The development of technological capabilities in immature countries through collaborative innovation networks – the Brazilian Genolyptus case

(May 5th, 2005)

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Abstract

This paper aims to discuss the importance of organisational structures in a collaborative innovation network, namely the Genolyptus Project. This project is a research network formed by 12 enterprises, 7 universities and a government agency – the Brazilian Agricultural Research Corporation – EMBRAPA, whose goal is to discover, sequence, map and determine the functions of genes with economic interest of *Eucalyptus*. It is indeed an original initiative in a sector with attested competitiveness in Brazil, the forestry sector, especially because it encompasses competing firms around the same innovation effort. Its understanding becomes of crucial importance for policies and efforts that seek to promote technological capabilities in developing countries. The objective of this article is therefore to investigate this network, assessing the role of social capital and evaluating the set of routines, rules, guidelines and objectives that make it feasible and successful.

We first describe the Brazilian Agribusiness Innovation System, presenting the main features of its technological regime (Edquist 1997; Britto 1999). Then we examine the Genolyptus network based on three main concepts: *knowledge sharing routines* (Cohen and Levinthal, 1990; Lundvall, 1992), *strategic objectives* (Doz 1996) and *social capital* (Kale et al. 2000; Casas 2003). Through interviews with the main executives engaged in the project, we propose a preliminary model that wishes to elucidate the connections among the sectoral system of innovation, the network and the social capital. Transparency (as contracts and clear rules), trust, social context (prior alliances) and resource complementary seemed to be the determinants for the alliance formation and performance.

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Introduction

In the context of the learning economy (Lastres, Cassiolato and Maciel, 2003; Lundvall et al, 2002), greater technological effort is demanded of those countries which are still in the catching up stage, to the extent that the international technological frontier advances in a discontinuous, non-linear fashion and that, with each paradigm, science is more intensively applied to the production process (Freeman and Perez, 1988; Bernardes and Albuquerque, 2003). Organizations and institutions must adjust to this new environment, hallmarked by fierce competition and valuing knowledge as the economy's paramount asset. Within this context, technological cooperation networks and other forms of cooperation become interesting alternatives to foster and nurture national technological capability, becoming sources of competitive advantages (Child, 2001). They bring about interaction among the agents, which is indispensable for innovation, as put forward by evolutionary theory, that perceives it as "an interactive learning process" (Lundvall, 1992).

In network literature, special importance is accorded to learning. Networks can be understood as arrangements among organizations rooted on systematic bonding, which may or may not be cooperative. Companies are formally independent and their relations breed a peculiar form of coordinating economic activities (Britto, 1999). Their flexible structure allows them a mix of centralization and decentralization, which makes them mobile - and mobility is a *sine qua non* feature in dynamic environments.

Inasmuch as learning by interaction is external to the company and associates capabilities linked to *learning by doing* and to *learning by using* (Britto, 1999, p.124), we argue that networks are a fertile space for inter-organizational learning, whose effects reach beyond the limits of a given company or organization, generating positive impacts on the national innovation system.

Interactivity is sorely missing in countries such as Brazil, whose innovation systems are "immature", as suggested by Albuquerque (2003_a). In other words, connections are partial between the scientific-technological dimension and economic growth. Albeit such countries do have some scientific and technological infrastructure, their critical mass is not sufficient to go beyond a threshold of scientific output which triggers and strengthens all the interactions among the system elements and, thus, increases its efficiency (Bernardes and Albuquerque, 2003).

This research dwells on and fine-tooth combs through these issues. Its starting point is Brazil's Genolyptus Network, which highlights the process of knowledge creation in an inter-organizational context. It is based on the concepts of knowledge sharing routines (Grant, 1996; Dyer and Nobeoka, 2000) and of social capital (Casas, 2003; Tsai, 2000), understood as chief aspects referring to one's capability to innovate in a network. We seek to understand how routines are formed, that is, which mechanisms are involved in defining institutions, processes and methods governing the relations among the network members. As the research's main outcome, we found evidence that such routines relate dynamically to social capital through mutual feedback mechanisms.

This article is structured as follows. First, we lay out the conceptual underpinnings supporting this survey, discussing the concepts of knowledge sharing routines and social capital. We then describe the Genolyptus network and its institutional context, mainly the Paper and Cellulose industry and its technological regime. Next, we present the analysis of our field research and our main findings. There follows a section dedicated to discussing development - we argue that this network is a differentiated institutional arrangement which can promote technological capabilities of countries such as Brazil. Lastly, our final remarks conclude this article.

Theoretical Discussion

Knowledge Sharing Routines

The concept of routines is a fundamental element in the evolutionary perspective. Within this framework, a company is seen as an organization pursuing responses to knowledge-related problems. More than that, it is indeed a concept that explains the core phenomena in this theory - variation, selection and transmission - and, thus, is identified as its central analysis unit (Becker, 2002, p. 3). This was originally put forward by Nelson and Winter (1982) as an alternative to

understand organizational behavior, based on the argument that routines are the repository of a firms´s knowledge, *id est*, routines are the locus wherein this knowledge is stored, reproduced and expanded.

