a more sober perspective that showed the process to be expensive and yield less results than expected.

Attention then turned again to bio-prospecting high bio-diversity regions, especially if the company can get information on traditional uses of the raw material or obtain information directly from a research institution.

Gigantic pharmaceutical and biotechnology firms dominate the market. They will do anything to have access to high bio-diversity bio-prospecting material. Local firms are small and fragile, still depending in good part on the incubation process.

This is a broad perspective.

For each particular substance with possible pharmaceutical or cosmetic use, market studies must be conducted. However, it is obvious that the lenses that must be used to prospect biotechnological capability in Amazon countries must focus on what the market is targeted to, especially because this latest technological trajectory is not close to being over.

The market must not be studied only under the perspective of prospective licensees. It must guide the search for biotechnology capability itself.

Licensees will only become partners for the benefit of the region if other variables are considered. Education and training are the most significant: no technology transfer will take place without endogenous capability.

Without taking these into account, licensees will be licensees and will not become research partners. Patel suggests that R&D activities of companies outside USA are around 10% of the total and Japan is much less. If Latin American countries want more than sell bio-prospecting libraries, markets should be studied also considering their manpower needs and the perspective of attracting direct local investment.

B. Mapping the technological richness

The market has pointed out what are the products and technologies one must be searching for. There is no crystal ball to point at what will be the best technological alternatives for institutions or regions. One may, however, use this information, together with the present behaviour of the technological field, to understand the tendencies and the functioning of a certain innovation system.

The literature on technological prospecting, due diligence or technological forecasting is very scarce concerning Latin American countries. There is a general use of these evaluative and policy instruments in merger periods in large corporations (Angwin 2001, Green & Carroll 2001), where "due diligence" is more appropriate. Besides that, due diligence refers to the short stage in the beginning of the innovation chain or technological management.

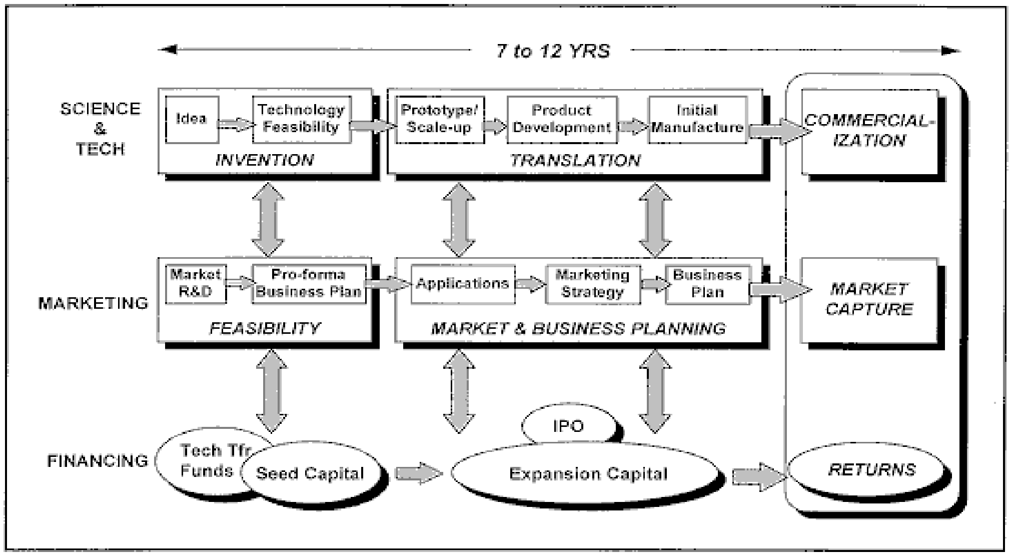
European policy-makers, in a sense similar to the one here employed, more commonly use technological prospecting. Technological forecasting has specialized journals and is a discipline with well-defined content. It is different, however, from the use of Technological Prospecting here and what one has in mind when identifying "encrypted technological products" in PRIs research results and researchers unaware of their entrepreneurial talents. Technological Forecasting concerns much larger scale technological changes, technological risks, large-scale technological cycles, etc. (Phillips 2001).

The reasons seem to be that Northern authors, in the Northern hemisphere, do most of the intellectual production in the area, where technological management begins once a technology is disclosed. In general, it begins with the patent, or the protected technology.

Observe, for example, the Technology Transfer Information Centre scheme from the United States Department of Agriculture (figure 2):

Figure 2

UNITED STATES TECHNOLOGY TRANSFER INFORMATION CENTRE DEPARTMENT OF AGRICULTURE FUNCTIONING SYSTEM



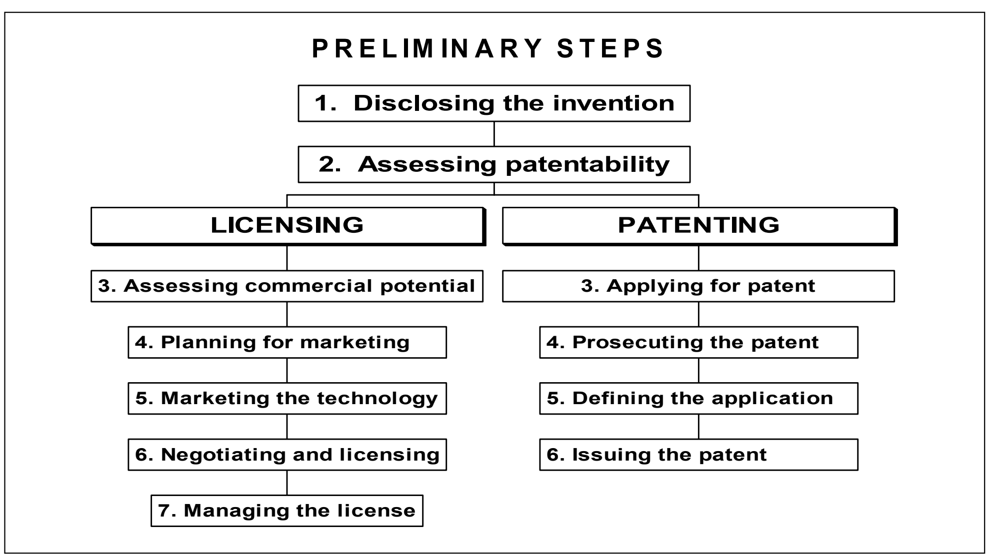
Source: U. States Department of Agriculture, US, (2001).

IPO: Initial Public Offering.

If done, intellectual prospecting would be limited to the small rectangle to the left of the picture. The Pennsylvania State University College of Medicine picture illustrates a university technology transfer perspective, where everything begins with technology disclosure (figure 3).

Figure 3

PENNSYLVANIA STATE UNIVERSITY COLLEGE OF MEDICINE TECHNOLOGY TRANSFER SYSTEM



Source: Pennsylvania State University (2002).

The many Association of University Technology Managers (AUTM) offices describe their methodologies that also begin with invention disclosure. There is no description of a pro-active activity towards university researchers, from who it is expected a more self-sufficient attitude: visit the web site, get information and seek support.

