A Model of Institutional Network Dynamics and A Comparative Case Analysis of Information Technology Transfer*

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Abstract

This paper examines the institutional network dynamics of information technology transfer with particular emphasis on the roles of publicly-funded centers for research and development at the national and regional policy-making levels. The conceptual model serves as a basis for qualitative case analysis and comparison of research management structures in two Canadian research centers located in Quebec Province. Conclusions are formulated regarding the complementarity of program and project dominant structures as well as the comparison of hierarchies and markets as technology transfer control mechanisms. Program dominant management appears appropriate to development of national innovation infrastructures, while project dominant management facilitates problem solving in regional innovation networks. The consequences of these conclusions for research management in global technological markets are discussed.

Introduction

Much recent research has focused on advancements in information technologies contributing to emergence of a global economy. A major preoccupation of government authorities in industrialized as well as less-developed nations is the promotion of competitive advantage through appropriate policies to create a national system of innovation (Niosi & Bellon 1994; OCDE 1995). One of the most important dynamics of such a system is the effective development and transfer of new information technologies and related competencies through technological markets. Information technologies are broadly defined here following Boaden and Locket (1991) and Barnett (1994) to include the technical configuration of the equipment itself for coding, storage, and manipulation of information; related scientific and technical knowledge and competencies for design and use of the technical configuration; organizational and institutional arrangements to support technology management; and new products, processes and services resulting from technology implementation. Information technology transfer involves organizational appropriation and adaptation of these integrated components.

Canadian federal and provincial technology policies have been redirected in recent years from fundamental science to applied technological innovation. The consequences of this evolution are twofold; basic science is increasingly excluded from the public policy agenda while universities experience growing pressure to develop applied research programs. Current trends show that in general, a growing proportion of university research funding comes from corporate sources rather than conventional public funding agencies (Godin & Trépanier 1994). It should be noted here that the Quebec economic environment is dominated by very diverse small business; a context sometimes difficult to influence by broad public policies. At the same time, the influence of national technology policy has been significantly limited by reductions in federal and provincial funding, internationalization of the economic environment, and the emergence of free-trade agreements controlling direct government support offered to businesses. According to Godin and Trépanier (1994), this context contributes to a transition from public policy-driven innovation to managed technology transfer.

Canadian federal and provincial technology policies aim to facilitate management of information technology development and transfer through a variety of strategies addressing the major institutions involved in the process. These strategies include funding to support public research centers at the national and provincial governmental levels (Niosi 1991; de la Mothe & Paquet 1994); publicly funded centers foster institutional contributions to fundamental and applied research through networking among public agencies, universities and other research institutions and private firms across all sectors of economic activity. The nature of interaction among network organizations and individual actors may be very diverse, including technical, commercial, legal, social and financial activities aimed at innovation, development and diffusion of information technologies. Thus network interaction contributes to information technology development and transfer by different processes, consistent with the open systems principle of *equifinality* (Katz & Kahn 1978). Open sys-

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tems theory posits that a system objective or outcome may be achieved by different means or methodologies. Federal and provincial technology policies illustrate this principle through the dynamics of institutional networks including publicly funded research centers.

While public research centers have focused mainly on development of national technological competencies and competitive advantage, the globalization of science and technology fosters more linkage among national systems of innovation and networking among public research centers specialized in similar or complementary areas of innovation (Brockoff & Schmaul 1996; Chiesa 1996). Thus the concept of national competitive advantage is profoundly transformed from emphasis on control through proprietary rights on technology to control through effective management systems and diffusion of new technologies beyond national boundaries. In light of the changing definition of competitive advantage, the present conceptual model proposes a view of public research center organization and management for effective institutional networking at the provincial, national and international levels of analysis. This model will orient a comparative case analysis of a federal and a provincial research center specialized in information technology innovations and their transfer.

An Institutional Network Model

Public research centers participate in provincial, national or international innovation networks defined as a configuration of institutions and individuals designed for systemic innovation and risk reduction. These networks present an interpenetrated form of market with organization (Séror 1996). Innovation networks include governmental agencies at the provincial and federal levels; agencies for international cooperation and development; professional, commercial and industrial associations; unions; universities and other institutions of higher education and research; and enterprises in the public and private sectors (Figure 1) (Smith 1995; King, Gurbaxani, Mcfarlan, Raman, & Yap 1994). Specialized publicly funded research centers form network nodes to implement science and technology policy and they play an intermediary role in technological markets where technology producers and users enter into exchange relationships (Tripsas, Schrader, & Sobrero 1994). Such publicly funded centers are part of the innovation community superstructure, coordinating activities of substructure organizations engaged in production of technological innovations. Research in economics has traditionally focused on substructure organizations, while linking organizations and their institutional contexts are critical to technological market dynamics (Lynn, Reddy, & Aram 1996).

Publicly funded research centers affect innovation and technology transfer in important ways. The objective of public policy with respect to such centers is the development of innovation networks from which government agencies may disengage when the networks become independently viable (Callon, Laredo, & Rabeharisoa 1991). Two primary types of intervention contribute to this policy objective: *structuring* interventions and *punctual* interventions. Structuring interventions are designed to foster the mobilization of a variety of actors and the coordination of their activities directed toward a common goal. They may be viewed as contributing to the development of technology