Through routines, authors establish connections between technology and market dynamics. Their origin comes from learning by agents, their previous knowledge, value system and pre-concepts. Routines can be understood as what is regular and predictable in an organization, including whatever is linked to strategic behavior, aiding the company to face and tackle new issues. Three types are identified: operating, investment and search routines (Dosi e Nelson, 1994).

Routines display an unintentional and undetermined character, generally described as "how things are done here". They describe behaviors which are solidly rooted on the organization and whose repetitive aspect breed automatic response. If there is a content of intentionality, deliberation or planning in the scope of routines, Dosi, Nelson and Winter (2000) propose they be known as capabilities. Becker (2002) synthesizes routine features as collective, non-deliberate, self-actuating, of a process nature, context dependent, embedded, specific and path–dependent. As he puts it, they must be understood as "recurrent interaction patterns" (Becker, 2002, p.11).

Due to these characteristics, routines take on a role of coordinating, controlling and sparing scarce cognitive resources. In a company, they also intermediate links between structure and action, to the extent that they impart sense to different sets of actions, ensuring both sequence and interaction (Becker, 2002; Cohen e Bacdayan,1994). Moreover, they play a major role intermediating matters linked to conflict and power in organizations. This occurs because they are standards providing continuity of relations and prescribing behaviors in view of adverse situations (Nelson and Winter, 1982).

On the other hand, understanding routines as a pattern denotes a rather pejorative connotation of repetition or 'lock in'. However, it is a concept which also bears the imprint of a capacity to change. Routines represent stability to the organization, yet they are also elements allowing 'mutation' and are open to choice and selection. Therefore, they are flexible patterns, anchored on alternative choices and interactive (collective) standards. Nelson and Winter (1982, p. 132) argue that to 'routinize' the innovative activity of an organization is a crucial task. This means structuring and institutionalizing search and selection processes, so as to make them systematic and recurrent in terms of constructing dynamic capabilities (Zollo and Winter, 2002).

Several authors suggest the importance of routines in the organizational context. Particular importance has been given by authors (Nelson and Winter, 1982; Cohen and Levinthal, 1990; Nonaka and Takeuchi,1997) who have dwelt on issues related to learning. They suggest that organizational routines lie at the core essence of a firm and that learning can occur whenever they are developed and adapted to the pursuit of new knowledge (Dyer and Nobeoka, 2000; Zollo and Winter, 2002). In this sense, there arises the concept of knowledge sharing routines, comprehended as instruments for inter-agent interaction allowing transfer, recombination or creation of specialized knowledge (Grant, 1996). Collectively, these routines may be seen as the network's capacity to manage flows of knowledge (codified but mainly tacit). They make it possible to exchange complex knowledge, difficult to be transfered and codified it among partners. Thus, if the network can create a sturdy identity, with rules of entry and participation, in which the production of knowledge is regarded as common property – therefore, shared by all members – this membership will access a far greater diversity of knowledge at a much lower cost.

Despite the possibilities open to participating companies by knowledge sharing routines, absorptive capability is central to this process. According to Cohen and Levinthal (1990), a condition is necessary for the company to succeed in absorbing, understanding and exploring internal and external knowledge. Such condition has to do with the internal development of varied expertise which articulates with whatever is being developed.

Social Capital

Social capital is a valuable concept to understand the emerging, growth and operation of network connections (Tsai, 2000). This is because, in considering this type or arrangement, we must rethink how agents behave. Networks assume some degree of mutual trust and confidence, reciprocity of actions, inasmuch as they hinge on controls which are anchored on consolidated time-honored traditions, defined from structures of authority but also from values and beliefs of the agents involved [1].

Following the definitions of Putnam (2003), OECD (2001) and Grootaert and Van Bastelaer (2002), social capital is understood as the outcome of interaction among different

[1] Thus, the assumptions of the Theory of the Costs of Transaction are challenged. They assume that all partners have the same likelihood of acting opportunistically. This investigation proposes to take into account the trends towards differentiated opportunistic behavior of each member (Barney and Hansen, 1994).

agents in society, characterized by standard patterns, values, attitudes and trust, allowing the development of a learning environment. Structural and relational are its two-fold dimensions. The dimensional structure is manifested by the locational characteristics of an actor in the network. For instance, there may be a central position from which the main agent enjoys some benefits. The relational issue refers to formal and informal relationships among partners and the trust and confidence they share.

Trust is fundamental in networks and can be a pre-requisite for transaction as well as a source of competitive advantage, as borne out by several authors (Casas, 2003; Kale et al, 2000; Barney and Hansen, 1994). Trust can come from interpersonal and social relations based on the reputation of the agents involved in the relation; or from socially constructed norms and conventions regulating agent behavior; or from facts associated to the institutional context of relation, which can either strengthen or interfere with the consolidation of trust and confidence.

