Firms and their problems: systemic innovation in Calgary

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1.0 Introduction

Discovery of oil and gas in the Turner Valley region south of Calgary early in the 20th century, followed by construction of pipelines in the 1950s, transformed Calgary's economic, political and social structures. Alberta transformed from one of the poorest provinces in Canada to the richest over several decades. Exploration and development in oil and gas have largely spurred the rapid growth of the Calgary census metropolitan area (hereafter, "CMA"). Through the '70s, '80s and '90s, Calgary's energy sector attained critical mass attracting the sector's national head offices. Now known as Canada's Global Energy Centre, Calgary is home to 87% of the country's oil and natural gas producers (CED, 2009).

The dominant oil and gas cluster has differentially affected firm capacities to function and develop. The major cluster focus has provided opportunities and positive spin-off effects from the associated economic growth while also impeding aspects of firm establishment and expansion (Langford, Li and Ryan, 2009). Firm-based innovative activity and behaviour connected with navigating in and around this and other problems is of interest for this paper.

This paper reports on the innovative behavior of firms interviewed in the city of Calgary as a part of a cross-Canada study of "Social Dynamics of Innovation" in cities[2]. Overall we look for the dynamics of regional innovation and attempt to identify systematic characteristics (Cooke, 2001). Echoing Foray's (2002, 38) interpretation of 'innovation' implied by the concept of a 'knowledge economy', we argue that the process of innovation is non-discreet, with firms in continuous flux and is, in essence, a fractal process that is similar at all scales. Thus, to understand regional innovation dynamics,

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categories of scope (e.g. radical, incremental) may not be the most fruitful. We suggest a classification of the Calgary innovation system—not by scope—but rather by type of problems innovations and innovative activities address.

2.0 Literature Review & Approach

Our categorization is based in grounded theory so that the innovation categorization emerges from the analysis of the data. As might readily be expected, all innovations could be characterized by the problems they "solved", whether these problems were identified in advance or emerged in the course of the work. As well, a fundamental observation drawn from our interviews is the need to recognize further complexity— beyond the distinction between inventions as the emergence of a new idea and innovation as its successful translation into use. In these data the additional factor that emerges strongly is that all of the events coded as innovations involve substantially distributed cognition (Rogers and Ellis, 1994) whereas that is not always similarly prominent in invention. Clearly, the notion of distributed cognition implies network phenomena, but it goes further as Rogers and Ellis (1994) argue:

> [O]rganizational and social constraints and practices impact upon individual, cognitive processes and the realization of these in specific tasks. Any adequate characterization of work activities therefore requires the analysis and synthesis of information from these, traditionally separate sources (p. 119).

From this perspective, the analysis of systemic characteristics places knowledge flows in the more active context of their structures of cognition with pathways "conceptualized as coordinated sequences of action that are continuously interrupted by the demands of a changing environment" (Rogers and Ellis 1994: 122). These activities, according to Rogers and Ellis (1994), represent the assembly of "various representational states" (122). Thus, our analysis is facilitated by a primary categorization of innovations that provides an *explicandum* based problem typology. This typology permits mapping the broad outlines of cognitive networks efficiently.

Four types of problems addressed by innovations are distinguished in the data. These are:
1. innovations designed to solve a problems identified by a client or clients,
2. innovations developed internally, motivated by a goal of organizational learning to increase competences or capacities,
3. innovations related to a market barrier problem that required circumvention, and
4. innovations required for creation of a new market often for a suite of related products and services.

On a second axis, these are divided into those innovations that support the competitive advantage of a particular firm from those that are collaborative among a group of firms and entail collective advantages. This distinction is significant when considering network phenomena. The scheme is summarized in Table 2.1.

Table 2.1 Problem oriented innovation typology

	Client need	Capacity building	Market barrier	New market creation
Firm advantage				
Collective advantages				

Knowledge flows are categorized into three varieties according to locality:
1. internal knowledge which circulates and is shaped primarily within a particular firm or innovative unit,
2. local knowledge which circulates primarily among innovative individuals and organizational units within the CMA based innovation system, and
3. non-local knowledge which arises from specific sources outside the CMA and is transmitted to the CMA via various channels, especially through industry specific pipelines or linkages such as 'invisible colleges' of expertise, conferences, shows, and informal contacts (Bathelt et al, 2004; Maskell et al, 2005).