Technological prospecting as employed here seems more concentrated in certain specialized firms, which offer their services to large organizations —private or public. Most of them do not describe any specific methodology except for UTEK (BTG http://www.btgplc.com). Firms such as QED (http://www.qed-ip.com/), Competitive Technologies (http://www.competitivetech.net), Generics (http://www.generics.co.uk/), Scipher (http://www.scipher.com/) and Management Due Diligence (http://www.md2inc.com/index.htm) exhibit almost the same little informative discourse: they promise to "create value expanding the organization's intellectual property portfolio". They all promise interdisciplinary support. UTEK claims to be "dedicated to building a strong bridge between university technology and organizations that can bring useful new ideas to the marketplace" and "strive to inspire all of our partners to push the envelope of technology to create new developments that improve the quality of life and create lasting value". Finally, they promise to "provide our corporate customers with a low cost outsourcing solution for technology development" while simultaneously providing universities with "100% of royalties to support and expand their research". They are closer to university prospecting needs.

What is needed in Amazon institutions is not expand a non-existent portfolio: it is a work of literal prospecting, almost in a geological sense. It is to uncover technological richness embedded in on-going projects and papers published less than a year ago. At this point, it is necessary to put them in patentable or business plan format fast.

This requires a period of project screening in partnership with the researchers, without whom this work is impossible: they are the eventual patents authors resulting from this work. Projects and papers must be carefully read, products must be identified, patent searches must be done for each one and commercial investigation must be carried out.

Besides that, it requires an inverted lens: instead of looking from research to market, it is necessary to look from the market to research. Thus, sometimes projects that would be selected on a scientific merit-base will not be the prior choice in this new perspective. A market focus must guide project screening since it does not make sense to patent or seek commercial partners for something that has no commercial interest.

Finally, the most important projects in this first screening must be investigated as to their "first partnerships": do they have formal partnerships? Informal? Will it be necessary to make special agreements or to seek government support for informal networks?

C. Keeping an entrepreneurial and cautious culture

The establishment of an entrepreneurial and cautious culture in institutions is of uttermost importance. Entrepreneurialship does not mean that all research activity from then on must be oriented by market demands. It means that it is important that researchers are attentive to social and market demands and that they maintain an active relation with the technology transfer office. Cautiousness concerns not disclosing potentially commercial research results without first consulting the technology transfer office. It also concerns the establishment of informal relations with foreign firms and researchers. Behind a relationship in which the other party is only purifying a protein, the foreign laboratory may be supported by a company, which binds them with cooperation clauses unknown to the Latin American researcher. It is not recommended to establish any cooperative relationship without a formal agreement.

D. Pro-active activities in search for commercial partnerships and the establishment of an entrepreneurial environment in the institution

Technology transfer programs are complex and demand stage planning. Prospecting is carried out through stages —units are sequentially chosen for evaluation— the establishment of a technology transfer office is done through stages, nothing is done at once. A pilot project is necessary in every institution to test the methodology (which needs adaptation for each one), to demonstrate what is viable to the whole institution. There simply is not enough manpower to handle a whole institution.

The pilot project does not mean that the region will not be analysed and that the whole institution is not involved in the prospecting work. All researchers must be aware of what is going on and be convinced that this service will turn out to be important to all of them.

Therefore, it is obvious that besides the pilot technology prospecting studies in specific unities a lot of educational work must be carried out inside the institution, this time targeting the whole community.

The argument here is that it is not enough to be sitting on the "green gold" without understanding how to convert it to value and it is not enough that a few people know how to do it: it is necessary that the researcher that handles the everyday work has the basic concepts of technological management. The goal of aggregating value to the intellectual property of research results is important: this will only change when researchers change —it is not enough that policy— makers change their minds. Thursby & Thursby (2000) have shown that the most efficient technology licensing method is the one where researchers are at the front line. The technology transfer office must be equipped to handle all ensuing problems, but it will not carry out the transfer alone.

As will be clear in the Brazilian case study, this is not an easy task: researchers will tend to resist giving up their informal means of offering technical service and using formal, institutional technology transfer mechanisms. It is not easy to make them see institutional patenting of an invention as the best alternative, since companies often offer much more to buy their technology.

On the other hand, many firms are already investing in the region. These companies might be interested in expanding their cooperation with local institutions.

E. Networking

Finally, it is important to understand that no institution will complete the investigative cycle in the Amazon —institutions are simply not equipped to do so.

However, their expertise is complementary: in Brazil, while MPEG and INPA have a more ecological calling, FCAP has a more agricultural approach and Federal University of Pará (UFPA) a more molecular experience. It is not necessary to concentrate all efforts in only one institution if there are bridges connecting research and inter-institutional agreements.

According to Aquiladeles & Antonakis (2001) new pharmaceutical innovation concepts and other contributions from economy freely associated with Michael Porter's clustering concept, Belém is equivalent to an Amazon "Boston", closing the research cycle from screening to substance analyses. Nevertheless, INPA, from Manaus, is no doubt the major research institution in the Amazon region. According to Howells and Wood (1993) there are several advantages in centralizing technological activities. They include: sharing scientific instruments and facilities; safer innovation efforts, reducing the risk of copying; the ability to create an arrangement involving research institutes, universities, companies, investors in a dense local innovation network.

The secret for Amazon research is networking and the formation of "invisible colleges", exchanging information, keeping mailing lists, connections of all types and cooperative research.

This is particularly true concerning technology management. The task, from beginning to end with its multidisciplinary teams goes beyond what any one institution alone may perform. Together, though, they may be able to face the challenge of managing their technology.

F. Small business

The result of entrepreneurial activity is the growth in the number of small high technology biotechnology businesses. Many of these small companies still depend on university incubators and their owners are professors or graduate students. Their close relationship with public research institutions and their growing numbers makes it important to assess their activity to understand the biotechnological capability of the Amazon region. Certain biotechnology activities in the region are not carried out by public research institutions, but by small high technology businesses that spun off from within university research departments.

A thorough report has recently been carried out for the MCT by BioMinas (Mascarenhas 2001) about the biotechnology companies in Brazil. Similar studies must be carried out in the other Amazon countries. It is important to know their numbers, research capability, products, capital, growing capacity, origin and location within the country.

These figures are not difficult to obtain concerning pharmaceutical, agro-business and veterinary companies, those close to the biotechnological market.

All this data is important to obtain in order to study the biotechnological capability of a country or a region.

This is a case study of a small high technology business in Belém do Pará. The case study in this paper is about Brasmazon, incubated in the UFPA incubator. Brasmazon is a paradigmatic case because: (i) it explores Amazon oleaginous flora for cosmetic and medicinal use; (ii) it has no assistance as to intellectual property rights; (iii) for this reason, it has been a victim of bio-piracy; (iv) it survives with threats of all kinds from large logging companies, and (v) it has relationships with many traditional communities and scientific institutions.

Brasmazon was founded in 1990 and incubated at the UFPA incubator. It developed many original processes. One example is the extraction of *bacurí's* oil and butter, *andiroba's* oil powder and making soap from *andiroba* and *cupuaçú* through an alternative method.

The firm buys the seeds and extracts oils from *andiroba, copaíba, bacurí, cupuacú, ucuhuba, muru-muru, burití, maracujá* and *pracaxí*. Besides that, they extract resins, sap and other vegetable products with which they make cosmetics (soaps, bath oils), an *andiroba* candle (insecticide) and they are targeting other markets.

Nevertheless, Brasmazon does not hold the patent of any of these products except the *andiroba* candle. As a consequence, Brasmazon has been a bio-piracy victim: in an informal association with the British firm Body Shop, they revealed the method of oil extraction from cupuaçu. Body Shop patented the method and two cosmetic products almost immediately, without acknowledging the source of their knowledge.

Brasmazon has relationship with many traditional peoples who collect seeds for it. They even extract oils, which the firms buy at much higher prices than the wood would be worth if logged. Mr. Luiz Morais, Brasmazon's P&D director, described how he adapted a traditional press for the extraction of Brazil nut oil at the Wai-Wai indian village at the Mapuera River bed in an indian reserve.