It must likewise be understood that trust is an asset built from the experience accumulated by the agents during a process. It is, therefore, an outcome of relational learning. This relationship leads to the creation of mutual confidence, breeding a reputation linked to the sustainability of the relationship (Gulati, 1995; Dyer and Singh, 1998).

Creating mutual trust and confidence minimizes behavioral uncertainty, which is associated to agent-adopted opportunistic postures. Such asset eliminates costs associated to contract arrangements, optimizes division of labor in the network, makes operating procedures compatible with technical standardization. This point is particularly belabored by Barney and Hansen (1994, p.176), who define trust as the "mutual assurance that neither partner will take advantage of the other's vulnerability".

These conditions make it necessary to assess the level of confidence among the partners. This research assumes that, the greater this asset, the easier it is to create knowledge sharing routines. Likewise, the larger the number of routines facilitating communication, creation of a common language, closer proximity, the greater the trust and confidence. Thus, more than just allowing the formation of networks and their knowledge sharing routines, trust also flows from the established relationship, contributing to ex-post relation capital evolutions, that is, developed during a specific network's lifetime.

The Genolyptus Network

Description

This research selected the Genolyptus Network for a more detailed investigation. It is a pioneer project in Brazil, in terms of its capacity to articulate competences recognized in the production industry and in the research institutions around a national network of pre-competitive research. This network aims at discovering, sequencing and mapping the function of genes with economic importance of Eucalyptus. It focuses on timber quality and disease control, integrating classical genetics and genomics into the programs of forest improvement and production. We understand this is a rare effort in less developed and 'immature' countries as Brazil, where the scientific, technologic and economic dimensions are weakly connected (Bernardes and Albuquerque, 2003; Albuquerque, 1997). Therefore, this choice is justified by the opportunity to extract possible lessons in order to promote interactivity among the agents.

The Genolyptus Network (*Brazilian Network of Research in the Genome of Eucalyptus)* formally started in February 2002, after a long preparation and negotiation process articulated by Dário Grattapaglia, current network coordinator which dates back to 1995. However, this discussion was consolidated by late 2000, when the first project-discussion meeting was held. Dário invited all companies from that industry and university researchers. Launched at the same time, the Sector Funds from the Brazilian Ministry of Science and Technology were decisive for the formation of the network,once they provided the financial resources. Genolyptus' final project was approved in October 2001, with an initial six-year timeframe.

As for funds, Project Genolyptus was budgeted at US$3.2 million, 70% of which financed by the Ministry of Science and Technology and the remaining 30% by the participating companies. If everything else involved in the project is considered (such as researchers' time), total project reaches US$ 4.6 million. All the resources are managed by Furnarbe (from Federal University of Viçosa), considered a highly efficient and reliable institution by all members.

Thus, this project cannot be underestimated in its scientific and technological challenge nor in terms of its nation-wide structure (13 companies, 7 universities and 3 Embrapa centers). This is not the original network configuration. The Portuguese group Portucel Soorcel joined the project in 2002 and there were two acquisitions in this industry (Bahia Sul Celulose was acquired by Suzano and Ripasa by Suzano and VCP). These institutions are coordinated by Embrapa, represented by researcher Dário Grattapáglia, who is also a Professor at Brasília's Catholic University. Participating institutions are listed in Table 1.

TABLE 1
Institutions participating in the Genolyptus Network

Companies	Universities and Research Centers
Aracruz Celulose S.A	Embrapa (CENARGEM, CNPF E CNPAF)
Bahia Sul Celulose S.A. *	Catholic University of Brasília
Celmar S.A . Indústria de Celulose e Papel	State University of Campinas
Celulose Nipo-Brasileira S.A.- CENIBRA	State University of Santa Cruz
International Paper do Brasil Ltda	Federal University of Goiás
Jarcel Celulose S.A.	Federal University of Lavras
Klabin/Riocell	Federal University of Viçosa
Lwarcel Celulose e Papel Ltda	Federal University of Rio Grande do Sul
Rigesa Celulose, Papel e Embalgens Ltda	
Veracel Celulose S.A .	
Votorantim Celulose e Papel S.A .	
Zanini Florestal Ltda	
Grupo Portucel Soorcel *	

Note: (*) Company not part of the original format the network

The Paper and Cellulose Industry

Institutional characteristics ought to be considered in the establishment of a network. It is thus important to present, albeit briefly, the Paper and Cellulose industry, to which the Genolyptus Network companies belong.

The paper and cellulose industry produces capital-intensive commodities, presenting major economies of scale. Paper and cellulose production is usually integrated and, in this case, the companies are responsible for tree planting and felling, cellulose elaboration and paper production as such. Competitiveness hinges on company productivity and on the production processes.