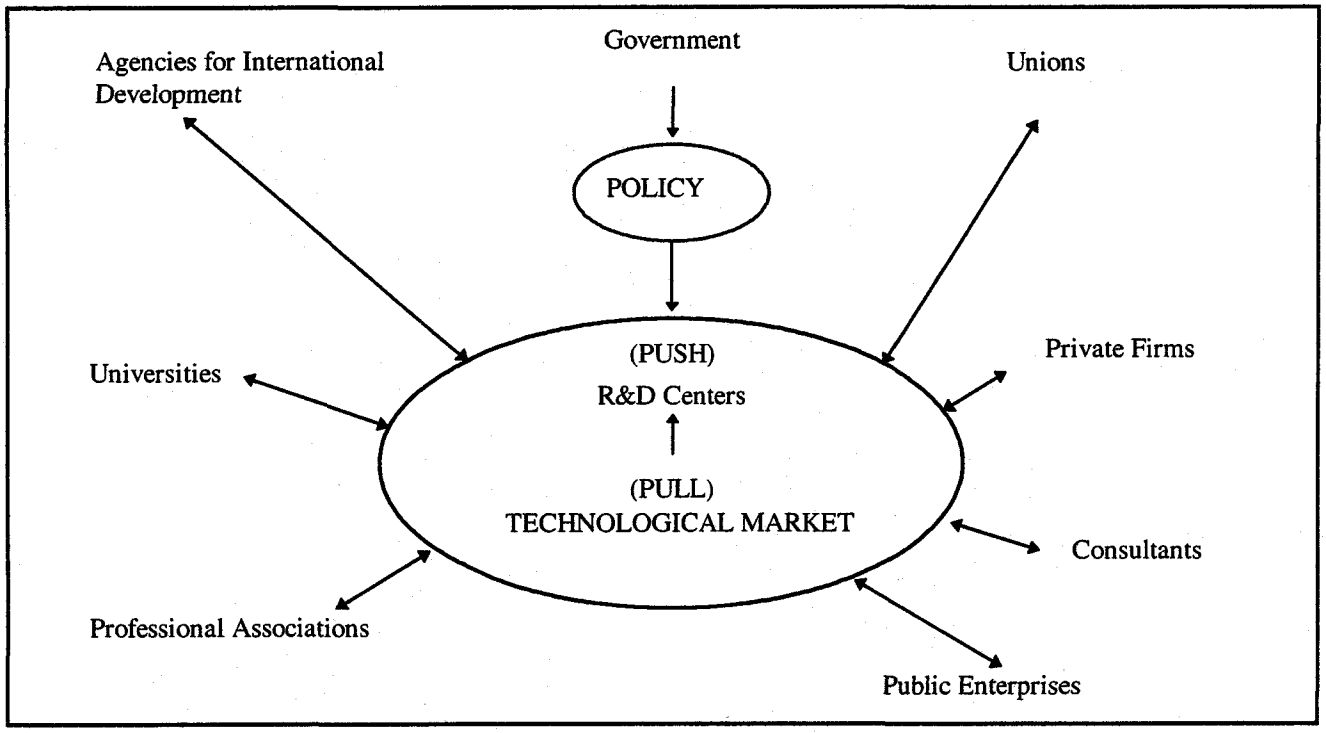

Figure 1. Institutional Network Structure

infrastructure to coordinate complementary roles in R&D for industry, government, universities and other institutions (Tassey 1991; Freeman 1991). On the other hand, punctual interventions are aimed at particular actors in any network linkage, where relevant activities are determined by the actors themselves. The resulting projects influence technological market dynamics (Callon, Laredo, & Rabeharisoa 1991). The success of these interventions depends on the adequacy of existing infrastructure and untraded network dependencies supporting technological markets as well as other factors such as territorial proximity (Alange, Jacobsson, & Jarnehammar 1998; Feser 1998; Gregersen & Johnson 1997; Cooke, Uranga, & Extebarria 1997; Morgan 1997).

It is important to note that in the context of innovation networks, technological capability and competitive advantage may result from the collaborative linkage rather than the technological product itself (McArthur & Schill 1995; Tijssen 1998). Such arrangements may be oriented primarily to program or to project management. A program of research is here defined as a set of projects directed to a common technological theme or objective, while a project involves a specific short-term objective and actors engaged in a specific context over a defined period of time. Research management may be designed in a *program-dominant* mode favoring development of scientific or technological themes in accordance with public policy priorities; this design is mainly appropriate to structuring institutional interventions. On the other hand, such management may be designed to promote specific problem solving in a *project-dominant* mode consistent with punctual institutional interventions.

Social and political trends in Canada, the United States and elsewhere increasingly require that publicly funded research activities demonstrate measurable contributions to goals set for them by national governments. Evaluation research focusing on such complex activities raises substantial methodological issues related to operationalization of research goals. Control and evaluation procedures are important features of research management systems, and they suggest variables and indicators useful for modeling efficiency and effectiveness outcomes of innovation processes. Recent literature on research evaluation stresses the need to integrate these two classes of criteria, and to evaluate not only innovation inputs and outputs, but also the ongoing processes which foster innovation and technology transfer (Autio & Laamanen 1995; Smith 1995; Link 1995).

Methodology

Two Canadian research centers were selected to show how national and provincial science and technology policies facilitate the dynamics of technological markets. The Center for Information Technology Development (CITD) and the Center for Research on Information Technologies (CRIT) were both located in large metropolitan areas of Quebec Province, Canada. Both centers received substantial contributions of public funding to support their research and development activities; CITD was funded primarily from federal sources and managed by Industry Canada, while CRIT received funding from the Quebec provincial government. At CITD, R&D activities were conducted in English and French, while at CRIT, the mission included an important commitment to technology development and application adapted in French language. Both centers promoted specialized research on linguistic issues associated with technology development and diffusion, particularly automated translation.

This program of research was designed to identify patterns characteristic of technology transfer at the organizational, provincial, national and international levels of analysis. Of particular interest were coordination and control processes, strategies for integration of new expertise in technology transfer, and the role of organizational and national cultures in research management. The perspective of the principal researcher was similar to that of a participant observer since she had conducted research projects in one of the centers, and had participated as an external reviewer for organizational science as a member of the Research committee at the other center. This participant knowledge and experience of the centers' managerial structures and processes contributed to the depth of the analysis.