As a consequence of these commercial relations, Mr. Morais has received death threats from logging companies that buy *andiroba* wood, still young, by R$5.00/log at the Arari River, in the Marajó Island.

Brasmazon is an example of important economic transformations: preserved woods with products being sustainably extracted elevates the value of the land. If thickened, the value is increased. If intellectual property value is added to it (oil extraction), the value is further increased. An association with a research institute elevates this value to unprecedented figures.

G. Technologies

A number of technologies must be considered when assessing the installed capacity of institutions or firms in countries or regions.

When focusing bio-prospecting activities, these include, even considering institutional networking frameworks, production of extracts of different levels of purification and substance synthesis, genomic and proteomic technologies (sequential and structural), the existence and maintenance of extract and substance data bases, GSI assisted research and technology for mapping and agro-eco-zoning, taxonomy, etc.

In the agro-business area, there must first be a complete study of the market needs of the region. It would be premature to list activities without knowing which are the competitive activities or the real social needs of the region.

H. Technology Management

This study is not complete without a thorough examination of the technology management capability of each country, region or institution considered. There is no innovative activity without technology management. Considering that most inventive activity in Latin America is concentrated in Public Research Institutions, a complete list of the development of technology transfer offices in such locations must be done and their ability to undertake different biotechnology transfer tasks assessed. In Brazil, technology transfer offices are organizing in a central association, which should make the task easier.

Without knowing the technology transfer capability of the research institution being considered, it is impossible to make assertions as to its biotechnological capability.

Since most of the institutions lack technology transfer capability, this listing is important to know where gaps should be filled and where local policies should be suggested.

I. Indicating the next step

Naturally, one does not study the biotechnological capability of a region for no reason. There is probably an intention of putting it to use. In this case, this author has already indicated that the first step in this study is the assessment of the market needs, since the market should direct the inspection of the institutions and regions themselves. Nevertheless, in the next step in the innovation chain, which should be to mobilize the inventions identified in this study towards intellectual aggregating tools, more aggressive paths should be taken.

Technologies must be managed, and this in itself is a complex activity. Once a market-relevant technology is identified, it may be: patented; require the recruitment of a commercial partner through a business plan; be mature enough for a start-up company, or follow many ways. These are all subjects for "technology management".

It is important to point out, however, that this is the natural course of this activity that one may call technology assessment or prospecting of research institutions.

V. A case study of the research capability in an Amazon country: Brazil

This is a case study that does not illustrate all the procedures just described because technological prospection is not presently being applied in any Brazilian Amazon institution, although this is planned for the near future. It is, however, an assessment of the research capability of Brazilian institutions through bibliometric and technology indicators. Two of these institutions have been visited and are described with more detail. It is a first step in a deeper technology evaluation. Several conclusions are possible from this early assessment: Brazilian Amazon is suffering from serious bio-piracy threats and its institutions still lack the technology transfer expertise to transform their technological knowledge into commercial products, thus aggregating value to their intellectual property; Brazilian institutions are concentrated in certain urban centres, which is beneficial for technology management; star scientists and the best Amazon research are concentrated in these institutions, but they lack institutional support in the country.

A few years ago, Dr. Alberto Duque Portugal, vice and ex-president of Empresa Brasileira Pesquisa Agropecuaria (EMBRAPA), declared that Brazil detains the greatest knowledge about tropical agricultural and veterinary sciences. Part of this is due to EMBRAPA's efforts. Yet, few people know that Brazil detains the absolute dominion over Amazon essential oils knowledge. This knowledge is concentrated in Professor Guilherme Maia's laboratory at the Museu Paraense Emilio Göeldi (MPEG). Professor Maia has all this knowledge properly catalogued, with additional information about traditional uses of the source plants.

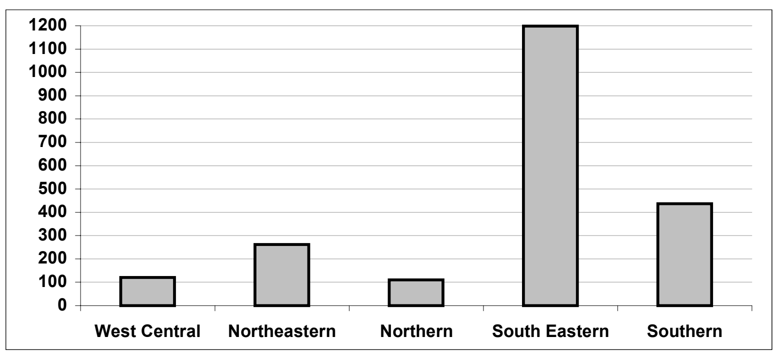
Among these essential oils lie potential drugs for the pharmaceutical market as well as material for all sorts of cosmetics. There are other examples of important technological knowledge accumulated in Brazilian Amazon institutions, which however, still do not network as they could. Using the number of patents as innovativeness proxy, it is easy to see that the region has not yet penetrated the innovative route. Pharmaceutical companies are very interested in this potential market. Even if they may develop their own R&D with material obtained through several means from the forest, they will aggregate an immense intellectual value to the products if they have access to the traditional and, more than that, to the scientific knowledge accumulated in the local institutions. If it is to their benefit or Brazilian interests, it is up to specific policies to address.

A. Research in the Northern region

Brazilian Amazon lies in the Northern region and the most important Amazon institutions are also Northern region's chief institutions. Therefore, Northern region here is used to investigate Amazon research.

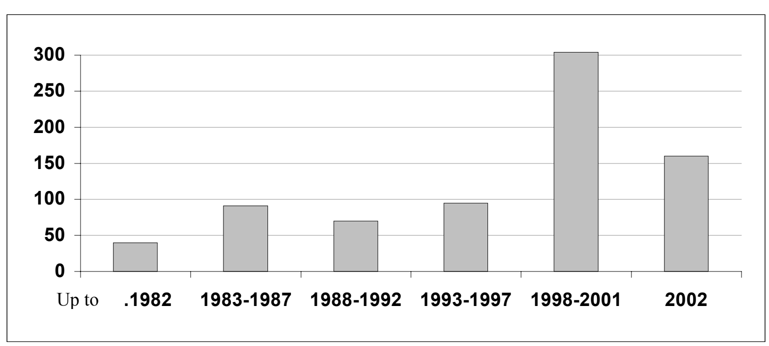
Considering that the North has a small number of researchers (figure 4) and the fact that it has been scientifically growing only recently (figure 5), the comparisons with indicators from the rest of the country are not so discrepant (table 1).

Figure 4
NUMBER OF RESEARCHERS IN EACH REGION



Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

Figure 5
GROWTH OF RESEARCHER NUMBERS BY TIME INTERVAL IN THE NORTHERN REGION



Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

Table 1

EVOLUTION OF RESEARCH GROUPS, RESEARCHER NUMBERS, STUDENTS, TECHNICIANS AND RESEARCH LINES BY TIME PERIOD

Period \ Biological sciences	Groups (G)	Researchers (R)	Students (S)	Technicians (T)	Research Lines (L)	L/G	R/G	S/G	P/L
Up to 1982	6	40	30	15	22	3.7	6.7	5	1.8
1983-1987	10	91	89	36	57	5.7	9.1	8.9	1.6
1988-1992	8	70	47	25	38	4.8	8.8	5.9	1.8
1993-1987	15	95	102	71	73	4.9	6.3	6.8	1.3
1998-2001	46	304	215	96	197	4.3	6.6	4.7	1.5
2002	25	160	85	29	98	3.9	6.4	3.4	1.6

Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

Productivity might seem low if compared to areas such as Biochemistry in the Southeastern region (table 2). Under this data, however, lies the fact that the region has the greatest specialists in certain areas. The attractiveness of these researchers over scholars from Brazil and abroad has already been documented.

