Journal of Technology Management & Innovation

Received November 12, 2007 / Accepted December 13, 2007

ORGANIZATIONAL LEARNING IN RESEARCH AND DEVELOPMENT CENTERS IN DEVELOPING ECONOMIES: THE INFLUENCE OF INSTITUTIONAL CONTEXTS

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Abstract:

The evolving role of public research institutes in the world in the recent decades has placed significant challenges for them. Governments and stakeholders continue to question their relevance and their ability to adapt to the changing circumstances and demands from society. Attempts to develop new organizational models and management strategies are common in both developed and emerging economies. Public R&D laboratories are thus faced with the need to undertake rapid organizational learning processes in order to adapt and to maintain legitimacy. However, these learning processes may be more complex and difficult when the institutional arrangements in which these organizations are nested are themselves immature. We present an analysis of those learning processes on the basis organizational case studies in Mexico and abroad. Theoretical and policy issues are discussed.

Keywords: Research and development; organizational learning; public research, Research and development centers, institutional restrictions.

Introduction

Public research has long been an important instrument for governments, as they attempt to address market failures and inadequacies in the production of knowledge. Public research institutions enable the generation of pre competitive technological knowledge as well as the generation of science-based solutions to social, health and energy issues, for example.

For industrial economies, the development path for public research organizations has been a long one (Layton 1977, Edgerton and Horrocks 1994, Libik 1969). They have widely diversified organizational forms and niches (Crow and Bozeman 1987, 1998, Doern and Kinder 2002) and many institutional arrangements for their support have been tried, evaluated and changed.

Even so, in the recent decade their role has been increasingly called into question (Lawton-Smith 1997, Doern and Kinder 2002, Smith 1997, Dickson 1994, Crow and Bozeman 1998) and continues to evolve as patterns in the social production of knowledge also continue to change (Larédo and Mustar 2004, Cesaroni et al. 2004, Erlich and Gutterman 2003, Gonard 1999, Westwick 2007, Arnold et al. 1998, Simpson 2004).

Even though their trajectory is significantly shorter, public R&D laboratories in emerging economies face important pressures for change as well. They try to respond to these environmental pressures by developing new strategies and management practices (Maculan and Moraes-Zouain 1999, Roy and Mohapatra 2002, Arechavala and Díaz 2004, Gupta et al. 2000, Katrak 1998, Rama Mohan and Ramakrishna Rao 2005). In many ways, external demands placed on them resemble those that laboratories in industrialized economies do, although within very different and usually inadequate institutional contexts (Sutz 2000, Peritore and Glave-Peritore 1995, Arocena and Sutz 2000, Marques and Gonçalves 2007, Cassiolato and Martins 2000, Scheel 2002, Koschatzky 2002) that represent important challenges for their development.

Change is thus a perennial condition for public R&D laboratories while, at the same time, their role and mission calls for stability and long-range capability development. For public R&D institutes in emerging and developed economies, then, it is important to strive continually to change and to adapt. But do differences in their institutional contexts differentially affect their ability to learn?

In order to address this issue, it is important to understand that they respond to pressures inherent to their role. Some theoretical approaches are relevant to understand the causes for these pressures. Being public organizations, resources that they need depend on decisions from people (government agencies) that must trust their ability and commitment to provide the social benefits. Since R&D is also an inherently uncertain activity, no guarantee can be produced beforehand about the solutions for technical problems being readily available, or with respect to the time the labs will take in producing knowledge, of significant economic and social value.

Thus, public research institutes face agency problems that reflect in performance evaluation criteria (Lyall et al. 2004, Coccia 2001, 2004), asymmetry of information and autonomy issues (Fernández 2007). Also, public R&D institutes necessarily have to cope with governance problems that arise from the national science and technology system they are part of (OECD 2003, Doern and Kinder 2002).

Environmental pressures exerted upon public R&D laboratories are expressed through those organizations with which they interact in order to obtain resources and legitimacy for their operation. We would thus expect that, to the extent that mutual expectations shift, or that there is discrepancy or ambiguity in those expectations, would those environmental pressures will tend to manifest themselves as inter organizational conflict and negotiation around performance evaluation, accountability, autonomy, and resource allocation decisions, for example.

In what follows we present results from an ongoing research program that addresses these concerns, and explores the ways in which differences in institutional contexts affect the ways in which laboratories learn the appropriate ways to develop and adapt the strategies with which they respond to the issues that have been discussed. Results are derived from organizational case studies and interviews conducted in several countries, highlighting similarities and differences in environmental pressures that public research institutes face, and in the strategies that they develop in response.