Brazil's forest productivity is high, due to the use of *eucalyptus* as raw material. This species outgrows *pinus* (used in Europe and North America) and has good quality. Its upside also includes few natural plagues, inasmuch as it comes from a different environment. This productivity ensures much of Brazilian corporate competitiveness. Yet, companies from developed countries make up for this forest productivity deficit with efficiency and scale.

Paper based on eucalyptus cellulose was developed in 1953. The Brazilian government played a major role supporting production and export of eucalyptus pulp, financing production

expansion and aiding the creation of three new producers of eucalyptus-based cellulose (Aracruz, Cenibra and Bahia Sul).

Despite its modernization, the Brazilian industry is still plagued by expansion-blocking problems. First of all, production capacity still lags below international standards, a possible consequence of sharp growth during World War II, when import substitution was very demanding. This led to small plants, low productivity and poor quality. In the 60s, the Brazilian government sought to increase capacity and to improve quality, encouraging companies to specialize, in order to ensure greater productivity and further integration in the production of cellulose and pulp, as per the recommendations of a survey by Associação Nacional dos Fabricantes de Papel e Celulose – ANFPC (National Association of Paper and Cellulose Producers).

All these efforts notwithstanding, paper and cellulose plants in Brazil still remain, on the average, below the production capacity of international competitors. For instance, capacity in 1999 was 106,000 and 39,000 tons/year for cellulose and paper, respectively, far behind the global leaders - Canada (529,000 tons/year), leader in cellulose, and Finland (281,000 tons/year) world leader in paper. Brazil's situation must not be associated to under-development, on account that Indonesia averages an annual output of 173,000 tons of cellulose and 107,000 of paper. This capacity and the good competitiveness of acacia cellulose are turning Indonesia into a major international player (3.8 million tons of cellulose and 7 million tons of paper in 1999), with average annual production growth of 20% for both (1990-1999).

International cellulose trade involves 34 million tons, 6 million of which in eucalyptus (Brazil has a 55% share). Altogether, 100 million tons are traded, with printing/writing paper accounting for 40% of this total. The Brazilian paper and cellulose industry has altogether 220 companies.

Brazil is currently the world's top exporter of short-fiber cellulose and also has the largest forest productivity. Featuring 220 companies, this sector employs 100,000 persons. Man-made forests amount to 1.4 million hectares and the industry does not use native forests. A total of 3 million tons of paper are annually recycled (45% of apparent consumption).

Concentration seems to prevail, inasmuch as the 11 largest paper producers account for 63% of the output. The top five cellulose companies concentrate 72.64% of the world market pulp production. However, this evaluation needs a concentration index more efficient than market

share. The Herfindahl-Hirschman Index (HHI), which corresponds to the market share of each company, is used here and, thus, values a smaller number of companies with greater individual participation. Up to 1000 means that the market has low concentration. Values between 1000 and 1800 indicate moderate concentration and values above 1800 point to high concentration. Values of 1096 for cellulose and 534 for paper were obtained in the year 2003 for the four largest companies in each segment. This suggests that the cellulose market is concentrated, which is not the case for paper. Nevertheless, both tend to greater concentration (values in 1987 were 764 and 423 respectively.

TABLE 2
Degree of Concentration of Paper and
Cellulose Sector in Brazil (1987; 2003)

	Cellulose		Paper	
Ano	1987	2003	1987	2003
CR4	52,10	63,00	33,72	42,90
CR8	76,95	85,74	54,51	58,20
HHI	764	1096	423	534

Source: Authors' elaboration from Bracelpa data
Note: HHI: Herfindahl -Hirschman Index
CR: Concentration Ratio

Technological Regime

The technological regime (Breschi and Malerba, 1997) into which the Genolyptus Network is embedded makes also part of its institutional context. It is assessed as per its four characteristics – knowledge base, conditions of opportunity, conditions of appropriability and cumulativeness.

Genolyptus' knowledge base involves both classic and genomic genetics. The latter is regarded as a new technological paradigm for which trajectories have not yet been consolidated. Uncertainty is thus very high. Due to the pre-competitive character, knowledge generated in this project – as regards genomics – is wide-ranging, generic and a specific end has not yet been defined. Moreover, genomics adds a high degree of technical multi-disciplinary complexity and a wide array of competences. One such example is the bioinformatics project, which interfaces with computer sciences. Given the tacit or codified status of knowledge, it may be argued that both dimensions are present. It ought to be emphasized that the nature of shared knowledge in the network has a strong impact on the type of defined objectives. (Casas, 2003, p.10), as well as on

transmission mechanisms i.e, the knowledge sharing routines. This point will be later examined in further detail.

Considering the project potential, the perception of all those interviewees is that it is quite high, that is, very important outcomes – even breakthroughs – are expected to be produced, bringing considerable benefits and opportunities to the participating organizations. Specially to the companies, so that they may introduce improvements and innovations into their production process.