In addition, we distinguish between tacit and codified knowledge adopting the common definitions. The term tacit knowledge, as coined by Polanyi (1966), suggests that when one acquires a skill, one attains a corresponding understanding (know-how) that is almost impossible or too cost-prohibitive (Cowan, Foray and David 2000) to articulate or codify. Gibbons et al (1994) suggest that tacit knowledge resides in the heads of those working on a particular process or embodied in a particular organizational context. The latter may include a machine or device. Codified knowledge, on the other hand, is expressed in documents, equations, and logically analyzable statements that are systematic, reproducible and related to facts or information and the principles that explain and, unlike its tacit counterpart, is easily shared (Lundvall, 2003) among all with suitable receptor capacity.

Table 2.2 outlines a location oriented knowledge typology that integrates tacit and codified knowledge with location factors.

Table 2.2 Location oriented knowledge typology

	Internal	Local	Non-Local
Codified	Manuals, formal procedures, etc.	e.g. Local grey literature, etc.	Scientific literature, trade papers, etc.
Tacit	Embodied, mentoring, etc.	Mentoring, workshops, networks, etc.	Training workshops, Invisible colleges, etc.

This paper approaches problem-solving as a distributed cognitive process dependent upon knowledge acquisition and sharing hybridized to become inputs to the activity of innovation. Specifically, we attempt to determine, from evidence of knowledge sources and problem solving approaches, whether an "innovation system" exists that can be analysed from a study based on the Calgary CMA. The defining characteristic of this work is that the Calgary CMA is taken as a geographic boundary for investigation, rather than a container for the activities of any system. The problem is particularly acute in a centre like Calgary where the largest cluster is in oil and gas and Calgary's contribution

is primarily managerial, technical and financial knowledge applied to resource sites widely distributed across the CMA's hinterland and the globe. Any resource-based system is geographically relational.

The analysis of the regional innovation system is organized through tests of three hypotheses:

H0. There exists an innovation system (no doubt lacking well defined spatial boundaries) that can be characterized by study within the Calgary CMA.

H1. There is a relationship between problem types and relative importance of knowledge factors.

H2. Both intra and inter-secotral knowledge circulation is significant but the distribution of knowledge sources over problem types varies by sector.

3.0 Methodology

This work is a part of an examination of the social factors influencing innovation in this resource based city region in the context of a national project of Canada's Innovation Systems Research Network (ISRN)[1]. The ISRN project prescribes interviews with senior executives of firms, community organizations, and government entities, as well as interviews with individuals identified as creative talent. These were carried out under a common set of guidelines for the ISRN research. During 2006-2008, 121 interviews were conducted in Calgary by researchers at the University of Calgary, including the present authors. For this particular study, a subset of full interview transcripts conducted with senior firm executives was selected.

This paper adopts a parallel methodology to that employed for a previous ISRN study of talent attraction and retention in the Calgary CMA (Langford, Li and Ryan, 2009). Each selected transcript was inspected to tag innovations identified in responses to questions about innovations over the past three years. The method tags sufficient text fragments (not keywords) to explain the category assigned. Next, text was tagged to identify the suite of knowledge resources assembled in the process of generating and supporting the innovations. In all cases, interview subjects were key participants in the innovative processes they described. Each innovation identified was categorized as addressing one or more of the two outcome types: either firm advantage or collective advantage; and one or more from the problem types: client need, capacity building, overcoming market barriers, or new market creation. For each innovation mentioned, all related mentions of knowledge factors were identified and categorized into the following types: one or more of tacit or codified; and one or more of internal (to the firm), local (to the city regional system) or non-local (primarily sector based pipelines). The frequencies of the use of each type of knowledge factor alone, and in combination, were recorded, counting multiple instances of the same component type individually.

Because the source data consists largely of narratives, this method relies most on the first three of Alexander's (1988) "nine principle identifiers of salience", primacy, frequency and uniqueness, to ensure that the interviewee identifies their perception of the most important information about their innovations in the limited time allotted for each interview.

4.0 Results

From the sample of 29 transcribed interviews, 495 knowledge items were identified, pertaining to 76 plausible innovations, an average of 7 knowledge items per plausible innovation (min=3, max=48). Of the 76 plausible innovations, 14 (18%) pertained to human resource practices required to attract and retain high quality personnel, 16 (21%) pertained to the introduction of complete suites of services, 21 (28%) pertained to new collaborations, while the remainder pertained to new tools or new knowledge use. Among the 76 plausible innovations, seventy-six percent (60) were directed at securing firm advantages, while a minority (16) (21%) were directed at securing collective advantage. See Table 4.1.