This article presents primarily a comparison between Canadian and Mexican public R&D institutes. This comparison is relevant in light of interesting similarities and differences in the two countries and in the institutional contexts in which their public laboratories develop.

Method

Results presented here are based on five in-depth organizational case studies that we have conducted so far in Mexico and Canada, and on more than 50 interviews conducted with research and management personnel from other R&D organizations in Brazil, Korea and the United States.

Organizational case studies were conducted in site visits between 2002 and 2006. For each one of them several methods for data collection were used:

1. Gathering and analysis of internal working and planning documents in each case (strategic plans, performance and evaluation documents, legal documents, governing board meeting minutes, and so on);

2. Site visits and systematic observation of the centers' working areas. When possible our research group participated in some relevant events in each center (evaluation of planning meetings, for example).

3. Interviews with managers, research and engineering personnel, technicians and administrative personnel, as well as with center's client firms (from small to medium and big enterprises).

The study also includes interviews with government officers and science and technology systems' managers involved in the design and operation of S&T policies that affect the centers' operation and development.

Analyses of national S&T policies and of the general performance indicators for the S&T system in the different countries provided important information used to

differentiate the level of rational policy planning from operative regulations implemented by subordinate federal or state government officers. All of the interviews used dealt with R&D centers' personnel perceptions of environmental demands.

Qualitative (content) analysis of interview transcripts was used to identify opinions and perceptions that are used to understand the strategy building processes in the centers.

Data Collection: Interviews in each case study were semi structured. A case study protocol (Yin 1984) helped ensure reliability. Interview guides ensured that data collection focused always on interviewees' perceptions of environmental demands placed on the organization and on the strategies that it generates at the organizational, group and individual level in order to respond to them. Construct validity is established by using multiple sources of evidence, and by triangulation of key references through other interviews and documents, as well as on-site direct observation (Yin 1984, Eisenhardt 1989, 1991).

Each interview was done by two persons, one who conducted the interview, and one who observed and took notes about the context, the attitude of the person interviewed, the interview guide and other secondary details. Interviews were recorded in electronic equipment and lasted for about 1.5 hours, on average. Depending on the center's profile and on availability of interviewees, a sample of the personnel population was selected, using the following criteria: 1. People who have worked at the center since its creation. 2. People from each part of the organizational structure (departments, divisions, groups, projects, functions, etc.). 3. People that represent each kind of role required in the organization (manager, researcher, technician, administrative personnel). 4. People that had recently entered the organization. 5. People identified as key informants because of their privileged vantage points in the organization and because of their ability to observe its history. In the Mexican case, some interviews were held with the national R&D system managers. Whenever possible, interviews were conducted with representatives of the centers' client firms (companies, trade associations, other laboratories, etc.).

Altogether, 204 interviews were made. 22.5% of them were conducted with members of higher and middle management, 61.8% with engineering and research personnel, and 14.7% with representatives of firms that the labs interact with, although percentages are not the same for each center studied.

Data Analysis: Transcripts of the interviews were analyzed using QSR NUD*IST (NVivo), a content analysis software. Content analysis was done through the following procedures:

1. An inductive codification process permitted the identification of categories not used in the interview plans, but that revealed specific organizational culture and language with respect to the processes of interest;

2. Theoretically derived systematic searches, as defined in case study guidelines;

3. Once coding categories were standardized, patterns of association among them were identified. From theoretically derived concepts of strategy and organizational learning, for example, equivalent references were identified in each center's particular language and patterns of discourse, and searches as well as coding runs were then repeated for all of the interviews, in order to find patterns of association among them.

In this fashion, for example, concepts like "partnering with industry" were found to be used as organizational mechanisms and strategies for responding to external demands and for improving a center's performance. Thereafter, equivalent phrases were used to identify occurrences of the concept, such as "joint ventures", "industry funds", and the like, as long as they were used contextually for the same purpose. Coded paragraphs were then kept for pattern analysis.

This process was repeated for each center, and then comparisons were made among them. This comparison permitted the identification and classification of strategies, and of their association with perceived environmental demands, or with specific organizational learning processes, for example.

Results

The function of strategies examined in those centers we have studied bears a strong relationship with two factors: environmental demands and internal organizational requirements. Although there are some differences, the study identifies in the different cases common processes and problems in strategy building. Also, we are concerned with strategies that operate at a working level, and not necessarily at an explicit and rational planning level.