Table 2

BIBLIOGRAPHICAL PRODUCTION IN THE NORTHERN REGION. AGRARIAN, BIOLOGICAL AND EARTH AND EXACT SCIENCES AREAS

Year of production	Total authors	Articles in peer reviewed journals		Articles in meeting annals	Books or chapters		Other biblio-graphical production	Abstracts and research communications	
		National	International		Books	Chapters		Peer reviewed journals	Meeting abstracts
Agricultural Sciences									
1998	444	337	96	395	26	119	222	24	951
1999	487	400	125	486	19	86	278	10	1 217
2000	489	381	179	477	34	137	232	20	1 338
2001	493	372	124	430	26	121	301	27	1 152
Biological Sciences									
1998	510	196	417	202	16	135	62	23	1 159
1999	544	250	408	206	14	139	114	26	1 380
2000	579	253	468	296	21	145	142	48	1 496
2001	577	238	373	247	21	171	155	42	1 459
Earth and Exact Sciences									
1998	255	73	188	154	11	20	24	4	574
1999	305	119	195	264	17	17	36	15	831
2000	283	105	235	156	6	44	53	9	760
2001	301	88	196	203	8	66	45	38	776

Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

It also hides a more subtle reality: in the environmental area, it is the Amazon issue that brings Brazil the highest impact and the researchers are located in the region, as shown in tables 3, 4 and 5.

An ISI research with the keyword "environment" and country of residence "Brazil" has shown the following data. If we observe visibility, considered as the total number of citations, we have figures as in table 3:

Table 3
NUMBER OF ARTICLES AND CITATIONS

Institution	Number of	
	Articles	Citations
INPA	6	19
Universidade Estadual de Campinas (UNICAMP)	7	17
Instituto do Homen e Meio Ambiente da Amazônia (IMAZON)	1	9
Universidade Federal do Rio de Janeiro (UFRJ)	4	9
Universidade de São Paulo (USP)	8	8
Museu Paraense Emilio Goeldi	4	7
Universidade Estadual do Rio de Janeiro (UERJ)	4	7
Fundacão Oswaldo Cruz (FIOCRUZ)	5	6
Universidade Federal Fluminense (UFF)	3	5
Embrapa	1	4
Universidade de Brasilia (UNB)	1	3
Universidade Estadual Paulilsta (UNESP)	2	3
Fac Med Ribeirao Preto	1	1
Museu Nacional - Dept. Anthropol.	1	1
Universidade Federal de Minas Gerais (UFMG)	1	1
Universidade Federal de Pernambuco (UFPE)	1	1
Universidade Federal do Paraná (UFPR)	1	1
Universidade Federal do Rio Grande do Sul (UFRGS)	1	1
Universidade Federal Rural do Rio de Janeiro (UFRRJ)	1	1

Source: ISI data.

Three of the first seven institutions were Amazonian.

Table 4
BRAZILIAN INSTITUTIONS ACCORDING TO THE RELATION CITATION/ARTICLE

Institution	Number of		Citation/article
	Articles	Citations	
IMAZON	1	9	9
Embrapa	1	4	4
INPA	6	19	3,166667
UNB	1	3	3
UNICAMP	7	17	2,428571
UFRJ	4	9	2,25
Museu Paraense Emilio Goeldi	4	7	1,75
UERJ	4	7	1,75
UFF	3	5	1,666667
UNESP	2	3	1,5
FIOCRUZ	5	6	1,2
Fac Med Ribeirao Preto	1	1	1
Museu Nacl, Dept Antropol	1	1	1
UFMG	1	1	1
UFPE	1	1	1
UFPR	1	1	1
UFRGS	1	1	1
UFRRJ	1	1	1
USP	8	8	1

Source: ISI data.

In this case, four of the first seven institutions were Amazonian.

Table 5
ARTICLES ORGANIZED ACCORDING TO THE NUMBER OF CITATIONS, WITH THE COOPERATING ORGANIZATION AND ITS COUNTRY OF ORIGIN

Citation	Brazilian Institution of Origin	Second cooperating Institution	Country of origin
11	INPA	Conservation Int.	USA
9	IMAZON	Pennsylvania State University	USA
9	Unicamp	U. California Berkeley	USA
4	Embrapa	GSF, Ist. Soil. Ecology	Germany
3	Fiocruz	London Sch. Hyg. & Trop. Medicine	UK
3	INPA	Smithsonian Inst	USA
3	UFF	None	n/a
3	Museu Paraense Emilio Goeldi	Univ Oklahoma	USA
3	UFRJ	None	n/a
3	UnB	Univ Oklahoma	USA
3	UERJ	Inst Pesquisas Jardim Bot Rio De Janeiro	Brazil
2	UFRJ	Inst Bot. SP	Brazil
2	Fiocruz	None	n/a
2	UNESP	Museu Paraense Emilio Goeldi	Brazil
2	Museu Paraense Emilio Goeldi	Univ Oklahoma	USA
2	INPA	Smithsonian Inst	USA
2	Unicamp	UFRGS	Brazil
2	UERJ	INPA	Brazil
2	UFRJ	None	n/a
2	UFRJ	Univ E Anglia	UK
2	Unicamp	None	n/a
1	USP	None	n/a
1	Fac Med Ribeirao Preto	Johns Hopkins Hosp	USA
1	Fiocruz	Unesp	Brazil
1	USP	SUCEN	Brazil
1	Unicamp	UFPE	Brazil
1	USP	None	n/a
1	INPA	Univ Virginia	USA
1	Unicamp	Tech Univ Braunschweig	Germany
1	USP	Columbia Univ	USA
1	USP	Howard University	USA
1	USP	Inst Venezolano	Venezuela
1	UERJ	Univ Vermont	USA
1	Fiocruz	None	n/a
1	Unicamp	UNESP	Brazil
1	UFPR	U Buenos Ayres	Argentine
1	UFMG	Museu Biol Prof Mello Leitao	Brazil
1	Fiocruz	None	n/a
1	Fiocruz	None	n/a
1	Museu Nacl, Dept Antropol	None	n/a
1	INPA	UFPR	Brazil
1	UFF	None	n/a
1	UFPE	Univ Antwerp	Belgium
1	USP	UnB	Brazil
1	INPA	None	n/a
1	UFRGS	Univ Wales	UK
1	Unicamp	USP	Brazil
1	UFF	None	n/a
1	USP	Inst Adolfo Lutz	Brazil
1	UERJ	None	n/a
1	Museu Paraense Emilio Goeldi	Univ Oklahoma	USA
1	Museu Paraense Emilio Goeldi	Univ Oklahoma	USA
1	UFRRJ	Univ Antofagasta	Chile
1	UNESP	None	n/a

Source: ISI data.

Four of the first seven institution are Amazonian. Besides that, three are associated to American Institutions and one with a German Institution. Only one of the seven lacks foreign collaborators.

The interpretation of bibliometrical data, thus, requires care. They not always reflect all the reality in the local research. It may reveal a mosaic of difficult interpretation situations, such as is the Northern region in Brazil.