As for appropriability, companies expect to have major opportunities to protect what has been generated, particularly subsequent (competitive) developments. Yet, uncertainty remains very strong, given the project's development stage. As per the network contract, all intellectual property generated in the project will be shared by all members and no royalties will be paid.

Finally, it is envisioned that institutions not participating in Genolyptus will lag far behind those which do. It is assumed that later developments will highly correlate with what is generated by the project. This, as Breschi and Malerba (1997) suggest, indicates the high degree of cumulativeness in this type of knowledge.

Fieldwork

Methodology

Data collecting was based on document analysis and on semi-structured interviews. These interviews were carried out in three companies, five universities and at Embrapa, totaling nine interviews. This was the first round of our fieldwork, which happened between December 2004 and March 2005. Senior researchers at the universities and project coordinators in the companies were selected for the interviews, which ranged from 45 to 140 minutes. They were all taped and transcribed. Four interviews were *in loco*, at the work place of the interviewee (four) and the remainders through phoneconferences (five).

We prepared a questionnaire based on our theoretical background that could guide us and, at the same time, could provide us with great flexibility. The first issue approached was the history of formation of the network, that is, we demanded the interviewee to tell us the process of constitution of Genolyptus network and of entrance of his institution. We focused then on the strategic objectives of the consortium and of each institution in particular, trying to investigate their evolution. Third, we examined the trust shared among members, aiming at establishing

conections between this aspect before and after the set up of the network. Fourth, we looked at the structure of Genolyptus, as well as at the routines that allowed the exchange of information and the knowledge sharing among partners. Finally, we analysed the features of the technological regime in which the network is embedded. The analysis of the empirical material was made through the software Nvivo and will be presented in the following sections.

Network formation

Formation of the Genolyptus network was a long and much-discussed process. Establishing the network was the end result of some outstanding work by a coordinator who articulated the academic knowledge of university researchers, competences and genetic materials from companies and government funding. Also influential in the network formation were the stage of technological development, the networks of relationships and the sector's *ex-ante* existing social capital.

As previously stated, genomics is a new branch of science, still in its basic-research stage. Expectations are high, regarding the new technology and possible returns. However, the fact that technological trajectories have not yet been outlined adds to the uncertainty and to the payback time of palpable returns. The solution found was to establish a network which, in addition to reducing risk and cost, could also jointly use knowledge of classic and genomic genetics, gather complementary – albeit scattered – resources and widen the research range. The stage of technology also allowed the network to have a pre-competitive character, inasmuch as the project generated knowledge that will not have any defined use. This will depend on the capabilities developed by each company to create its own products.

A Term of Commitment organized project objectives and defined each partner's tasks. This was the end result of much discussion, benefited from the alliance capabilities which all partners had in doing joint research.

Mr. Grattapáglia, the Project Coordinator, was the central agent in the network formation. His relations with the researchers and companies significantly affected the selection of network membership and attracted agents of major importance for its success. He first contacted companies in the paper and cellulose industry, proposing a project to develop eucalyptus through the interagration of genomic and classic genetics. He next contacted university researchers who were experts on project-relevant themes. His leadership on the Genolyptus project seems natural

for several reasons: the project was his idea to begin with, and he was chiefly responsible for its organization; his experience with eucalyptus genomics is well acknowledged and his technical capacity is valued by all those interviewed. A university researcher remarks:

> "... to me, the [Coordinator] is more knowledgeable about eucalyptus genomics than anyone else in Brazil and in the world. He just had to be the coordinator" (our translation from Portuguese).

Relationships were fundamental in organizing the network. The structure of the paper and cellulose industry has contributed much to network establishment. It is a rather small sector and the researchers know each other through congresses and seminars or have studied or worked together. Furthermore, there is high researcher turnover in the companies, thus furthering the relationships among scientists. The importance of these factors is pointed out by Casas (2003), who stresses the role of formal and informal relations to the formation of networks as well as by Kale et all (2000), who emphasize the importance of previous cooperation among agents for the creation of relational capital, what facilitates the establishment of networks. Hence, research membership in the network was based on the Coordinator's relations and on researcher technical reputation. Relations between researchers and companies were also important in influencing network membership.

Company participation was fundamental to project success. In addition to outlining their needs and supporting the definition of objectives, companies have outstanding genetic materials, major test areas and well-qualified personnel with proven experience. These are all essential factors for project success. A university researcher remarks:

> "In my own specific case, they provide genetic material and we evaluate desease resistance. That is how research is done in this case. Most tests and bio-assays are carried out here [at the University], but we need the genetic material which is in the companies" (our translation from Portuguese).