Table 4.1 Number of innovations by types

|	Client need	Capacity building	Market barrier	New market creation
Firm advantage	26	16	3	15
Collective advantage	3	3	3	7

The 495 knowledge items identified were each categorized according to locality factors: internal (int), local (loc), non-local (NL); and by knowledge factors: tacit (tac) or codified (cod). Each knowledge item, commonly a hybrid, could be categorized by one or more localities, and one or more of tacit or codified. A knowledge item exploiting internal and local tacit and codified knowledge flows would count once as an instance in each of cells A, B, C and D in Table 4.2.

Table 4.2 Problem types vs. knowledge factors

Knowledge Type	A (Int-Cod)	B (Int-Tac)	C (Loc-Cod)	D (Loc-Tac)	E (NL-Cod)	F (NL-Tac)	Total
Client Need	42	69	57	92	33	35	*328*
Capacity Building	23	50	47	73	22	43	*258*
Market Barrier	11	19	18	21	22	17	*108*
Market Creation	23	18	30	45	22	28	*166*
Total	**99**	**156**	**152**	**231**	**99**	**123**	***860***

In total, the 495 knowledge items contained 860 instances in which a cell in Table 4.2 was occupied (Figure 4.1). Local and tacit knowledge were the most prominent types of knowledge factors, while client need and capacity building were the most common problem types.

Figure 4.1 Knowledge factors by problem type
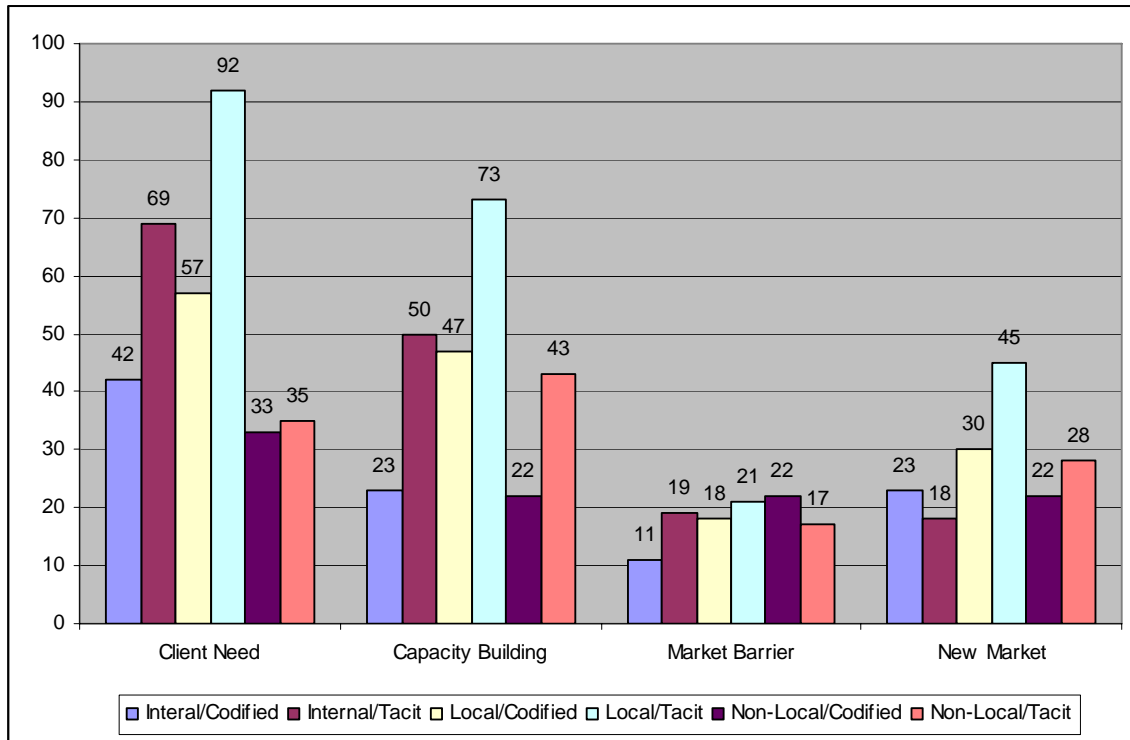
When the 860 knowledge items were divided by firm vs. collective advantage, the focus on firm advantage over collective advantage is once again reflected.