Even though both in Canada and Mexico very few interviewees could recall specific formal policy directives, a de facto pressure for transferring R&D costs to industry is consistently identified by interviewees in different levels in laboratories from both countries. In Canadian laboratories, this demand is perceived as strongly related to social and political evaluation of the centers' performance:

> "Even politicians now talk about 'return on investment' (...) they like to see activities that lead to new jobs, to job creation, because for government people the creation of jobs is a very good benchmark for success, for a strong economy (...) good fundamental

> science is important, but we know they are looking for more than that".

Canada has a longer tradition in the development of science and technology organizations, and social expectations in the development of wealth and social benefits are more strongly rooted in its culture. This is explicitly stated by interviewees:

> "To a large extent, the development of a culture of consistent support for science has to do with the role that it played during the war. In this, Canada is close to the US and Europe. They all saw how scientists played a large role in winning the war, mainly through the atomic bomb and the development of radar, for example. This support has followed the spirit of the (Vannevar Bush's) 'Endless Frontier'.
> "This (history) also explains in part the mission-oriented view of science we hold. Its role in (…) developing wealth for the nation is clear: it can be clearly seen in its applications in agriculture, forestry, fishery, biotechnology, for example (...) (the Canadian government) has invested consistently in research for many years…"

Many R&D organizations and programs are created with explicit mandates as to the economic benefits that are sought through them:

> "But (…) was established really because of the requirement of the government of Canada to look at economic development within the area of life science (...) its basic objective is therefore to act as a catalyst, to pull together this life science cluster in the province. That's our general mission (…) because in (the province) a lot of the existing industry is life science, forestry, fishing, environment (…) so with that I mean we have a lot of interest in life science."

Clear common values and government policies provide a sound and coherent framework in which strategic decisions can be made by higher management in Canadian laboratories, even though a still wide margin remains for choosing specific development strategies:

> "If you speak to people here about what our mandate is, you will generally get a similar answer (…) that our mandate, as part of the National Research Council is to conduct research in science and technology which will be of benefit to Canada. I think we all agree on those words. How you interpret that, and how you then establish a research program to deliver on that mandate is open to a lot of personal interpretation".

In almost every Canadian laboratory where interviews were conducted, differences in outlooks and interpretations need a deliberate effort to integrate them:

> (How do you integrate all of those visions from the organization into one coherent set of research programs?): "Not easily".

Different research units within a given laboratory would spell their interpretation of the organization's mandate in different ways, but mostly in terms of a continuum:

> "I think that if you speak to different people around here, in this building, I think you would find very different views of really what constitutes research that is focused in creating knowledge that is valuable for firms (…) some people have a very long term view, and will say that fundamental research in genomics, very early technology development in gene discovery, while it may be very far away from commercial applications, is still research that is fundamentally important for the country and yeah, that's true. In the other extreme, people will talk about research that will lead to new developments that will help existing companies to grow, that will attract external companies to come, or will perhaps even lead to the creation of new companies".

Higher management and research units constantly have to make decisions with long term implications, which commit them along different development trajectories:

> "We cannot do all things equally well. Traditionally, because of the nature of our organization, we are first and

> foremost a research organization (…) also we have certain advantages because of the history of our organization, and because the kind of budgets we have had in the past, we have been one of the few organizations in Canada that has been able to establish a (specialized technology) facility (…) we have the ability to engage in large, fundamental projects, that would be very difficult for others…"

Even though no formal policy measures are cited, a push towards more relevance for public research institutes is a clear and distinct message perceived by most interviewees:

> "I own feeling is that we are probably at a turning point, where NRC will migrate, over the next few years, and be more focused on the downstream applications of turning research into economic activity. This is only my opinion, there is discussion about this just now but, if I listen to some of the things that our senior people say, and listen to politicians talking (…) even politicians now talk about return on investment."

In order to chart their course and to adapt to these external demands, Canadian laboratories carefully and explicitly select their strategies:

> "One way we do (adapt to external demands) is by the people that we hire. There are some areas we work in, and some areas that we will not work in (…) rather than spread out our activities a bit in many different (fields) we strategically decided to restrict our focus, in order to have a critical mass (…) we do make those strategic decisions on an ongoing basis."

Each organization selects its own position in the basic – applied research – innovation continuum:

> "We want to concentrate in fields where we have the opportunities to create some new discoveries that will be useful (…) possibly to create some intellectual property which we could provide to companies to help them, to give companies a strategic advantage (…) if we can't identify potential applications, and even some potential partners, companies that might be willing to adopt the discoveries that we make, then it's probably not an area we would engage in."