The analyses are based on data gathered in early 1995 by semi-structured interview with managerial and research staff, and by examination of formal and informal internal documents such as annual reports and five-year plans (Walsham 1991; Yin 1994). The interviews were conducted by the principal investigator with the Director General, Director of Operations, five program managers and one external consultant at CITD, and with the Director General and six project officers at CRIT. Respondents were asked to describe the institutions associated with their programs and projects and the dynamics of institutional network structures. They were also asked to identify strategies for integration of new expertise in technology transfer processes and to describe control mechanisms for program and project management. Metaphorical analysis was used to develop a holistic, more qualitative understanding of the dynamics of institutional networks. A metaphor is an image identified to represent a phenomenon or dynamic otherwise difficult to describe (Palmer & Dunford 1996). In this study, respondents were asked to identify images that would best portray the roles of their respective centers within the institutional network structure identified earlier in the interview. Data from interviews were compiled to validate conceptual models of centre transfer activities and to identify specific illustrations of these activities. Internal documents served to identify salient features of each center's managerial structures and processes. Integration of data from multiple sources was particularly important in light of the changing

environment of Canadian research and development in general, and the high degree of uncertainty experienced by managers and researchers in each center.

Results

Table 1 presents comparative case profiles, mission statements and research management structures of the two centers: (1) the *Center for Information Technology Development (CITD)*, and (2) the *Center for Research on Information Technology (CRIT)*.

The Center for Information Technology Development (CITD)

From the time of its creation in 1985 by the federal government, the mandate of the Center for Information Technology Development was to establish effective mechanisms for transfer of research results for use by Canadian industry, to integrate institutional roles in science and technology, and to create a center for dissemination of information and exchange of personnel at the national and international levels. The Canadian identity of the center was assured by the requirement that partner organizations be Canadian, while international collaboration could be structured with sponsor organizations and their beneficiaries of the same country. In practice, this provision tended to further contribute to the Canadian identity of the center, since virtually all sponsor organizations were Canadian.

The research programs conducted under the CITD mission in 1995–1996 represented the specific priorities and competencies of the center. In the view of CITD management, the core competencies of the center provided access to a wide variety of research areas: language technologies, multimedia and multimodal user interfaces, and sociology of technology. These competencies were unique to CITD, a complex integration of knowledge, skills, technologies, tools, applications, methods and processes.

The functional management structure included an information service and scientific operations with five program units (CITD, 1994d). This center, with some 150 employees at the time of data collection, maintained a permanent and contractual staff of professional researchers and support personnel (CITD 1994d, e). About half of this number, including graduate students and contracted or exchange personnel, were classified as researchers, although only a few individuals of this number possessed training at the doctoral level. The organization chart revealed a clearly defined hierarchical structure with differentiation of administrative, information, and research

Table 1. Comparative case profiles

Descriptor	CITD (CITD, 1994a)	CRIT (CRIT, 1994b, 1995)
Creation—Ministry	1985—Communication and Culture (Federal)	1987—Education (Provincial)
Current Ministry	Industry Canada	Industry, Commerce, Science and Technology
Mission	To conduct . . . advanced applied research in information technology in order to improve Canada's competitiveness.	To contribute to improvement of organizational performance in Quebec by stimulating the transfer of university knowledge and expertise in information technology applications.
Research Themes	• Technological innovation and new forms of work organization. • Performance support systems. • Adaptive information systems. • Cultural information network systems. • Computer-aided translation.	• Business process reengineering. • Cost-benefit analysis of applications. • Information systems and strategic planning. • Linguistic aspects of information systems.
Organization	150 Employees Differentiated hierarchy: research (50%) and functional management.	6-10 Employees Integrated matrix: functional management and project development.
Project Types	• Missionary: exploration of a new domain, creation of new core competencies, or generation of new research. • Platform: integration of research for lower cost and improved utility, quality, or performance • Derivative: incremental exploitation of validated research results.	• Transfer of expertise, competencies, products, or processes. • Development of strategic information. • Diffusion of applied research results.

functions. Research program management was subordinate to the director of operations who in turn reported to the director general of the center. Research activities were integrated in a model of core competencies. This model was consistent with the center's role as a "supply-push" market force. Within the hierarchical structure of the center, committees were formed to facilitate horizontal coordination of center activities and integrate external evaluators of center functioning. In the case of research operations, these included program research and operations management committees mandated to evaluate scientific merits of programs and funding to be allocated to new and ongoing projects. Scientific judgments and managerial decisions were formally generated by different committees, although in practice this differentiation of function was not maintained. The research committee regularly discussed institutional coordination and resource allocation since these issues could not be separated from considerations of scientific merit. However, the operations management committee made the final recommendations concerning the conduct of projects within program structures. Responsibilities within the organizational structure were attributed to committees and organizational units rather than individual actors.

Research *programs* within the center were defined as continuing research activities under long-term planning with the objective of establishing or maintaining a clearly identified area of expertise, while *projects* contributing to program objectives were defined in the shorter term (1–2 years) with respect to specific outputs or deliverables such as research, products, services, or conferences. Research projects were further categorized as *missionary, platform,* or *derivative* in nature. Missionary projects involved exploration of a new domain, creation of new core competencies, or generation of new research results with associated high risk and potentially high return. Platform projects represented the integration of results from exploratory or derivative research to achieve significant progress on technology dimensions such as cost, quality, utility and performance. These projects also were supposed to embody the unique core competencies of the center. Derivative projects on the other hand involved incremental exploitation of validated research results with low risk and low return. The most active application area was electronic commerce, with the largest proportion of exploratory projects in progress. This area was under the responsibility of a consultant to the center, reflecting difficulties experienced within established program areas to respond to rapid developments in technological markets.