Table 4.3 Problem types by internal, local and non-local knowledge factors

Knowledge type	Internal			Local			Non-Local			Total		
Advantage	CA	FA	*Sum*	CA	FA	*Sum*	CA	FA	*Sum*	CA	FA	*Sum*
Client Need	21	90	*111*	43	106	*149*	17	51	*68*	81	247	*328*
Capacity Building	8	65	*73*	27	93	*120*	8	57	*65*	43	215	*258*
Market Barrier	2	28	*30*	10	29	*39*	2	37	*39*	14	94	*108*
Market Creation	11	30	*41*	34	41	*75*	16	34	*50*	61	105	*166*
Total	**42**	**213**	*255*	**114**	**269**	*383*	**43**	**179**	*222*	**199**	**661**	*860*

CA – Collective Advantage; FA – Firm Advantage

Table 4.4 Problem types by % internal, local and non-local knowledge factors

Knowledge type	Internal			Local			Non-Local			Total		
Advantage	CA	FA	*Sum**	CA	FA	*Sum**	CA	FA	*Sum**	CA	FA	*Sum*
Client Need	19%	81%	*34%*	29%	71%	*45%*	25%	75%	*21%*	25%	75%	*100%*
Capacity Building	11%	89%	*28%*	23%	78%	*47%*	12%	88%	*25%*	17%	83%	*100%*
Market Barrier	7%	93%	*28%*	26%	74%	*36%*	5%	95%	*36%*	13%	87%	*100%*
Market Creation	27%	73%	*25%*	45%	55%	*45%*	32%	68%	*30%*	37%	63%	*100%*
Total	**16%**	**84%**	*30%*	**30%**	**70%**	*45%*	**19%**	**81%**	*26%*	**23%**	**77%**	*100%*

*Percent out of total sum for problem type

5.0 Analysis

As will be readily seen, the first two hypotheses (H0, H1) were consistent with the data.

Across all problem types identifications of local knowledge factors were equally or more numerous than non-local and internal knowledge factors. Local knowledge is the leading factor, consistent with the system hypothesis. The ratios of local to non-local knowledge use for collective advantage (~2.5)) is much higher than the comparable ratio (1.5) for firm advantage. This indicates a quantitative difference in the ways in which local and non-local knowledge are used (Table 4.4) in the CMA. Local sources play a proportionately larger role when firms collaborate on a problem, underlining the role of active collaboration in knowledge flow, Non-local knowledge pipelines play an important role most prominently in solving market barrier problems, arguably an indication of the sectoral character of such barriers. Non-local pipelines are also quite prominent in new market creation, but not more so than local knowledge. The data are also consistent with the expectation that tacit knowledge is more readily available locally than from afar.

5.1 Intra-sectoral knowledge flow and the oil and gas cognitive-cultural platform

Tests of the third hypothesis (H2) led to recognition of the central feature of the Calgary innovation system. The analysis of knowledge flows must begin from decisions as to what is to count as a functional grouping of activities in this innovation system. The analysis of a centre with a strong dominant cluster (e.g. natural resource based but without the natural resources themselves within the boundaries of study) creates special problems for grouping that reflects the complexity of (especially) innovation. An inspection of statistical data on the CMA shows that standard statistical classification of sectors does not offer a fruitful base for analysis of these data. Which industries are clustered is one criterion. Spencer and Vinodrai (2006) have developed an expanded cluster definition that starts from the common criterion of an employment location quotient (LQ) >1.00. It is suggested that industries with LQ > 1 are candidates to be non-basic in the sense that they produce outputs exceeding the needs of the immediate community. This is an important characteristic for support of economic development. In Calgary the leading examples are oil and gas (LQ = 5.03), mining (LQ = 1.59), construction (LQ = 1.98) and business services (LQ = 1.57) Mining has close relation to oil and gas as does business services. Of the remaining industry classifications identified as clustered (Spencer and Vinodrai, 2006) only ICT services (LQ = 1.38) and logistics (LQ = 1.25) exceed 1.2 in LQ value. ICT manufacturing is also clustered, but unlike services does not have a close association with oil and gas. The linkage is rather one of being a "spin-off" some years ago (Langford, et al. 2003).