One of the most visible demands placed on public R&D organizations in many countries is to increase the relevance of their work to industry. In Mexico however, the application of science and technology to innovation has a much less developed tradition. The country has not participated in any major war in the last century, and its industrialization process started only in the second half of the century. Under import substitution policies, the role that science and technology can play in industry is still not a part of the average business manager's culture. The types of solutions that can be expected from them are not part of his working horizon. As in other Latin American countries, like Brazil, the process of creation of R&D centers occurs belatedly, and in a context where there is little demand for their services (OECD 2001).

Specific ambiguities exist in the institutional environment of the Mexican centers, as perceived by both managers and research personnel in the centers, that thwart their attempts to deploy successful development strategies. When questioned about it, interviewees perceive no evident or formal policies that are consistently applied. Rather, they perceive inconsistent or opposing demands from those organizations with which they must routinely interact.

Opposing signals are not deliberate. In the view of a former high-level official of one of the organizations that oversee the centers' operation, they work rather within an institutional gap: while their budget is allocated by the Education Ministry (SEP), they are expected to follow directives from the National Council for Science and Technology (CONACYT). For both institutions public R&D centers represent a negligible fraction of their budget, and to both of them they also represent little performance visibility:

> "(…) as part of the scientific system public research institutes (PRI's) mean little, and in the technology area very little was done … (between 1992 and 2000) CONACYT did not fund them, it was the SEP where they got their budget from, and they were accountable for very little. (PRIs) were funded federally, and they were not accountable to (CONACYT's) director for its use. The head of the Education Ministry named the PRIs' CEO's and only eventually asked CONACYT's officials for an opinion. (PRI's are of little interest for SEP, it would just bundle them under one

> heading. The essence of its policy was to give them money and do nothing. There's nobody to control them, which is the important point. The SEP-CONACYT joint directorship did not control them. They would meet with [the labs' CEO's] only twice in the administration's six year term. The under secretary for planning would decide about budget increments for them. Zero importance within the federal system. They operate in a kind of vacuum. At that time they fell into an institutional vacuum. To fire or not to fire a PRI's CEO was not a relevant decision for CONACYT's Director General, and the under secretary did not want any problems with them."

In the Mexican cases, this directive is not part of a formal policy measure, either. It is rather applied through different informal mechanisms, such as profitability studies conducted by World Bank personnel, or mentioned in governing boards' meetings:

> "During X's tenure (as Director General of CONACYT) we were held accountable for budgetary self-sufficiency and, as far as I understand, that was a directive that came from the World Bank, following models that were established in other countries. (…) At the General Directorship level in CONACYT there was talk that if public R&D labs did not achieve budgetary self-sufficiency, they would be privatized."

Higher CONACYT officials have pushed in the last decade for increased profitability and for privatization of the laboratories. Some of them have adapted their strategies, their internal workflows, their formal and informal structures, and even their culture to this aim. However, these efforts are severely hindered by restrictions imposed by other government agencies. Procedural norms imposed by institutions in charge of overseeing administrative processes require lengthy and elaborate processes to ensure the correct management of public funds. While the National S&T Program has set ambitious growth goals in this area, the Federal Treasury imposes severe restrictions in hiring of new personnel and systematically turns down applications.

Organizations that routinely interact with the centers do not yet offer a fertile ground for the dissipation of these ambiguities. The labs' governing boards, for example, typically include members of federal and local governments, industry associations, overseeing organizations, CONACYT, firms' CEOs, and federal support organizations. Content analysis of these governing bodies' meeting registries reveals that, lacking knowledge of the inherent requirements of the centers' activities and mission, participants tend to fall back on procedural (normative) issues and bureaucratic rituals. Only exceptionally are the centers' strategic objectives discussed. Industry issues and needs are not. Decisions regarding the center's development path or technological competencies are discussed less than normative and bureaucratic requirements, the projects' costs and the income generated.

> "(…) the Board of Directors had become involved more as protocol than in an effective manner. For some, being a member of the Board was not a task that deserved investing time or dedication, and so they would send a representative and, as I have said, it wasn't even always the same person. This practice meant a high turnover among those who attended the meetings of the Board of Directors. Sometimes even the "representative of the representative" would be the one to attend, but the worst was when somebody, without having attended any previous meeting, or knowing anything about the R&D center, would make statements and pass judgment on important issues, that would even become part of the board's decisions and recommendations… and nobody would hear from him again. Thus, knowledge about the organization, about its plans and its accomplishments, was very poor, and contributions to the center's direction were therefore also very poor. Instead of facilitating the CEO's role, all of this would severely restrict the ability to chart long-range plans for the organization."