Project proposals by eventual CITD partner organizations could be introduced through center researchers, the director general, or the operations director for sponsorship by one of the program directors. Proposals judged consistent with the core competencies of the center were presented by a CITD researcher or by an outside promoter of the project for discussion to the research committee. Project presentation included a general description of objectives and related activities, research methodologies, required budgets, deliverables, collaborating researchers and institutions, and prospective clients. An effort was made to develop a gating system for projects in progress including *idea generation, conceptualization, project planning,* and *project execution.* Committee deliberations were intended to evaluate and develop the project with respect to center orientations, methodological rigor, project team competence, expertise of partner organizations, and clients' interests. The committee's function was to formulate a recommendation to the operations management committee concerning the scientific aspects of proposed projects for final decisions concerning project funding and execution.

The most important collaborating organizations were producers of information technologies including products and services generating employment opportunities for Canadians, followed by Canadian universities and other research institutions and technological pioneer organizations in both public and private sectors of activity. Forms of collaboration between CITD and its partners were diverse. Research contracts were appropriate to remunerated R&D projects submitted by client organizations to CITD for execution in one of the areas of core research competency. The client organization retained proprietary rights over deliverables of the project, while CITD retained such rights over its technological contribution to the project. Joint projects involved contributions by both CITD and its partner organizations. These contributions were financial or in the form of human resources. The effect of financing modes applied at CITD was to create a dynamic of market push through policies to promote applied research themes and the definition of these themes with reference to internal research competencies. New expertise could be integrated in the center structure or transferred to client organizations through the personnel exchange program, with the condition that after completion of the specified term of contract, the employee should return to his or her regular employment. The center also offered graduate student internships and sabbatical positions to university or government researchers. Exchange of human resources was a distinguishing strategy at CITD for the transfer of new information technologies and related competencies.

Project network configurations at CITD across program activities validated the central institutional role of the center. Projects of a missionary scientific nature were executed in collaboration with other specialized R&D centers and with Canadian universities, while larger platform or derivative projects involved government ministries and agencies in development of integrated applications such as collaborative technologies and telework. As illustrated in Figure 2, each of the five programs encompassed missionary, platform, and derivative project activities. Synergies generated by this managerial model contributed to program continuity and diffusion of innovations, as evidenced in the Program on New Forms of Work Organization including projects on management of satellite of-

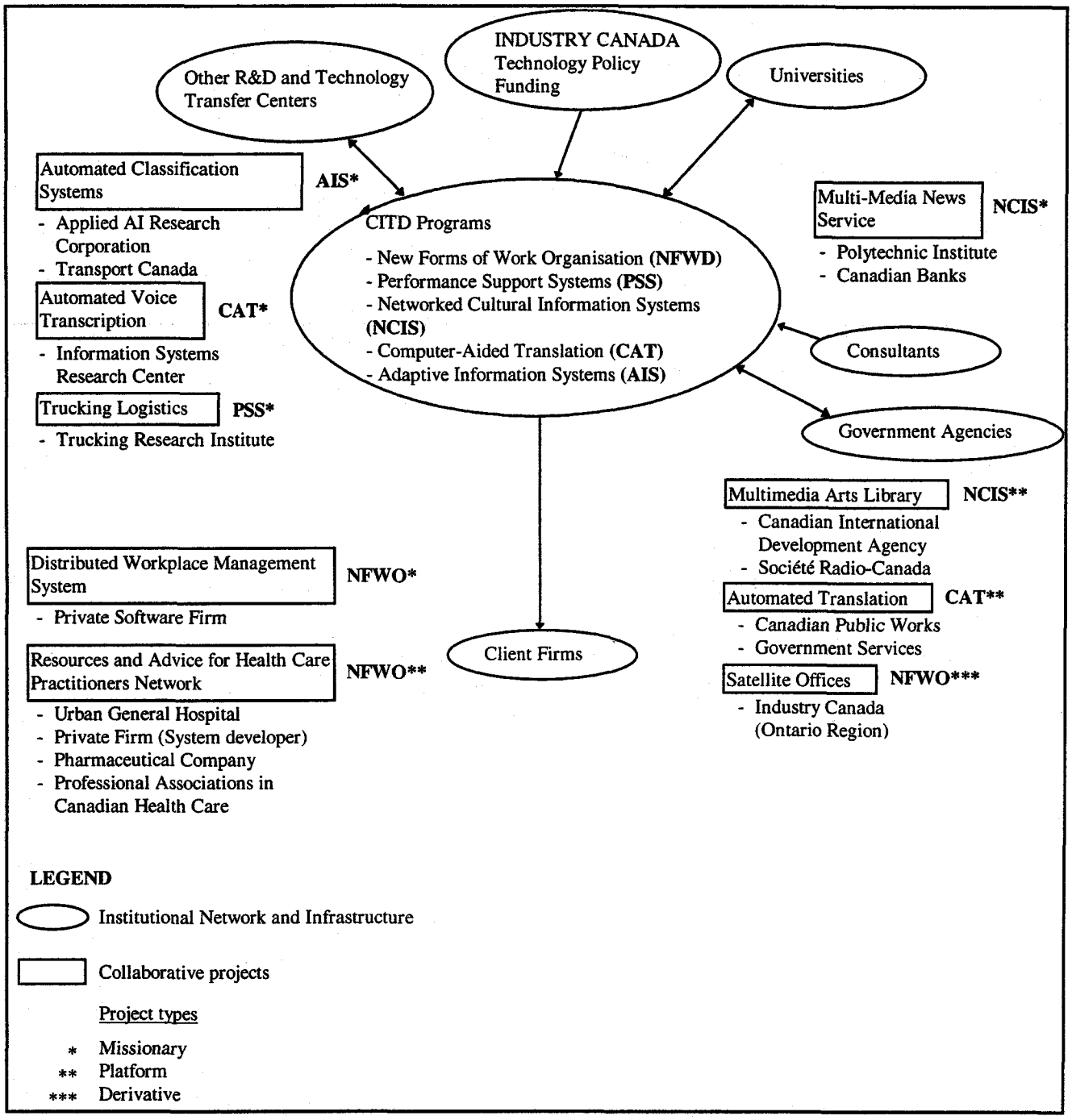

Figure 2. CITD Project Network Configuration

fices, telework, and the distributed workplace. Project network examples are illustrated in Figure 2.