Thus, the more firms participate in the project, the greater are the possibilities of success and the stronger is the likelihood of a wider project scope. In consolidating a network of this size, previous company networking experience has been important. After all, social capital is the continuity of joint works in a sector and its analysis must take into account the sector's history and evolution (Casas, 2003 and Chung, Singh & Lee, 2000). As companies enjoy research

experience and tradition, and have done joint work with other firms, trust already prevailed in this sector - which was very instrumental in implementing a network of such magnitude.

Formation of company networks is a growing phenomenon. Companies pursue partnerships with competitors and other firms in their industry. The literature repeatedly stresses how important inter-organizational network participation is for knowledge creation (Alter and Hage, 1993; Ring and Van de Ven, 1994; Grandori and Soda, 1995; Dodgson, 1996; Child, 2001). Oftentimes it is no longer the organization but the inter-organizational network which is the *locus* for innovation. Therefore, knowledge is created in the "intersections among companies, universities, research laboratories and clients" (Powell, et al., 1996: 118). In this sense, Genolyptus is an example of a network focused on knowledge creation.

Objectives

The overall objective of the Genolyptus Network is to generate biological knowledge and resources aiming at the discovery, mapping and determination of the function of *Eucalyptos* genes with economic importance. It has a particular emphasis on timber quality and disease control. The network's overriding focus is to generate knowledge beyond academic value, i.e., which proves useful for the production activity. Most companies are aligned to this objective, mindful that this is a pre-competitive project, which will not bring them a physical product nor direct application to their production process.

Genolyptus' identified objective is aligned to the work by Casas (2003, p.8;10), who investigated a series of collaborative alliances in Mexico and ascertained, among other objectives, the development of new knowledge.

Project objectives were jointly defined, both technically and from the standpoint of responsibility for execution. Companies posed their issues and university researchers could lay out their ideas and proposals, in their areas of competences. In the course of debates and meetings, they came out with the final format, a result of this 'communion of ideas'. Furthermore, goals were quantified (i.e., number of sequences to be carried out), a fact of fundamental importance for good network operation.

The Network's overall objective did not change during the project, but its more specific goals underwent some alterations, due to the technological development itself which led to group repositioning. A company researcher comments:

> "The project's macro objective did not change, which is to generate knowledge in the area of Eucalyptus genoma.... Specific objectives underwent slight changes which are needed for project alignment. In some projects, the intended technology became obsolete" (our translation from Portuguese).

Analysis of the evolution of objectives in the alliance was based on Doz (1996), in such a way as to emphasize its dynamic character. The author claims that some aspects impact partnership formation and continuity, such as strategic objectives. For him, companies establish partnerships seeking to homogeneize their strategic objectives. An alliance or a network cannot be instituted without the observation of this issue. Nevertheless, partnerships present a dynamic character as both firms and the external environment change constantly. As a result, strategic objectives may change. Therefore it turns out to be important to assess how these objectives evolve along the partnership, since their alteration may also spell their end.

All interviewees evaluated that network objectives, targets and phases have been met so far, in compliance with a pre-set schedule. Scientific results have also been good. It must be recalled, however, that this is a partial evaluation, inasmuch as the project is intended to last until 2007. On the balance, the project has been very successful, up to now. The following quotes from a university researcher enlighten this issue:

> "[Genolyptus] is a very successful project. From management to its scientific part, it is a model for other recent projects in Brazil (...) Everyone wants to copy this model" (our translation from Portuguese).

Knowledge Sharing Routines

As mentioned above, Genolyptus' objective is to generate and exchange knowledge. Towards this end, special attention in the survey is paid to knowledge sharing routines. Our field research reveals that the main routines in the network are annual conferences, courses, reports, technical meetings, Deliberative Board assemblies, e-mails, telephone calls, congresses, exchange of material, and reciprocal visits.

Exchange of both information (codified knowledge) as well as of experiences and values (tacit knowledge) occurs in Genolyptus. As a company manager points out:

> "My research team follow step by step along the way … participating in congresses, symposia, and similar national and international events, which are so important. But there is also plenty of personal interaction, such as my people going to another company and vice versa. Sometimes we, from

> both companies are at Embrapa and somebody else comes, from a third firm. That's how things begin to fall on the right track. There are more formal things, such as congresses, symposia, meeting and the like, and there is also much informality - what we label personal relations" (our translation from Portuguese).

The means most often used to exchange knowledge was the e-mail, due to its swift and practical nature. As a university researcher puts it:

> "An e-mail is very intensive. Some days I get more than thirty".

These routines display the features found in the literature (Becker, 2002; Dyer and Nobeoka, 2000; Dosi and Nelson, 1994). They are repetitive and the outcome of interactive patterns, that is, they are collective, regular and predictable. At the same time, they are dynamic and evolve with the participants' experience and learning during the project. This confirms that the project is deliberate, involving the pursuit of better work practices. A clear example is the establishment of relations with the media, given the need and willingness of the group, in the absence of a pre-set regime. The network structure makes such changes feasible, on account of its flexibility and capacity to adapt to different moments and needs in the project.