Another resulting ambiguity is in the choice of performance indicators: the centers can be periodically evaluated with sets of indicators that are inconsistent. A center may be evaluated in the same period with criteria that favor basic science and international publications, while being required also to deliver radically different results, such as the income generated from services to industry.

> "Look, the idea of conducting research, as far as I can recall, was that CONACYT would send us money

> (…) it would send us money and then, while everybody is out trying to sell (services to industry), … when all resources are dedicated to selling services to industry (…) CONACYT keeps funding us. There are no research results. This caused a problem between the CEO and the Board of Directors. ¿Where are the research results? So then his strategy was to tell everybody to forget about research, and that those within 'productive' areas were not expected to do any research at all".

Thus, what interviewees perceive as operational directives are opposed and inconsistent signals that they receive from different sources. For example, the National Research System (SNI, for its acronym in Spanish) rewards individual productivity, as reflected in international publications, while work units and the centers themselves are expected to increase the income derived from services to industry every year. This absence of coordination gives the centers the opportunity to select and bargain for performance criteria suitable to their own profile and interests, in order to obtain and justify necessary resources.

While this would seem to be a favorable context in which to operate, it increases the inconsistency in their development paths. It also requires shifts in goals and objectives that prove costly in the short run, in the long run, or both. Resources have to be allocated to non complementary tasks (research vs. routine services, for example), or diverted from previous objectives into new ones as priorities change, or as incentive systems change the payoff assigned to different tasks. These strategies are not always consistent among themselves.

Table 1: *Policies, requirements and strategies in Mexican R&D Labs.*

INSTITUTIONAL RESTRICTIONS	ORGANIZATIONAL REQUIREMENTS	STRATEGIES
• Limited funds for research personnel's positions and salaries.	• Shortage of personnel needed to carry out a growing number of projects funded by industry.	• Outsourcing projects in order to face demand.
• Reductions in funding. • Pressure towards labs' financial self-sufficiency. • Erratic budgetary allocations from funding agencies.	• Increase income from services to industry.	• Develop income-related performance indicators at individual, group and organization levels. • Increase sales of low value-added services.
• Pressures towards R&D centers' financial self-sufficiency. • Reductions in federal funding. • A mandate to attend to the needs of Mexican industry, particularly SME's.	• To foster business demand for locally developed technology.	• Need to increase income drives them to give priority to demands from multi-national corporations.
• Slow administrative formal and bureaucratic procedures imposed by normative requirements.	• Subordinate technical workflow to client time demands and problems.	• Priority of a timely response to firms' needs faces problems with overseeing government agencies.

Inconsistencies in priorities and strategies give rise to internal divisions among work units, since their different profiles and composition lead them to select and push for the use of different performance criteria for them. Units that have much contact with clients push for one set of performance criteria, while units in charge of developing long-range technological competencies will advocate a different one. The ensuing tensions are costly for the organization, since at some point these tensions will feed back on themselves, and severely hinder the organization's ability to fulfill its mission.

The centers attempt, for example, to increase the income derived from services to industry, while at the same time they try to build a far-sighted technological knowledge base. Thus, research personnel and work units are always under a tension to achieve results under inconsistent performance criteria. As this tension builds, a gap between engineering or technical service personnel and researchers creates a sharp division within the organization.

Within these constraints, the centers are trying to open and develop industrial technology markets. In order to do so, they need to provide low-level services, in order to

gain a foothold in industry. However, this seems to be a dead end path, since in this venue firms usually hire the center's services for non essential processes, because higher level technology development is usually performed at the transnational corporations' headquarters.

Despite these hindrances, some cases arise in which the structure and logic of private enterprises' technological needs promote the development of joint learning processes between the firms' and the centers' personnel. Some of the cases of these processes found in our fieldwork, however, have difficulty in achieving the necessary continuity for the development of long term technological competencies. In the view of some of the entrepreneurs interviewed, for example, as the center's personnel are reallocated to different workgroups, in order to pursue higher income projects, the learning process, and the building of confidence and trust that go with it, needs to be restarted.

In this context, the centers themselves, their work units, and individuals in them, cope by attempting to fulfill their mission by learning on several fronts. While in some cases this learning is quite active, deliberate and dynamic, it is not always so. Sometimes the organization will linger with a workflow or formal structure that is not functional.

