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Innovation Agencies in a Resource Based Economy The Case of Alberta: Leadership, Energy, and Innovation

Ross, Terry

UNIVERSITY OF CALGARY

Innovation Agencies in a Resource Based Economy

The Case of Alberta: Leadership, Energy, and Innovation

by

Terry Ross

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Abstract

There are government created organizations with a mandate to affect the sub-national system of innovation. These 'innovation agency' organizations provide functionality that enables additional innovation activity; this functionality may be delivered by organizations external to the innovation agency.

The Alberta Oil Sands Science and Research Authority (AOSTRA), Alberta Heritage Foundation for Medical Research (AHFMR), and the Alberta Informatics Circle of Research Excellence (iCORE) are three innovation agencies that exemplify significant innovation policy investments by the Alberta government. This thesis uses historical analysis and case studies to examine these three innovation agencies. The historical analysis examines Alberta's complex coevolution of institutions, policy leadership and technically challenging natural resources that set the stage for these innovation agencies to emerge. Case study techniques are used to explore the emergence, operations and impact of the innovation agencies. The findings are then positioned in the system of innovation literature.

It was found that the Alberta system of innovation was highly influenced by institutional control over natural resources and that the oil sands were particularly important, given their value and the scientific challenges that they presented. Peter Lougheed's role in entrepreneurially shaping institutions was a contingency for the emergence of the cases. It was found that the innovation agencies generally acted to subsidize research activity in other organizations, although there were significant exceptions (e.g. AOSTRA's IP policy and Underground Test Facilities). Finally, the instrumentality of the organizations

was significant, leading to development and adoption of technological systems by industry and enhanced research capabilities at Alberta universities.

To the love of my life, Nancy: What I am and will become is because of your love and support.

To my children Noa, Aria, Juno, and Apollo. I love you forever, I love you for always, as long as I'm living my babies you'll be.

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Table of Contents

Table of Figures

Table of Tables

1 Introduction

1.1 General topic

Effective innovation policy is critical to the sustainable economic development of a region with abundant natural resources and is a primary concern for national and sub-national governments. A common approach to the delivery of innovation policy is the creation of arms-length agencies with a mandate to affect specific functions of the sub-national system of innovation. The main topic of this thesis is whether innovation agencies can be instrumental is affecting the capabilities of a sub-national system of innovation.

1.2 Literature overview

The OECD defines innovation as "the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations." (OECD, 2005). Innovation does not happen within an isolated individual, group or region; rather, it is a complex phenomenon that must appreciate the systematic processes and the breadth of impactful economic elements (Smith, 2000).

The system of innovation approach attempts to understand the determinants of innovation, incorporating a historical perspective and appreciating that elements within the system coevolve under the guidance of institutions (Edquist, 1999). Systems of innovation can be conceptualized nationally which minimizes variation in culture and institutions (Lundvall, 1998). Sub-national systems of innovation build on the national system of innovation approach where the proximity to resources (e.g. knowledge networks, natural resources) and regionally controlled institutions can influence the character of the system over time (Doloreaux, 2002). Cooke et al. (2000) describe sub-national systems of innovation as being comprised of 'interacting knowledge generation and exploitation sub-systems linked to global, national and other regional systems for commercializing new knowledge'. The government plays an important (but often underappreciated) role as the creator of many institutions that can address system deficiencies, and the government can actively shape the evolution of a system of innovation (Mazzucato, 2013; Mazzucato, 2016). Institutional entrepreneurship literature suggests that individual actors can craft a vision and align the principal actors to drive endogenous change in institutional structure (Battilana, 2009).

In many regions, natural resources are fundamental to economic growth (Lundvall, 2007) and can profoundly shape the development of sectors in the sub-national economy (Hawkins, 2012). The impact of natural resources on sub-national development is determined by social and economic factors, for example intensity of exploration, extraction and refining technologies, institutions governing natural resources, markets for local natural resources, etc. (David and Wright, 1997; Sachs and Warner, 1997; Sachs and Warner, 2001). A central goal of sub-national governments in natural resource intensive regions is to develop social and technological elements (e.g. educated workforce, geological surveys, extraction technologies, etc.) that could lead a resource focused economy towards a comparative advantage (Wright, 1990; Edquist, 1999; Wright and Czelusta, 2004). Another important goal of the government is to mitigate the risks associated with the natural resource based economic bonanzas with policies designed to help smooth government expenditures, support investments in economic diversification, and make quality of life improvements (Magud and Sosa, 2011).

The functions of the government can be managed directly by government ministries or by arms-length government-created organizations. In this thesis organizations that are mandated to provide an innovation related function to the sub-national system of innovation are referred to as 'innovation agencies.' Agencies are established by the government, are not part of a government department, are mandated with performing a public function, are accountable to the government through a defined reporting relationship, have some degree of autonomy, and are subject to government involvement in the appointment of key individuals (McCrank et al., 2007). Agencies can contribute five different types of activity to the sub-national system of innovation; research (basic, developmental, and engineering), implementation (manufacturing), end use (customers of the product or process outputs), linkage (bringing together complementary knowledge through investment) and education (learning and skill development) (Liu and White, 2001). Agencies may deliver their functions directly (e.g. by conducting research inside of their organizational boundaries) or affect the behavior of other organizations and thereby create an effect on the innovation system (Liu and White, 2001).