In general, the form of project network configuration was identified as a hub where CITD was the central network node, an R&D laboratory as well as an organizational structure for coordination and control of information technology transfer activities. Metaphorical analysis of center dynamics was consistent with patterns of project structure and yielded the images of *incubator* and *laboratory* expressing the importance of physical space supporting transfer roles. In particular, the laboratory was a social space where research collaborators, partners, and clients could meet and exchange ideas. In the view of many respondents, this social space was critical to center effectiveness.

The Center for Research on Information Technology

Since its creation in 1987, the objectives of this center included promotion and coordination of R&D as well as support services offered to member organizations for integration of information technologies in their business processes. In early 1995, more than 70 organizations, mainly private, were CRIT members. Research orientations, al-

though constantly evolving, were focused in early 1995 on study of the organizational and managerial implications of information technology applications. A small, flexible staff of 6 to 8 project development officers shared responsibility for the project portfolio as well as the conduct of other functions including office management, university relations, corporate development, public relations, and information services. The most salient characteristics of this organization were relative absence of functional differentiation and hierarchical structure, versatility of managerial staff, integration of project management with other managerial functions, and managerial focus on network relations. Project officers were closely involved with management of both internal functions and external relations. These characteristics defined organizational adaptability to the demands of its business and research environment. Like CITD, CRIT was managed under the responsibility of a director general with a board of directors (*conseil d'administration*) composed of corporate and institutional members of CRIT (CRIT 1993a, b, c). Responsibilities within the centre were generally defined at the individual level of analysis, although these responsibilities could be assumed by various members of the staff depending upon operating contingencies such as availability or departure of a staff member. The administrative and functional staff had access to a university network of some 300 academic researchers (CRIT 1994c).

Projects were judged eligible for inclusion in the CRIT program of applied research if they were consistent with the broad research priorities of the center. Each project was managed by one or more university professors or researchers, and involved the formal participation of one or more other organizations (CRIT, 1994c, 1995). Specifically, research and development projects, including competitive and precompetitive research, strategic studies and survey research, were formulated by CRIT project officers in collaboration with university research teams and client organizations (Labrousse & Bergeron 1993). The role of project officers was critical in matching the technology transfer needs of clients with the interests and expertise of researchers. Project officers were also responsible for the evaluation of project budgets. After its evaluation, the project was validated according to the level of CRIT investment by a second CRIT project officer, the Director General, or an external evaluator. After the process of evaluation and validation, the project was submitted to the executive committee or the board of directors for acceptance. A formal gating procedure was not used, but large projects were defined in modules to permit evaluation of project activities in progress. After project completion, a final evaluation was performed on criteria related to research results and outputs, technology transfer, administration, and budget management. Final evaluation often served as a basis for follow-up and subsequent formulation of new projects.

This process fostered a technological market orientation. Although broad themes presented above served as general research orientations, they did not preclude the presentation of new projects involving qualified researchers and interested clients. The center was therefore able to contribute to a wide variety of projects expressing emergent interests in technological markets. In early 1995, the major CRIT strategies were (1) the transfer of expertise, competencies, or products; (2) transfer of strategic information, and (3) diffusion of applied research results to public and private sector organizations (CRIT 1995; Labrousse & Bergeron 1993). In the case of the transfer of expertise, competencies, or products, university researchers generally contributed expertise related to information technologies while the client organization contributed sectoral or context-specific expertise. The resulting new product or process sometimes gave rise to new employment in universities or in client organizations, or creation of a "spinoff" commercial enterprise. Examples of "spinoffs" were small companies created to develop and distribute software applications, such as a system for computerized financial analysis, and an integrated tool for identification of corporate training needs. The second form of transfer, strategic information, involved data collection by questionnaire surveys or by case analysis techniques to assess the use of information technologies by Quebec enterprises. This assessment served the center's clientele in preparation of business strategies and diagnosis of information technology needs expressed in Quebec markets. The third mode of transfer, diffusion of research results, involved presentation of conferences and seminars, as well as publication of articles in professional journals, and newsletters. These activities facilitated communication and learning in the network formed by member organizations (CRIT 1994a, b, c).

Individual project configurations observed at CRIT (Figure 3) included competitive and precompetitive research projects for transfer of technological expertise (organization reengineering, identification and analysis of legal cases), products (software for text analysis), processes (risk analysis and management), and strategic information (Quebec manufacturing SME profiles). In general CRIT played the integrating role between technology providers and users and appeared as a link in a chain of transfer including individual boundary-spanners and their institutions (CRIT 1994a, b, c; 1995). Where multiple participants were involved, CRIT played a managerial role with respect to client firms, while a single university research team assumed the lead in research management and control. A variant of the chain configuration was observed in the case of collaboration with a professional association to obtain specialized legal expertise where a circular or all channel network was observed. Choice of metaphors by center staff members reflected project network characteristics; in particular, *technology broker, virtual network center, bridge, missionary,* and *risk vendor,* portrayed desired roles of institutional liaison, vision and leadership with emphasis on virtual rather than physical space.