With all this evidence, there is an "established truth" according to which good Amazon research is carried out by the Southeastern institutions. Part of this "certainty" about the Southeastern priority comes from internal power structures.

The Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq) divides the life sciences in six coordination areas. Each one is divided into smaller Committees. Ecology belongs to the Limnology and Aquiculture Committee (COGEC-EL: Ecology, Limnology and Aquiculture, table 6). The CNPq has a large "Earth and Environment" program, under the general Earth and Environment Sciences General Coordination. This is divided into regional programs, one of which under the Ecosystems Management Research Committee (where Ecology, Limnology, Botany and Zoology are grouped). Besides these programs, there are much larger ones, such as the LBA (Large-scale Biosphere-Atmosphere Amazonian Experiment).

Table 6
COGEL-EL COMPONENTS

Nome	Sub-área/especialidade	Instituição
Angelo Antonio Agostinho	Pesca	UEM
Iracema Andrade Nascimento	Poluição	UFBA
Francisco De Assis Esteves		UFRJ
Ulrich Christian Karl Heinz Bruno Seelinger		FURG
João Vasconcelos Neto	Entomologia	UNICAMP
Armando Augusto Henriques Vieira	Aquicultura	UFSCar
Geraldo Bernardino	Aquicultura	IBAMA/CEPTA
Wagner Cotroni Valenti	Aquicultura	UNESP/JAB

Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

Six out of the eight names above come from Southern or Southeastern institutions.

Besides that, well-funded projects are usually supported by FAPESP, the strong São Paulo funding agency. It may support Amazon projects as long as at least in partnership with institutions from São Paulo.

B. What does the North produce?

Bibliographic productivity indicators are not reason for desperation. Let us observe table 7, though.

There are practically no patents in the Northern region. But there are a significant number of authors, only 3.3 smaller than the number of bibliographical works authors. The production, however, is concentrated in "technical works" and "meeting presentations". These are general terms for informal services of all kinds. This is a virtual bleeding of technological resources in Brazilian Northern institutions. And it is not researchers' fault: their salary is meagre and there is no efficient technology transfer system.

Table 7

TECHNICAL PRODUCTION FROM 1998 TO 2001 IN THE NORTHERN REGION. AREAS: AGRARIAN, BIOLOGICAL AND EARTH AND EXACT SCIENCES

Area / Year	Total number of authors	Software		Technological products		Techniques or processes		Technical works	Other production	
		With and without:							Presentation of papers in meetings	Others
		Patent or registration				Catalogue registration				
		With	Without	With	Without	With	Without			
Agrarian sciences										
1998	144	1	1	0	2	0	5	145	120	78
1999	165	0	7	2	4	0	7	205	141	129
2000	164	1	5	2	8	0	11	255	151	132
2001	152	0	6	5	3	4	6	296	112	141
Biological Sciences										
1998	163	0	7	5	2	1	6	181	173	94
1999	185	0	3	2	4	0	2	279	165	151
2000	178	1	3	0	4	1	7	322	147	201
2001	175	0	8	3	2	2	3	393	113	181
Earth and Exact Sciences										
1998	62	0	0	0	5	0	5	65	40	30
1999	72	0	1	0	7	0	4	86	47	43
2000	72	0	3	1	1	1	4	110	42	29
2001	74	0	3	0	3	0	2	120	35	20

Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

Data about corporation investment in Northern PRIs can be either positively or negatively interpreted. It is positive because it shows there is interest in cooperation. It is negative considering that this approach is being done with no intellectual property protection in the Northern PRIs.

Table 8 shows that several companies invest in PRIs in the Northern region in many different fields: agriculture, forestry and others.

There are 61 groups that receive investment from 70 firms.

A high technology small business is another type of entrepreneurial activity that tends to grow in the Amazon.

In the report "National Biotechnology Firms" ordered by the Ministry of Science and Technology to BioMinas (Mascarenhas 2001) there are only 9 firms in the North and Northeast, from a total of 304. Only one of them is in the North, in Belém. Reality, however, is somewhat different: small businesses and entrepreneurial activities emerge informally in the Amazon and there is no way of accounting for them in official lists.

Amazon entrepreneurship is neither simple nor easy. The legislation apparently designed to incentive small businesses is dangerously antagonist to its interests: raw materials, extracts and other bio-diversity materials may only be sent abroad with the approval of CONAGEN. There are, however, other legal routes through which materials may be sent abroad in large quantities, since the previous law is limited. It is compliant bio-piracy.

A case study is presented in the item "small business".

Table 8

PRIVATE INVESTMENT IN RESEARCH GROUPS IN NORTHERN PUBLIC RESEARCH INSTITUTIONS PRIs

Sciences	Groups	Firms	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
EMBRAPA																
Agricultural	12	13	7	13	4	4	1	1	10	4	4	4	1	10	3	1
Biological	2	3	3	3	2	2	1	1	3	2	3	2	1	2	3	1
FCAP																
Agricultural	4	4	1	4	1	1	1	1	1	1	2	1	1	1	1	1
FUCAPI																
Engineering and Computer	5	4	0	0	0	0	0	3	0	0	0	0	0	0	0	1
INPA																
Biological	3	3	3	3	3	2	0	1	2	1	2	3	1	1	2	1
Exact and Earth	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Health	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
UFAM																
Agricultural	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Human	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Applied Social	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Health	1	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0
Engineering and Computer	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
UFPA																
Exact and Earth	5	9	9	6	0	0	0	0	3	2	6	5	0	2	3	2
Applied Social	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Engineering and Computer	7	8	5	8	4	5	2	5	7	5	2	1	0	4	3	1
UFRR																
Exact and Earth	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Applied Social	1	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Engineering and Computer	1	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
ULBRA																
Agricultural	3	2	2	2	1	1	1	1	2	2	1	2	1	1	1	1
Applied Social	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Health	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1
UNAMA																
Human	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Applied Social	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
UNITINS																
Agricultural	1	1	1	1	0	0	0	0	1	1	0	1	0	0	0	0
Human	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Total	**61**	**70**	**44**	**56**	**21**	**18**	**9**	**16**	**34**	**21**	**25**	**24**	**8**	**24**	**19**	**14**

Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

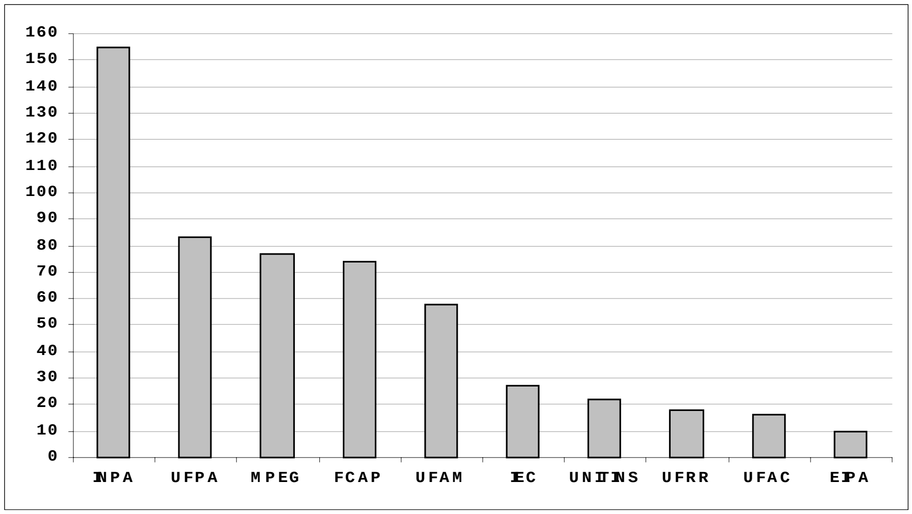
Columns:

(1) Technical consultancy activities not described by any other category.
(2) Non-routine engineering activities and development of prototype or pilot-plant for the partner.
(3) Non-routine engineering activities including development/production of equipment for the group.
(4) Non-routine software development by the partner for the group.
(5) Software development by the group for the partner.
(6) Material supply, by the group, for activities not specifically related to a project of mutual interest.
(7) Material supply, by the partner, for group research activities not specifically related to a project of mutual interest.
(8) Scientific research with immediate perspectives of results employment.
(9) Scientific research without immediate perspectives of results employment.
(10) Technology transfer from group to partner.
(11) Technology transfer from partner to group.
(12) Group personnel training by the partner, including courses and “in service” training.
(13) Partner personnel training by the group, including courses and “in service” training.
(14) Other types of relationship not covered by these categories.