Other routines refer to standard procedures, aiming at providing regularity and practical aspects to network development (such as Deliberative Board meetings and the participation of Funarbe, the network's administrative organ). Alongside these more formal and operational routines, there are those that guide the behaviour of the technical coordinators, such as follow-ups, telephone calls and e-mails, which check all activities related to the sub-projects. They also guarantee the regularity and steadiness of the network.

The technical meetings, annual conferences, seminars and e-mails are the forums for knowledge exchange and sharing. They are markedly informal and arise pursuant to the needs of the sub-projects and teams involved.

In search of and identity to the network, partners endeavoured to set up a common language. Seminars, meetings and theme sessions had a crucial role as they aimed at levelling the knowledge and unifying the language

Moreover, field research restates the conclusions found in Cohen and Levinthal (1990), as the interviewees indicated the different absorptive capacities among the participating firms in Genolyptus depending on their previous investments in technology and infrastructure. They

perceive the differences in the specialization and competencies of universities and firms and consequently, in the learning capabilities of organisations. A researcher from a company noted:

> "Knowledge is exchanged but not very intensively. Not all companies are as technically competent as the universities, to discuss on an equal footing with them. Some are and can pursue exchanges, but it has to come from us. We have to show our knowledge and be willing to influence. The premise is that all the competency lies in the universities" (our translation from Portuguese).

Lastly, it can be said that Genolyptus Network relies on two sets of routines: those created in the establishment of the partnership and those developed along its evolution. The former had a decisive impact in clarifying the proceedings to be adopted, giving safety to its development. The latter are a result of the processes of learning and interaction taken place inside the group and indicate the dynamic nature of the project.

Building Social Capital

The relational component of the ex-ante social capital (Tsai, 2000) manifested itself through the existence of close relations among researchers of the field and of previous experiences in joint work. This trust gravitated toward the coordinator Dário Grattapáglia and was anchored on the well-known technical competence of the members. In fact, many members knew each other prior to Genolyptus or had worked together in other projects or companies. Researchers trusted their peers, due to previous long cooperation in companies or universities. This reduced uncertainty in the network, encouraging companies to join it and the cooperation with competitors. These results match the work or researchers such as Kreiner and Schultz (1993) and Liebeskind et al (1996), who stress the essential role of informal relations among the partners, specially within the scope of research.

In this sense, the pre-competitive nature of the project cannot be underestimated. This factor ensures a far more comfortable position to the institutions as well as impacts the overall trust and confidence among the partners. The structure designed for Genolyptus ensures this position, not demanding that the partners expose their strategic assets and guaranteeing property rights. Thus, the space to exchange information, experiences and knowledge is very well defined, facilitating confidence in the network.

However, this does not mean that contractual agreements and terms of commitment are not important. Rules were clearly established from the beginning, through discussions and negotiations among the participants. Contracts aim at ensuring participant security and would hardly be wavered by companies, which are accountable and have to report to their shareholders and to other stakeholders. Yet, contractual agreements are not sufficient in such a sort of alliance, unless they are anchored on mutual cooperation and trust, which corroborates Barney and Hansen's (1994) arguments.

Furthermore, there is a sort of ethical and moral code, not formally declared, that embedds the relations in the network. For instance, as regards media relations, unwritten rules were discussed and prevail in the group.

As regards to the establishment of internal norms or directions to the relationship with partners, it has not been reported any case in which it happened. It is argued that members already enjoy experience with this type of alliance and many have known each other for quite a while. One can thus assume that alliance capabilities (Kale, Singh e Perlmutter, 2000) were to a certain extent already formed.

Any firm, up to now, has shown any opportunistic behaviour or have violated tge rules or contracts. Nonetheless, it should be noted that any property rights have been attained yet, what can generate a somewhat discomfort, even if there are clear terms governing this aspect.

Most partners have perceived that trust has increased in time and that relations are closer. This can be witnessed in projects and agreements entered into by some members, as a network byproduct, thus leveraging results. More than that, several participants envision more projects such as this one, as results materialize. One university researcher puts it this way:

> "... when the project is over, two years from now, I am sure we will all continue our relations, because we enjoy a great harmony [...]. We are friends, visit each other's home, travel together. Technically, we also get along fabulously. We complement each other; so, this is bound to last ...." (our translation from Portuguese).

The fact that the network objectives are being reached also reinforces mutual trust and confidence among the membership, encouraging new alliances. Casas (2003) argues that, when objectives are accomplished, interactions among network members do not end but take on different forms and dynamics.

In what concerns legal mechanisms governing the project, it is not possible to say that they have lost importance as the network evolved, to the point of being no longer necessary. This is mainly true because of the presence of companies in the network. Companies are used to working with contracts and with a whole legal apparatus, both internal and external. Universities and companies clearly view this issue differently. Contract importance is much clearer to firms - indeed, it is part of their culture. A company made its opinion clear on this issue:

> "You must have a legal mechanism, the more so since we are all listed in the stock exchange as publicly-traded companies. You need mechanisms to explain what you have done" (our translation from Portuguese).