Content analysis of interviews reveals that learning takes place at different levels in the organization. Individuals adapt to perceived priorities, as reflected mostly by incentive systems. Groups shift their efforts in developing technological competencies accordingly. Higher managers direct the work units' efforts toward different industrial market and commercializing strategies, as they perceive opportunities and restrictions in the environment. The learning process is mostly associated with:

1. An attempt to deal with restrictions imposed by organizations that the centers depend on, the purpose of developing technological competencies that have market potential, while at the same time having long range possibilities,
2. The identification and selection of industrial markets, their technological needs, and the ways in which to respond to them,
   the ways in which to interact with client firms,
3. The operationalization of these strategies into performance targets for individuals and work units, and to deal with the tensions that they create,
4. The design of an adequate formal structure, of an appropriate division of labor and integration mechanisms, the adjustment of work unit composition, workflows, etc., in order to achieve performance targets,
5. Cultural values and work patterns that are more conducive to achieving the desired results.

It is noticeable that, in some instances, this learning process is referred to as happening in contact with institutions that perform equivalent roles in foreign countries, rather than from contact with other national laboratories or with local firms or government organizations. Contact with foreign laboratories occurs either when those institutions concurrently serve clients in Mexico, or when the center approaches them explicitly for advice.

Discussion and conclusions

Even though not completely similar, many of the strongest environmental demands that public R&D labs face are similar in the different contexts. However, in emerging economies the process through which these organizations learn the right strategies for responding to them is made more difficult by institutional ambiguities and by the lack of consistency in the interaction patterns that the lab must have with other organizations with which they must interact.

The strategy followed in Mexico, as in many other developing economies, of attempting to pursue (either implicitly or explicitly) policies implemented elsewhere, is misleading for those organizations involved. As has been documented elsewere (Fontes and Coombs 1996, for example), this approach misleads policy makers and organizational leaders into trying to incompletely implement foreign models, where essential parts of the structures and processes are either absent of incompatible. Such a naïve imitation of foreign policies thwarts the organizations' possibilities to learn effectively and succeed in fulfilling their missions.

When the drive to increase relevance of public institutions to industry and social welfare is confused with lowering the cost of public research for governments, R&D labs are faced with mandates and directives that are not compatible with the institutional environment they are in. In developing economies, public support and funding for science and technology do not have the strength and tradition that they have in industrialized economies. R&D laboratories are thus forced to attempt the fulfillment of their mandates without the support of other organizations with which they interact, and without adequate resources.

Public R&D centers reflect those constraints and opportunities that are present in the organizational networks they belong to. As other organizations exert demands and pressures over the labs, they attempt to adapt to those restrictions and opportunities through diverse strategies. However, these strategies do not necessarily enhance productivity either within the centers or in the networks that develop around them. Some strategies create visible costs and tensions within the centers and between them and the organizations they interact with.

As compared to full-fledged innovation clusters, observed networks in our fieldwork seem to be in the process of developing the necessary interactions and processes. It is evident, however, that participating

organizations are still falling short of being able to interlock their activities in order to achieve common goals. This problem has both a formal and a cultural component. Formally, organizational mandates and directives in the networks may be either inconsistent or divergent. Roles performed by different organizations in the network may not be complementary.

A common view of science and technological development as a source of regional competitiveness and social wealth seems to be essential for the system to function. A significant social capital must also be present, in the form of trust that enables joint learning, in order to allow for the proper kinds of inter organizational collaboration.

Public R&D institutes cannot fulfill their mission on their own. If innovation networks are to appear in other than a random fashion, an explicit "institutional engineering" effort has to be undertaken. This effort must include the participation of many organizations, at the regional and the federal level.

Institutional engineering needs to be done in the Mexican context, with the whole network in mind. A sense of common purpose and values needs to be built. A common vision must grow out of shared goals and values. This endeavour requires significant leadership in the networks. To a large extent, this leadership role is currently being undertaken by the centers themselves. However, trial and error learning is costly for the whole system, and the necessary continuity in the learning processes is still short of what is needed. Perhaps more important, a significant amount of social capital is lost whenever nascent networks fail.

Regional governments can also take the leadership. Under the realization that economic changes deeply affect their regional economies, state governments in Mexico are beginning to outline regional economic initiatives. Some local governments are designing policy measures to promote a stronger integration of foreign investment to local capabilities and innovation.

In order to be fruitful, investment in science and technology should be a priority in these strategies, both at the local and at the federal level. It is also important to realize that, left to themselves, these networks will seldom develop successfully, and even then, will not yield their benefits in a timely manner.

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