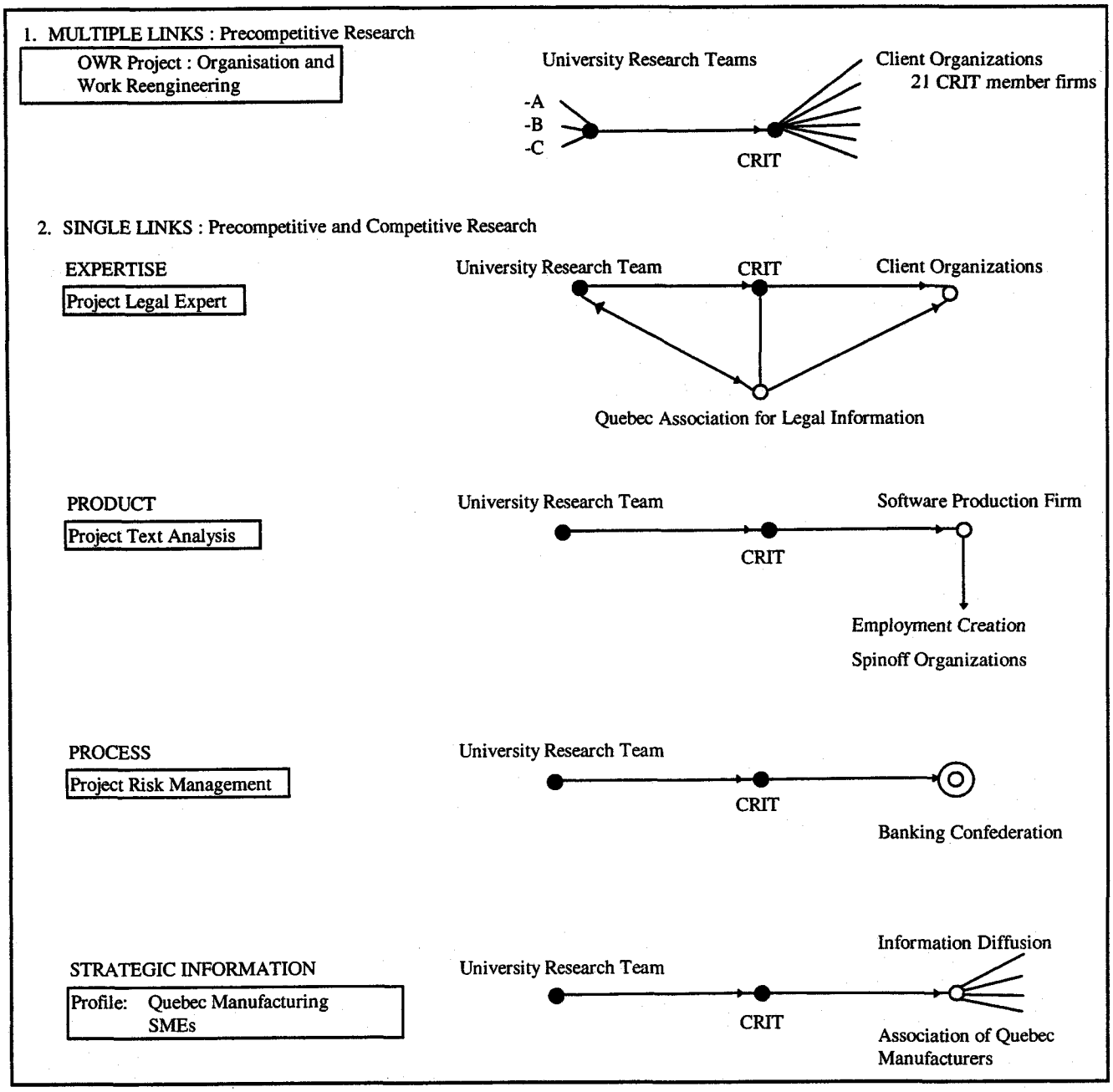

Figure 3. CRIT project network configurations

Comparative Case Analysis

Comparison of the two modes of research management illustrated in discussion of CITD and CRIT reveals some similarities in addition to important differences in their modes of applied research management and technology transfer (Table 2). CITD exhibited an organizational system characterized primarily by structuring, program-dominant management while CRIT showed punctual, project-dominant management. At CITD, the organizational system tended to be bureaucratic, centralized and highly differentiated to distinguish administrative from research activities; while in the case of CRIT the structure was organic, decentralized and considerably less differentiated with respect to these activities. Reflecting the institutional level of responsibility at CITD, decisions were made in collective context, for example in committees or within programs. On the other hand, at CRIT, responsibility was defined at the individual project level and decisions were made by project officers and by principle investigators to be validated at the institutional level. These differences gave rise to hierarchical control processes at CITD with a focus on proprietary rights of contributors, while at CRIT, the control process was based on technological market dynamics and the added value resulting from network relations and the process of technology transfer.

Evaluation of research and other transfer activities was focused on "programs" defined in different ways in each center. At CITD, research programs were designed to pursue technological themes consistent with core research

Table 2. Summary: Comparative case analysis

Dimension	CITD	CRIT
1. Management Structure	Program-Dominant	Project-Dominant
2. Intervention	Structuring	Punctual
3. Control	Hierarchical Product	Market Process
4. Evaluation	Technological Effectiveness	Managerial Efficiency
5. Motivation	Policy Enactment	Problem Solution
6. Transfer	Exchange	Consultation
7. Market	Push	Pull
8. Differentiation	High	Low
9. Decision Making	Centralized Collective	Decentralized Individual
10. Network Configuration	Hub	Chain
11. Organization	Physical	Virtual
12. Metaphor	Incubator	Broker, Bridge

competencies and public policy priorities. In contrast, CRIT applied evaluation criteria to programs of similar types of projects such as research and development projects, strategic studies, technology transfer, and conferences and seminars. Criteria appropriate to evaluation of thematic programs were designed to measure technological effectiveness, while criteria applied to project types such as applied or survey research related to efficiency of resource allocation and administration for project outcomes.