To a large extent, field research corroborates our hypothesis that a relational capital preceded Genolyptus formation, associated to the institutional context into which the network is embedded and which evolves with the network. Research results also allow examination of the process through which the ex-post relational capital is created. Stress must also be placed on the contribution of knowledge sharing routines to make feasible the flow of knowledge and learning resulting from knowledge creation, that is, the results expected from the project. The fact that goals are being reached has been crucial, as pointed out by Arino and de la Torre (1998) and Kumar and Nti (1998). Furthermore, how the network has developed so far, considering its pre-competitive character, has been perceived favorably by the participants, resulting in increased confidence. In short, there is evidence that the social capital and the knowledge sharing routines inter-depend, that is they have mutual feedback mechanisms which can leverage a virtuous process of learning and production (diffusion) of knowledge.

Innovation networks enhancing technological capabilities in developing countries

Our fieldwork showed that the Genolyptus Network has created a mutual learning environment for the participating organizations. On the one hand, companies have expanded their absorptive capacity and, on the other, the universities have gained access to a type of differentiated knowledge, linked to the practice of productive activity. These effects are due to the intensification of interaction among partners, since it encourages greater sharing of knowledge, closer relations and trust.

This project has been successful in the sense that it has reached the pre-established goals and objectives and has expanded the social capital in the Paper and Cellulose industry. However,

these positive effects surpass the limits of the organizations and of the network. They impact the innovation system as a whole, in promoting interactions among the production and scientific sectors and the government, in order to foster competitiveness in the country. In this sense, the Genolyptus Network shows how it is possible to develop innovative, productive (Albuquerque, 2003_b) and social capabilities (Abramovitz, 1986) in a less developed country.

The evolutionary theory understands technological progress as the engine driving economic growth, inasmuch as it poses the innovation process as an element endogenous to it, capable of transforming it both quantitatively and qualitatively. The economy is seen as a process of continuous change and learning, based on institutions. Nelson (2004, p. 6) puts it this way:

> "The new evolutionary theory that is emerging sees economic growth as the result of the coevolution of technologies, firm and industry structures, and supporting and governing institutions. I propose that a satisfactory theory of the processes involved in economic growth must consider all three of these aspects, and that the driving dynamics involves their interaction"

From the standpoint of this school of thought, the trajectories of national growth and development must be understood in terms of these arguments. The basic challenge of an economy aiming at catching up is to learn how to master new ways of doing things, even if they are already being used for some time in the more advanced nations (Nelson, 2004).

Social capital is also fundamental for growth to the extent that it creates an environment which is propitious to learning, collaboration and exchange. Success of innovation is conditioned to long-term relations and to close interactions with agents external to the company (Lundvall et al, 2002). In fact, the evolutionary theory regards trust as one of the three most important institutions in developing national systems of innovation: "The institutions that constitute trust are crucial for interactive learning and inovation capabilities. The strength and the kind of trust embedding markets will determine to what degree interactive learning can take place in organised markets" (Lundvall et al, 2002, p.220).

Lastly, the Genolyptus Network is an example of a differentiated institutional arrangement which can work in countries such as Brazil, developing their technological capabilities by intensifying interactivity among the agents, such capabilities being specially absent in immature systems such as ours (Albuquerque, 1997). However, the specificities of each country and industry must be taken into account. As discussed above, this research stresses the

importance of conditions previous to network formation, such as ex-ante social capital, industrial structure and the stage of technological development, which limit the possibilities of network replication.

Final Remarks

The Genolyptus network is an example of how developing countries can overcome various problems, such as lack of human, financial and scientific resources, in order to develop new and complex technologies. These are crucial factors for the growth of sectors and the enlargement of national competitiveness. Integration is necessary but it needs a favorable environment to flourish. In other words, the country must have scientific and technological research, government financing options and trust among the partners. In short, the existence of ex-ante social capital is very helpful to network consolidation.

Field research conclusions indicate that network operation and success are associated to a clear definition of network objectives and of partner roles in the project, to the establishment of knowledge sharing routines, to existing social capital in the sector and to a well-executed coordination. These aspects not only ensure that goals are met within established timeframes but also increase trust among the partners and create alliance capabilities, which speed the consolidation of new networks and increase their chances of success.

Therefore, the establishment of the Genolyptus network is promoting the creation and development of several factors needed for national economic and social development, such as: skilled labor, increase in scientific and technological research, more inter-company cooperation as well as cooperation between them and universities and research centers. These factors increase social capital in the sector and bring about a learning environment, which diffuses knowledge more swiftly and provides conditions for quick and continuous growth of companies, consequently creating jobs and income.

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