C. Northern institutions

To investigate which are the outstanding institutions in the Northern region, all research lines from the "biological" area were listed. The only exception was FCAP where a careful observation led to the conclusion that in this institution research that is commonly classified as biological in other organizations is here classified as "agricultural". FCAP was then also researched in the agricultural area (figure 6)

Figure 6
RESEARCH LINES BY INSTITUTION

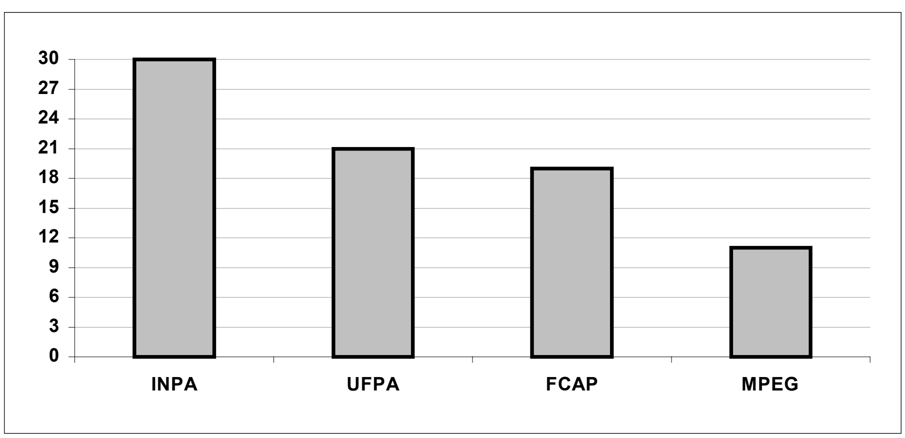


Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

Memo: The following institutions had no research lines: FUCAP, FVA, UEPA, UNAMA, UNIR and UTAM.

Considering only those with more than 60 research lines, the number of research groups was counted (figure 7).

Figure 7
NUMBER OF RESEARCH GROUPS PER INSTITUTION.



Source: Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq), census year 2002.

The research groups were then analysed as to their "principal area" (self-classification) (table 9).

Table 9
PRINCIPAL AREA IN THE RESEARCH GROUPS FROM THE OUTSTANDING NORTHERN RESEARCH INSTITUTIONS

Principal Area	Number of groups			
	FCAP	INPA	MPEG	UFPA
Agronomy	7			
Veterinary Medicine	4			
Forestry	5			
Zoo-techniques				
Fishing resources sciences				
Ecology	1	9	3	1
Zoology		9	5	1
General Biology		1		1
Botany		6	3	
Physiology		1		1
Genetics		3		10
Microbiology		1		
Immunology				1
Biochemistry				2
Morphology				1
Pharmacology				2
Parasitology				1

Source: Data obtained from the Diretório dos Grupos de Pesquisa do CNPq, 2002 census.

First, it is notable that there is greater concentrations of outstanding research institutions in Belém do Pará. Second, that INPA and MPEG have relatively the same profiles. Finally, FCAP is the agro-business end of the cycle, while UFPA focuses molecular research.

Two Amazon institutions were studied more thoroughly: INPA (biggest), and MPEG (oldest and most traditional).

1. National Institute for Amazon Research (INPA)

INPA was created with applied perspectives. It was created in October 29, 1952. The early fifties were a period of more optimism with science and technology in Brazil and its national development: the CNPq was created then and also CAPES (Higher Education Personnel Improvement Agency, an important scholarship granting agency).

INPA's international vocation came also from its origins: it was UNESCO's idea to create an Amazon Hileia International Institute. INPA would have been the nationalist response to UNESCO's intentions. It has always been the focus of much foreign attention and never ceased to attract cooperation with researchers from abroad.

In the beginning, INPA merely did expeditions and surveys in the region —nothing compared to the huge institute with front line research that it turned out to be.

INPA received support from SUDAM and SUFRAMA (organs that supposedly supported development initiatives in the Amazon), besides the CNPq.

In the golden years of Brazilian science, by the end of the 60's and early 70's —when the military government poured an unprecedented amount of financial resources into research—, INPA became equipped as a research institute and started publishing the Acta Amazônica. Paradoxically, in those years the groups that studied the negative impact of governmental intervention in the Amazon became consolidated.

In 1976, together with Federal University of São Carlos (UFSC), University of Campinas (UNICAMP), University of Brasilia (UnB), and Federal University of Rio Grande do Sul (UFRG), INPA created two of the pioneer ecology graduate programs in Brazil. These pioneer courses directed the paths of what would become Brazilian Ecology.

In the 90's, INPA's mission acquired a new perspective with the inclusion of its program in the Excellence Centres Project, a large governmental initiative to foster national scientific development. This has prompted the institution to generate a Strategic Planning where INPA's mission has been re-defined as one of "generating, promoting and broadcasting Amazon scientific and technological knowledge for environmental conservation and sustainable development benefiting primarily the regional population". As a result, many managerial and institutional changes are taking place to attend to the new principles of the "National Integrated Policy for the Legal Amazon".

According to INPA's site claims, "INPA is presently discussing a new management model to respond to new knowledge and technology demands. The project Excellence in Technological Research, supported by the CNPq and carried out by the Brazilian Association for Technology Reseach Institues (ABICT), aims at promoting the improvement of research activities and the development of technological services."

This will be no easy task, considering the internal conflicts natural to the "development of technological services" in an institution that has always been geared towards academic or community based research. The program's implications in terms of intellectual property rights and other technology management related subjects are items of intense debate.

Whether it wants it or not, in spite of having no patents, INPA's research, if successful, will inevitably generate products that will need technological management. The 2002 projects include 109 national programs and 14 with foreign partnership.

Among them we find titles such as "Genetic characterization (chromosomes, proteins and DNA) of Central Amazon and Rio Negro Basin ornamental fish", "Amazon Palm tree use potential evaluation" and others.

There are 15 types of national programs in INPA, listed bellow (table 10). Except for those financed by the Petróleos Brasileros (PETROBRÁS) (2), no category lacks projects with immediate technological economic interest. Some examples of such projects are listed bellow.

The new projects also tend to applicability at the short and medium term. There are 13 projects listed in the site. All of them have applied perspectives and many of them will generate important technological knowledge such as "Amazon Woods", where they intend to study "the basic characteristics and the main uses of several wood species, including physical and mechanical properties, drying parameters, treatability with chemical preserving agents, the natural resistance to fungi and insects, machinery use ease and the potential for manufacturing laminated and aggregated wood materials. The objective is to indicate them both to traditional final uses and in new propositions". Another such project is the "Brazilian *pupunha* research and development network".