Integration of scientific and technical expertise in the process of R&D and information technology transfer was significantly different in the centers under study. At CITD, the permanent program structure internal to the center reflected core research competencies related to public policy priorities and, to some degree, other political considerations. New expertise could be integrated in the center structure or transferred to client organizations through the personnel exchange programs. At CRIT, R&D and technology transfer activities were conducted under the responsibility of university professors and researchers for the term of specific project duration. Thus the integration of academic and technical expertise in the process of transfer was flexible, and projects could be identified and conducted as a function of newly emergent technologies and expressed market needs. Although this was not always the case, political or policy considerations were generally secondary to technological market concerns. The institutional activities at the national level at CITD contributed to define an infrastructure in which problem solving project activities could be framed at the provincial level. This complementarity of R&D activities at the national and provincial levels in the two centers was facilitated by their physical proximity and by a process of evolution in which their respective roles were defined (Feser 1998; Cooke, Uranga, & Extebarria 1997; Gerson & Johnson 1997).

Analyses of technology transfer activities also identified the contrasting roles of network institutions and individual actors as institutional integrators of technological market supply and demand. At CITD, such integration occurred primarily by exchange of personnel and other critical resources; while at CRIT, university professors and other experts maintained their academic or professional affiliations, and benefited from use of resources of their institutions of employment in the transfer process. Academic project directors collaborated with appropriate managerial and technical staff in client organizations and effectively accompanied them through the R&D and transfer process. This process was generally embedded in the client organization milieu, which fostered its specific adaptation to clients' needs.

CITD was described by researchers as a research laboratory, an institutional and social meeting place where critical ideas and scientific exchanges were generated. CRIT, on the other hand, was described as a node in a virtual network structure. The physical context of transfer activities and applied research was located either in the university milieu of contracted researchers or at physical facilities offered by participating client organizations. Analysis of project network configurations were consistent with metaphorical description of transfer activities as an incubator in the case of CITD and a broker organization or a bridge between technology providers and users in technological markets in the case of CRIT. At CITD, such configurations presented the form of a hub where the R&D

laboratory was the center of research activities, while CRIT was a link in a loosely coupled institutional chain of technology transfer showing linear or all-channel communication patterns.

The next section of the paper presents a discussion of the major conclusions from cross-case comparison and implications for future research and policy-making on information technology transfer.

Conclusions and Recommendations for Future Research

The foregoing case descriptions of modes of research management within two publicly funded research centers specialized in information technology transfer show how program- and project-dominant managerial systems may accomplish complementary objectives. Modes of public funding together with managerial systems for monitoring and control of programs and projects have significant consequences for those processes and for institutional roles of government and universities in innovation networks. In both centers, managerial structures were designed to facilitate public support of technology transfer priorities without conferring an unfair advantage to specific actors in technological markets (Tripsas 1994; CITD 1994d). In particular, use of research consortia and public diffusion of research results contributed to national competitive advantage without prejudice to domestic technological markets. This benefit may extend to international technology transfer as global research network structures emerge.

Both centers conducted their research and development activities in the context of institutional innovation networks, frequently involving similar organizational actors including governmental agencies at the provincial and federal levels, universities and other institutions of higher education and research, and private enterprises. The key actors in the CITD network were defined at the institutional level, in contrast to CRIT where these key actors were individual integrators of technological supply and demand. The diffusion of technological competencies was accomplished by institutional exchange, particularly of human resources in the case of CITD, while in the case of CRIT, the mode of diffusion in the conduct of projects was through a matrix structure integrating academic researchers and technical experts with managers at appropriate levels of client organizations. These structures were created and monitored by CRIT project officers. Modes of public funding of the two centers were consistent with differences in their research management structures. At CITD, federal funding supported the programs of applied research, effectively promoting technological supply and market *push*, while at CRIT, a significant proportion of provincial funding was allocated as a function of client organization contributions to project activities, thus promoting technological demand and market *pull*. Thus the dynamics of the two centers were complementary, and they illustrate the open systems principle of equifinality (Katz & Kahn 1978; Morgan 1997). Furthermore, both market dynamics are essential to an effective process of technology transfer in national and regional or provincial innovation systems.

The most important area for continued future study is the structure of research management systems and the influence of such structures on technological market dynamics. In particular the convergent roles of researchers and managers in the process of technology transfer need to be examined to better understand integration of technological and contextual expertise. The complementary relation between program and project dominant R&D modes needs to be further studied as it relates to national and regional technology policy-making (Alange, Jacobsson, & Jarnehammar 1998; Feser 1998; Gregersen & Johnson 1997; Cooke, Uranga, & Extebarria 1997; Morgan 1997). An important research question is how to integrate policies to develop broad infrastructures supporting competitive national innovation systems as well as diverse local problem solving networks. Within research management structures, politics, collaboration and competition among teams may have desired or dysfunctional consequences depending on the type of R&D or transfer activity and corresponding project configurations. Related to these concerns are ethical issues, particularly proprietary rights and conflicts of interest arising in collaboration between public and private interests. Institutional networks integrate technology producers and consumers for achievement of innovation outcomes. Network configurations appropriate to various types of projects, from fundamental to applied research as well as international collaboration, need to be identified and evaluated with respect to other critical factors such as sector of economic activity and national culture.

Research in these areas will contribute significantly to advancement of knowledge in organizational theory and elaboration of theoretical models of innovation, organizational learning, and information technology transfer. Such models are critical to continuing research and the development of tools useful in public policy-making for regional, national and international economic development.

References

Alange, S., S. Jacobsson, and A. Jarnehammar. "Some Aspects of an Analytical Framework for Studying the Diffusion of Organizational Innovations." *Technology Analysis and Strategic Management* 10(1), 1998, pp. 3–21.

Autio, E., and T. Laamanen. "Measurement and Evaluation of Technology Transfer: Review of Technology Transfer Mechanisms and Indicators." *International Journal of Technology Management* 10(7/8), 1995, pp. 643–664.

Barnett, A. "Knowledge Transfer and Developing Countries: The Tasks for Science and Technology in the Global

Perspective 2010." *Science and Public Policy* 21(1), 1994, pp. 2–12.