For this analysis, we choose oil and gas with mining as a "natural resources sector" grouping but recognize that important parts of construction, business services, financial services, and ICT services are closely integrated with and into oil and gas projects. To regard knowledge flows among these as across sectors would be to misrepresent the structure. One interviewee remarked *"…in Calgary you can't do anything if it's not linked to oil and gas"*. Data from interviews revealing firms closely integrated to oil and

gas will be grouped with oil and gas and knowledge flows will be considered as within the sector. This "sector" is a distinct sort of unity representing a cognitive and cultural platform (Cooke, 2002, Hess, 2004) that produces a wide range of outcomes by hybridizing a rich variety of conventionally distinct inputs. It generalizes the "mode 2" concept (Gibbons et al. 1994) of transdisciplinary problem solving from the project to a "sector". This characteristic is probably shared with other major centres of the petroleum industry.

Among professional, scientific and technical services where employment data yield an LQ of 1.7, environmental services can be recognized as arm's-length from the oil and gas platform to a significant degree even if it is in many cases a spin off. It forms a usefully distinct second sector well represented in these data. A sub-sector of both the business services (LQ = 1.57) and creative and cultural (LQ =1.12) that demonstrates non-basic character can be grouped as advertising and multi-media. It does not owe its origins to the oil and gas platform and was identified in the data. Interviewees suggested that Calgary is achieving "buzz" in this area. Finally, other innovative firms that are mainly drawn from manufacturing are grouped here simply as "other". Thus intra- and inter-sector knowledge flows will be treated here as those among the four groups summarized in Table 5.1.

Table 5.1 Groupings for analysis of inter-sector knowledge flow			
Natural resources (oil and gas)	Environmental consulting	Advertising & multi-media	Other

5.2 Distributed Cognition and Flow of Knowledge Among the Dominant platform and Other Sectors

Distributed cognition within firms and among firms appears crucial to the problem-solving capabilities of Calgary's regional innovation system. Further, a dominating share of essential elements of the system are local to the Calgary CMA. To complement our quantitative analysis, the following section provides not only a qualitative overview of the sample data set analyzed herein (n=29) but also is populated with observations from our larger data set as a whole (n=121). These observations are highly qualitative in nature but offer insight into the distributed nature of knowledge sharing and related activities among the re-defined sectors (or platforms) in the Calgary CMA. More specifically, knowledge flows are characterized through movement of personnel, the assembly of firms in order to service client need, the social networks and the informal linkages that serve to sustain these activities as well as activities around artifact creation that facilitates knowledge sharing amongst CMA constituents. Finally, the special case of spin-off from the dominant cluster is considered.

5.2.1 Movement of People

Ten of the 14 both small and large firms mentioned internal human resources as key to innovations for purposes largely internal to firms These innovations serve to simultaneously enhance the firm's (or the sector's) overall ability to offer an advanced suite of services. This is indicated by the firms' statements that taking on complicated projects was predicated on the pre-existing ability to access requisite local talent.

> *"You don't need a lot of people, you need the right people, who believe similar things but come from different perspectives, who can take those random ideas and create something unique."*

Talent acquisition from other sectors appears to be an explicit act to expand the reach of a firm's shared memory or previously solved problems (Minsky, 1988) from within and outside the industry, in order to enhance its ability to solve new ones.

Further, small firms tended to maintain a roster of contract talent for engagement in specific projects, while larger firms tend to pro-actively seek out and ascertain unique talent in the anticipation that their expertise would non-specifically enhance overall firm-based capabilities.

> *"We have invested heavily in senior business marketing consultants who actually pivot point on everything the agency does... They bring in all our disciplinary experts to create a plan out of that, so they're really architects... The people... are from hugely diverse walks of life, everything from a lady who ran three different business units at Microsoft for a decade, to people from General Dynamics, which are engineering type companies... we've got engineers on our planning group."*

The serendipitous recognition of the usefulness of knowledge gained in one sector for the launching of an enterprise in a distinct sector is also observed in the dataset. In one example, imaging knowledge is transferred from the geophysical domain (oil/gas platform) to the medical devices industry. In another, firm-based spin-out activity and the transfer of people versed in web development in the multi-media/advertising sectors into a new firm designed to explicitly serve dental practices.

5.2.2 Consortia and associations

A significant number of innovations aimed at collective advantage were identified above. Most of these are realized through formal, if transitory consortia. Both financial and technical knowledge are shared in these and foster multi-organization distributed cognition. This is a standard mode of operation within the oil and gas platform. These consortia reach out to engineering firms, environmental and financial actors. Consortia were also identified in the advertising/multi-media sector that interact with the oil/gas platform.