INPA is, like Brazil in general, at a crossroad: either it rapidly acquires technological management capability or it will not know what to do with all these projects, both developed and under way.

Table 10

EXAMPLES OF PROJECTS WITH COMMERCIAL POTENTIAL IN EACH OF INPA'S PROGRAMS

Program	Project
Program 1 Amazon Ecosystems	Amazon flooding areas sustainable management: forest resources use, in combination with fishing, cattle and agricultural activities.
Program 2 Natural Resources	Studies about the management, reproduction and growing of *pirarucu* (arapaima gigas), *ematrinxã* (brycon cephalus) and *tambaqui* (colossoma macropomum) in captivity; Studies on the alternative use of wood and non-wood resources at Central Amazon.
Directed Research Project (PPD)	Extensive fish growing activity in flooding forest area; High economic value species genetic diversity and genetic flux; *Pupunheira* (bactris gasipaes kunth), *açaí* characterization, processing and use.
North Graduate Program (PNOPG)	Anti-malarial teas toxicological analysis and anti-malarial Amazon species phytochemistry (ATACA - MALÁRIA); Use of logging residue for the product fabrication using Modularity Principle.
Amazon researchers and professors graduate forming network (RENOR)	Tuberculoses: new knowledge and control action for the State of Amazonas
Banco da Amazônia S.A. (BASA)	Molecular markers (RAPDS) in the distinction of primitive races of *pupunha* (bactris gasipaes) maintained in active germplasm bank; Study of the alternative use of logging industry generated residues in Manaus e Itacoatiara, Estado do Amazonas.
National S&T plan for the Oil and Natural Gas (CTPETRO)	Development of new agents for the control of insects of the genus *culex e anopheles* based in common semi-synthetic piretroids and the natural substance dilapiol.
Humid Tropic Program (PTU)	Genetics and reproductive biology of the *cupuaçuzeiro* (theobroma grandiflorum): contributions for increasing the production of fruits and seeds
Conselho Nacional de Desenvolvimento Cientifico y Tecnológico (CNPq)	Mariuá: ecological, technological and socio-economic bases for the sustainable management of ornamental fish and *quelonians* from the Rio Negro, Amazon basin (PRONEX); National Genome Project - financing from the Sequentiating National Network: the Brazilian Genome Program/CNPq
National Environment Fund/MMA	Conservation and management of endangered species: *pau-rosa* e *acariquara*.
O Boticário Proteção à Natureza Foundation	Systematics and ecology of *heteropssi kunth*, with emphasis to the species occurring at the Florestal Adolfo Ducke Reserve
PETROBRÁS S.A.	Insufficient data
MINERAÇÃO RIO DO NORTE	Soil mesofauna: structure and participation in the decomposition of organic matter in forested areas with native trees
MANAUS ENERGIA	Alternatives for supplying electric energy to isolated communities in the Amazon
Other projects	Study of the biological and phytochemical activity of: - *tachia grandiflora* (Genetiaceae) stem; - *tachia grandiflora* (Genetiaceae) leafs and roots.

Source: Agenda de Pesquisas do INPA. http://www.inpa.gov.br/projetos.pdf.

2. An example of a traditional Amazon institution: the Museu Emilio Göeldi (MPEG)

This case study focuses an institution that, due to its tradition, age and particularly to its research with Amazon oleaginous flora, has attracted much foreign attention —both academic and corporate.

MPEG is an old institution, created in 1866. According to Ferraz & Cunha (2001), MPEG became a real research institute in the first two decades of the XXth century. Since 1955, it became an organism of the Ministry of Science and Technology.

Studying MPEG's scientific activity is no simple task: the scientific indicators are heterogeneous and unequal between departments. Their CNPq data are not updated and a simplistic analysis would drive one to classify it as unproductive relative to the average productivity of each os its areas in the country. However, there are "star scientists" which produce up to eight international peer reviewed papers per year, half of them in high impact journals. This is what gives MPEG its most significant characteristic: it is a place where excellent, front line research is practiced about a very delimited object: the Amazon. Thus, Dr. Maia's laboratory concentrates the international control over the knowledge of Amazon's essential oils.

Essential oils are very concentrated plant extracts. They are complex substances where one may find alcohols, *aldehyds*, esters, ethers, *ketones*, phenols and *terpenes*. Each of these components may be classified into even more detailed categories. For example the *terpenes*: there are *monoterpenes, sesquiterpenes, sesquiterpene lactones, di-terpenes*, etc. These components' biological and cosmetic activities have been demonstrated in various fields.

Research with essential oils attracts increasing interest around the world. Woodward *et al.* (2002) have studied the increased immune-competence effect acquired with six vegetable oils and proved the superiority of the low linoleic acids. Klaas *et al.* (2002) studied the anti-inflammatory properties of phyto-pharmaceutical preparations from Arnica, among which there are essential oils. Ostlund *et al.* (2002) showed that phytosterols in commercial corn oil significantly reduce cholesterol absorption in humans. Matthaus (2002) detected anti-oxidant activity in extracts obtained from many vegetable oils. They may be used as protection against oxidative deterioration. Trabloulsi *et al.* (2002) identified the insecticide properties against *culex pipiens molestus* (Diptera: Culicidae) in vegetable oils. This type of research points to possible uses in the control of deseases transmitted by mosquitoes, such as malaria and yellow fever. This is all recent literature. One must not forget that taxol, the most significant anti-cancer agent today, for example, is a *terpene*.

MPEG's botany department is not restricted to *terpenoid* research, as shows remote sensing studies of the Amazon region such as M.A.G. Jardim's (2001), those of Forline (2000) in ethno-botany, of Johnson et al. in nutrient cycling and of Mahli et al. about the formation of an international data base network to understand the dynamic aspects of the Amazon forest.

All these works have international circulation. The international impact of MPEGs research is historical. Since the middle of the XXth century, scientists from all parts of the world and of Brazil seek and meet at the MPEG in search of such information richness. The reason is that it is all concentrated in one Amazon institution recognized for its scientific excellence.

How much is this knowledge worth? At this point, it is hard to estimate. The following figures work for all Amazon institutions: in a study about deforestation, Andersen (1997) from Institute of Applied Economic Research (IPEA), has attempted to study the value of non-deforested areas, with traditional use and reached a figure of US$18,000/hectare (ha). If the traditional use was thickened, this value could reach US$24,000/ha with "spill-over" urban effects that would make it worth US$120,000/ha. Presently, the deforested land is worth US$9,000/ha.

Seroa da Motta *et al.* (1996,1994) also studied the economic losses caused by deforestation, due to which certain extractives products are not explored anymore.

If it is not trivial to estimate how much an un-deforested area is worth, with simple extraction of products to be sold as commodities —as done for centuries (Bunker 1984)— it is much more complicated to estimate its value if not deforested, if the products are extracted, processed according to knowledge accumulated in Amazon institutions, protected by patenting mechanisms (aggregating value to the intellectual property) and commercialised.

As recognized by the first authors in the theme of National Innovation Systems, transferring and assimilating new technology —Latin America's hard upward walk on acquiring biotechnological capability— is much harder than to trade in commodities (List 1841, after Archibugi & Michie 1997).

Amazon institutions are sitting on the famous "green gold", possess the scientific tools to extract scientific capital from such gold, but still lack the capability to aggregate value to the intellectual property of their scientific capital.