Boaden R., and G. Lockett. "Information Technology, Information Systems and Information Management: Definition and Development." *European Journal of Information Systems* 1(1), 1991, pp. 23–32.

Brockhoff, K., and B. Schmaul. "Organization, Autonomy, and Success of Internationally Dispersed R&D Facilities." *IEEE Transactions on Engineering Management* 43(1), 1996, pp. 33–40.

Callon, M., P. Laredo, and V. Rabeharisoa. "Des Instruments pour la Gestion et l'Évaluation des Programmes Technologiques: le Cas de l'AFME," *L'Évaluation Économique de la Recherche et du Changement Technique.* J. DeBandt and D. Foray (eds.). Paris: Éditions du Centre National de la Recherche Scientifique, 1991, pp. 301–330.

Chiesa, V. "Managing the Internationalization of R&D Activities." *IEEE Transactions on Engineering Management* 43(1), 1996, pp. 1–23.

CITD, internal documents: *À la recherche de nos "Core Competencies,"* 1993a; *Synthèse de sélection des projets*, 1993b; *Activity report, 1993–1994*, 1994a; *Rôle du comité des programmes et des projets (proposition)*, 1994b; *Notre identité*, 1994c; *Le partenariat au CITD, une bonne façon de faire de la recherche*, 1994d; *Electronic performance support systems*, 1994e; Revue des operations, 1995.

Cooke, P., M. Uranga, and G. Extebarria. "Regional Innovative Systems: Institutional and Organizational Dimensions." *Research Policy* 26(4-5), 1997, pp. 475–491.

CRIT, internal documents: *Plan quinquennal, 1994-1999*, 1993a; *Plan opérationnel, 1994-1995*, 1993c; *Plan directeur, 1994-1995*, 1994a; *Rapport annuel 1994*, 1994b; *CRIT, une valeur ajoutée pour les enterprises québécoises*, 1994c; *Gestion du transfert: guide d'évaluation et de suivi des activités*, 1994d; *Réalisations de transfert au CRIT*, 1995.

de la Mothe, J., and G. Paquet. "Circumstantial Evidence: a Note on Science Policy in Canada." *Science and Public Policy* 21(4), 1994, pp. 261–268.

Feser, E. "Enterprises, External Economies, and Economic Development." *Journal of Planning Literature* 12(3), 1997, pp. 283–302.

Freeman, C. "Networks of Innovators: A Synthesis of Research Issues." *Research Policy* 20(4), 1991, pp. 499–514.

Godin, B., and M. Trépanier. "La Politique Scientifique et Technologique Québécoise: la Mise en Place d'un Nouveau Système National de l'Innovation." *CRIT*: unpublished manuscript, 1994.

Gregersen, B., and B. Johnson. "Learning Economies, Innovation Systems and European Integration." *Regional Studies* 31(5), 1997, pp. 479–490.

Katz, D., and R. Kahn. *The Social Psychology of Organizations* (2nd ed.). New York: Wiley, 1978.

King, J.L., K.L.V. Gurbaxani, F.W. Mcfarlan, K.S. Raman, and C. Yap, "Institutional Factors in Information Technology Innovation." *Information Systems Research* 5(2), 1994, pp. 139–169.

Labrouse, F., and F. Bergeron. *Rapport d'Étude sur la Mise en Application au Centre . . . du Transfert en Technologies de l'Information.* Québec: CRIT, 1993.

Link, A. "Evaluating Program Performance: The Case of Federally Funded Collaborative Research." *International Journal of Technology Management* 10(7-8), 1995, pp. 847–852.

Lynn, L.H., N.M. Reddy, and J.D. Aram. "Linking Technology and Institutions: The Innovation Community Framework." *Research Policy* 25(1), 1996, pp. 91–106.

McArthur, D., and R. Schill. "International Cooperative Technology Arrangements: Improving their Role in Competitive Strategy." *Journal of Business Research* 32(1), 1995, pp. 67–79.

Morgan, K. "The Learning Region: Institutions, Innovation and Regional Renewal." *Regional Studies* 31(5), 1997, pp. 491–503.

Niosi, J. "Canada's National System of Innovation." *Science and Public Policy* 18(2), 1991, pp. 83–92.

Niosi, J., and B. Bellon. "The Global Interdependence of National Innovation Systems: Evidence, Limits and Implications." *Technology in Society* 16(2), 1994, pp. 173–197.

OCDE. *Les Incidences des Programmes Technologiques Nationaux.* Paris: Éditions de l'OCDE, 1995.

Palmer, I., and R. Dunford. "Conflicting Uses of Metaphors: Reconceptualizing Their Use in the Field of Organizational Change." *Academy of Management Review* 21(3), 1996, pp. 691–717.

Séror, A. "Action Research for International Information Technology Transfer: a Methodology and a Network Model." *Technovation* 16(8), 1996, pp. 421–429.

Smith, W.A. "Evaluating Research, Technology and Development in Canadian Industry: Meeting the Challenges of Industrial Innovation." *Scientometrics* 34(3), 1995, pp. 527–539.

Tassey, G. "The Functions of Technology Infrastructure in a Competitive Economy." *Research Policy* 20(2), 1991, pp. 345–361.

Tijssen, R. "Quantitative Assessment of Large Heterogeneous R&D Networks: The Case of Process Engineering in the Netherlands." *Research Policy* 26(1), 1998, pp. 791–809.

Tripsas, M., S. Schrader, and M. Sobrero. "Discouraging Opportunistic Behaviour in Collaborative R&D: a New Role for Government." *Research Policy* 24(3), 1994, pp. 367–389.

Walsham, G. "Organizational Metaphors and Information Systems Research." *European Journal of Information Systems* 1(2), 1991, pp. 83–94.

Yin, R .R. *Case Study Research.* Newbury Park, CA: Sage Publications, 1994.

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