Associations are also important venues of knowledge flow. Many of these are national and even international, but ones centred on Alberta are common, and given the

differential industrial structure of the two major Alberta centres, Calgary and Edmonton, several of these can be thought of as primarily Calgary organizations. There are also important local associations such as Calgary Technologies, Calgary Advanced Technology Association, and the Wired City project. Commonly the national groups are sector focused with some boundary interactions and the second group are explicitly inter-sectoral.

One multimedia/advertising firm learned about the need for bundled capabilities from fellow association members who are also executives in other sectors.

> *"Our real advantage is that we focus and specialize on that alignment of marketing to business... whatever needs business has... helping to get those [distributed]senior executives to line up what they're doing with their marketing efforts... Oil and gas companies do not need to go to market, they have already a market... but they have reputation management, they have other issues."*

5.2.3   Social Networks

Informal networks were mentioned widely in the interviews. Interviewees from oil and gas, engineering, environmental and multimedia/advertising sectors all mentioned the interdependence of their social, industry-based knowledge networks, even though each sector's internal networks were distinguishable. At one end of the spectrum the Calgary "Plus-15" system of linking major downtown buildings above street level functions to promote "accidental" contact. As this was put in one interview:

> *"You bump into someone on the Plus 15 and it reminds you should talk and you set up a meeting."*

Similarly there are arranged gatherings is social settings such as this example linking oil and gas and environmental expertise:

> *"[T]here's currently a group of us who get together at the [local restaurant] once a month, swap ideas on water treatment for oil sands, drink lots of wine, that sort of thing. It's quite a social forum, but it's a technically useful social forum."*

5.2.4 Artifacts of tacit knowledge externalization

Artifacts from externalization of tacit knowledge can also be distributed. One GIS firm offers its expertise through a software library, while an advertising firm uses a central data analysis, collection, and visualization tool to translate local tacit knowledge into explicit knowledge for consumption inside and outside the firm, translating sectoral tacit knowledge into a form communicable outside the sector.

5.2.5 Spin-off from oil and gas.

Sectors that grew up in a context closely linked to oil and gas can exploit the knowledge developed in new directions and toward entirely different markets. This occurs in the software and GIS areas and is well documented for wireless telecommunications and global positioning systems (Langford et al 2003). The link to oil and gas is not prominent in the current innovative activity (last three years in questions in the instrument), but there is a historic transfer from the old sector to the new. This may be one of the key growth advantages conferred by the dominant cluster.

6.0 Concluding Statement

Employing a parallel methodology to that used for a previous ISRN study of talent attraction and retention in the Calgary CMA (Langford, Li and Ryan, 2009), firm interview data were inspected to tag innovation-related information and activities identified in responses to questions about innovations over the past three years. Two of three of our hypotheses were found consistent with the quantified results.

First, there exists an innovation system that may be characterized within the Calgary CMA. Local knowledge is a leading factor and is consistent with the system hypothesis - but with a caveat about the locus of the system. For example, activities in the dominant oil and gas sector are highly linked to regional activities within oil fields outside of the immediate CMA (e.g. Fort McMurray) and to globally distributed projects.

Second, according to the results, there is a relationship between problem types and the relative importance of knowledge factors. There is indication of quantitative differences in the ways in which local and non-local knowledge are leveraged within the Calgary innovation system. For example, local sources are important when firms collaborate on a problem while non-local pipelines are prominent in solving market barrier problems. And, of course, tacit knowledge is largely locally sourced and leveraged.

Examination of our third hypothesis led to recognition of a key central feature of the Calgary innovation system. Analysis of knowledge flows must begin from decisions of what is determined to be a functional grouping of activities in this innovation system.

The existence of a dominant cluster – the oil and gas sector – creates a unique situation that reflects the complexity of innovation in the Calgary CMA. Data from interviews reveal firms closely related to the dominant sector that should be grouped with oil and gas and, as such, knowledge flows amongst these actors would be considered intra-sectoral in nature. The complex forms a knowledge platform producing a wide range of outcomes from the hybridization (i.e. Mode 2 knowledge production and sharing) of a rich variety of what can be considered to be distinct inputs for problem solving activities amongst the firms. Thus, analysis of the Calgary CMA and the data collected within this study defies standard statistical classification of sectors. Although this requires further research, it is fair to assume that this unique characteristic is shared with other major centres operating in the petroleum industry.

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