MPEG has many formal partnerships, such as those signed with Mineração Rio Norte, Pará Pigmentos, Texas University or the Ministry of the Environment (Ferreira & Cunha 2001 p. 38). These partnerships are agreements with certain departments, with well-established grants and they are controlled by MPEG's legal department. There are, however, numerous informal partnerships. One example is the one established by members of the botany department who research essential oils to help traditional communities in a more rational use of their resources. In this process, researchers carry out an extensive survey among the herb planters, establish relationships with them, buy their herbs, extract and study the oils. With this, they hope to feed back valued products and a chance for the planters to sell industrialized products instead of commodities (the herbs, with a low value per ton). This is, however, an informal relation.

Another informal and much more dangerous relation for the researcher is the one that may be established with a foreign partner —academic researcher or corporation. Where intangible goods (know how, information, formulas) or even plant extracts are exchanged, great, irreversible losses may result if not protected by contracts and agreements— there is an extensive and bitter experience on that in Brazilian institutions.

VI. Amazon countries: concluding remarks

One significant information relative to Amazon countries is that their innovative activity is not showing an increase in recent years (table 11):

Not surprisingly, most patents are granted to non-residents but the significant fact is that the total number of patents to residents is growing very slowly.

This is no surprise given the analysis that resulted in identifying these countries as immature innovation systems.

Alcorta and Peres (1998) analyse the National Innovation Systems in Latin America and the Caribbean. They claim that in spite of specific successes, overall, the region's national systems of innovation have evolved since their inception in the 1950s into weak entities. Import substitution policies would have been very successful since they were employed in the early 50's. Nevertheless, industry remained local and unable to compete in the international market. Difficulties arising from growing foreign debts are being faced since the 90's with difficulty, improving exports and foreign payments, but the countries are unable to export higher value-added products. Many remain at the commodities level.

According to Alcorta and Peres (1998) "Science and technology institutions and organizations are not fully performing an enabling role; links and interactions between government support organizations, businesses and academia are tenuous; investment in intangibles and human capital is low; and, public policy is only partially effective.

The main result of such weakness is that Latin American countries' innovative performance has, as measured by the index of the technological specialization ITS which relates the world's normalized shares of high to low-tech exports, with the only exception perhaps of Mexico, remained stagnant or has fallen and has lost relatively to many countries that started at similar levels twenty years ago."

Table 11
GRANTED PATENTS PER COUNTRY

	To	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Colombia	Residents	35	35	53	95	81	45	15	55	22		
	Non-residents	390	213	227	595	259	329	362	385	604		
	Total		425	248	280	690	340	374	377	440	626	
Ecuador	Residents		1	3	2	5	7	5	18			
	Non-residents		59	62	23	82	129	362	291			
	Total			60	65	25	87	136	367	309	156	
Peru	Residents			10	15	9	7	7	6	5		
	Non-residents			104	221	267	174	173	132	266		
	Total				114	236	276	181	180	138		
Venezuela	Residents	63	73	26	299	365	180	76	62	24	26	75
	Non-residents	724	520	483	1 804	2 873	2 195	1 195	684	751	783	1 224
	Total	787	593	509	2 103	3 238	2 375	1 271	746	775	809	1 299

Source: El Estado de la Ciencia. Principales Indicadores de Ciencia y Tecnología Iberoamericanos / Interamericanos 2001, Red Iberoamericana de Indicadores de Ciencia y Tecnología (RICYT), Buenos Aires, 2002.

They argue, however, that the maladies of the region are in great part due to technological variables, diverging from the classical literature that focuses in low investment of foreign capital and government under-investment. Lack of interaction between National Systems of Innovation components, a flawed industrial innovation policy and other factors would have led the region to remain immature, in spite of the large growth in the R&D scientists and personnel (87.5% for the region). An unbalanced distribution of R&D resources, largely concentrated in universities and coming from government sources would be another factor. More than that, innovation efforts are directed towards primary products and not on high technology goods. In Brazil, for example, only 12% of the total R&D expenditure was devoted to the manufacturing sector.

But other aspects must be considered: with the proper policies, these countries might be relatively prepared to make further expenses in bio-prospecting, since Agriculture, forestry and fishing already concentrate much of their S&T efforts, as shown by the data on Peru (table 12).

Also, as shown by the data on Colombia (table 13), natural sciences concentrate much of the country's researchers.

Table 12

EXPENSES IN ACADEMIC RESEARCH AND RESEARCH AND DEVELOPMENT (R&D) BY AREA IN PERU

(Expenses in S&T by field)

	1993	1994	1995	1996	1997	1998	1999
Academic Research							
Agriculture, forestry and fishing	38.8	9.7	10.6	10.7	8.3	8.0	11.8
Industrial and technology development	2.3	0.6	0.7	0.6	0.6	0.7	3.0
Energy	4.3	1.7	2.4	2.6	2.1	3.1	3.4
Infra-structure	0.1	0.0	0.0	0.0	1.8	1.8	1.8
Environment	0.1	0.0	0.1	0.0	0.5	0.3	0.5
Health (excluding contamination)	9.6	4.1	11.8	9.3	8.3	8.7	9.2
Social development and social service	17.2	5.9	3.5	2.8	2.9	3.0	2.8
Earth and atmosphere	1.3	0.7	0.6	0.8	0.6	0.5	0.5
General promotion of knowledge	23.3	76.0	68.9	71.7	73.3	72.7	65.8
Civil Space							
Defence	3.0	1.2	1.4	1.5	1.5	1.2	1.2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Research & Development (R&D)							
Agriculture, forestry and fishing					31.9	30.6	26.4
Industrial and technology development						4.5	29.0
Energy							6.9
Infra-structure					0.2	0.0	0.7
Environment					6.9	7.9	
Health (excluding contamination)					10.1	1.8	1.6
Social development and social service							
Earth and atmosphere					3.5	3.3	1.9
General promotion of knowledge					47.5	51.9	33.5
Civil Space							
Defence							
Total					**100**	**100**	**100**

Source: El Estado de la Ciencia. Principales Indicadores de Ciencia y Tecnología Iberoamericanos / Interamericanos 2001, Red Iberoamericana de Indicadores de Ciencia y Tecnología (RICYT), Buenos Aires, 2002.

Table 13

RESEARCHERS BY FIELD IN COLOMBIA

	1996	1997	1998	1999	2000
Natural and Exact Sciences	27.1	26.9	26.8	25.5	24.5
Engineering and Technology	21.1	20.9	20.8	21.0	21.2
Medical Sciences	12.0	12.0	12.5	13.0	13.6
Agricultural Sciences	8.5	8.8	8.4	7.7	7.4
Social Sciences	26.6	27.4	26.6	28.7	29.1
Humanities	4.8	3.9	5.0	4.1	4.1
Total	**100**	**100**	**100**	**100**	**100**

Source: El Estado de la Ciencia. Principales Indicadores de Ciencia y Tecnología Iberoamericanos / Interamericanos 2001, Red Iberoamericana de Indicadores de Ciencia y Tecnología (RICYT), Buenos Aires, 2002.

It is true that Amazon countries all belong to the category of immature innovation systems. As I attempted to show, however, a thorough technological prospecting effort might uncover unexplored technological richness that may help overcome this condition if concerted policies are adopted. This information might help develop a specialized technological system in these countries where they are able to explore their relative advantage given by the access to the Amazon.

Some of the Amazon countries have a relatively well-developed biotechnological capability others do not. However, as pointed out earlier, by working in country and institutional networks, shortcoming may be overcome.

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