1.3 Scope and limitations

The scope of the thesis is limited to the conceptually relevant aspects of the sub-national system of innovation in Alberta; however, since Alberta is embedded within the Canadian system of innovation and the global system of innovation there will be occasional references to national or international elements if they pertain to the functioning of Alberta's system of innovation. Of the dozens of innovation agencies that have operated in Alberta, three agencies were selected for in depth study:

- AOSTRA (Alberta Oil Sands Technology and Research Authority): Focused upon energy innovation
- AHFMR(Alberta Heritage Foundation for Medical Research): Focused upon biomedical innovation)
- iCORE (Alberta Informatics Circle of Research Excellence): Focused upon informatics innovation)

These agencies were selected due to their significant funding and length of operation, and because each was mandated to impact a different economic sector. Throughout the thesis, these agencies will be referred to collectively as "the Trio".

Each agency had a broad range of programs that created diverse impacts, not all of them related to innovation policy as such (for example, AHFMR had impacts in terms of clinical practice). To keep the research focused, only programs with direct relevance to innovation policy were examined. The time frame was also limited primarily to the lifespan of these agencies, which began in the 1970s and ended in December 31, 2009 with the enactment of legislation from the Alberta government that wound down several innovation agencies (including the Trio) and replaced them with four 'Alberta Innovates' organizations (see Appendix C: Bill 27).

The thesis was limited to examining a narrow thread of the sub-national system of innovation narrative. Alberta's system of innovation is embedded within the national system of innovation and a global system of innovation; the Alberta system does not exist by itself. Furthermore, within the Alberta system of innovation there are numerous elements that comprise the complex innovation landscape that are acknowledged to be important; however, the complete role of all the elements cannot be captured in this thesis as the scope would be unmanageable.

1.4 Current situation and the research gap

The literature on sub-national systems of innovation has a broad perspective of economically relevant elements and their systemic interaction. However, there are some important gaps in the literature that are important to address. Firstly, studies of sub-national systems of innovation may not truly reflect the contextual elements that give the regions a distinct character. Furthermore, studies of sub-national systems of innovation may not incorporate the instrumentality of innovation agencies into their frameworks. Also, the systems of innovation literature do not adequately appreciate how impactful institutional entrepreneurship can be, particularly in a sub-national system of innovation. Finally, there has not been a comprehensive examination of the Alberta sub-national system of innovation and how it evolved to support the founding of the three case study organizations. These are gaps in the existing literature that this thesis aims to address.

1.5 Importance of the research

Addressing these issues are important since innovation agencies play an important role in the delivery of a governments innovation policies. Understanding how and why innovation agencies are founded, how they affect the sub-national system of innovation and what type of impact they can have are important considerations when considering how systems of innovation operate. Posing these questions in an Alberta context is important as agencies play a critical role in the government's efforts to improve Alberta's economic prospects (McCrank et al., 2007). The thesis examines three Alberta innovation agencies:

AOSTRA (focused upon energy innovation), AHFMR (focused upon biomedical innovation), and iCORE (focused upon informatics innovation). The thesis refers to these three organizations as 'the Trio'. The thesis aims to both extend the knowledge around these agencies as well as understand their instrumentality on the Alberta system of innovation. By examining how these three innovation agencies were created, and how they attempted to create impact, the thesis will gain valuable insights into how innovation agencies have been instrumental to Alberta's system of innovation. The findings from this thesis can assist policymakers to understand better how to design innovation agencies for optimal additionality in the sub-national system of innovation.

1.6 Research question

The topic of this thesis is whether innovation agencies can be instrumental in a sub-national system of innovation. Thus, the main research question is: "Have the Trio of innovation agencies been instrumental to the development of Alberta's sub-national system of innovation?". This main question is explored with three sub-questions: How did the Trio emerge and evolve? How did the Trio attempt to create impact? Did the Trio have a discernable impact?

1.7 Research method

The thesis uses a combination of historical analysis and case study methods to answer the main research question. This mixed method approach allows a richer sampling of data than a single method alone. The historical analysis focused upon the events, individuals, institutions and natural resources that were essential for understanding the subsequent innovation agencies. The case study of the Trio was constructed by analyzing Trio documentation and interviews with individuals that were significantly involved in the formation or operation of the

Trio. The data collected from the historical analysis and the case studies was analyzed through a system of innovation perspective.

1.8 Important findings

The main research question asks whether the Trio was instrumental in the Alberta system on innovation and it was found that they were. AOSTRA used economic incentives, a major test facility and an IP framework to qualitatively change the structure of the Alberta economy by supporting the development and adoption of in-situ oil sand techniques. Both AHMFR and iCORE were instrumental in upgrading the research capabilities of Alberta universities and post-secondary institutions.

Additional important findings in relation to the research question are:

- Institutional control over natural resources and the attributes of the natural resource (e.g. market value and technical challenges) have an important impact upon the evolution of the sub-national system of innovation.
- The actions of an individual institutional entrepreneur can have a important influence on the sub-national system of innovation.
- The Trio were established with varying degrees of authority and accountability; these attributes can shift over time.
- Subsequent innovation agencies can learn from the previously established innovation agencies in the hopes of increasing the efficacy of programs.
- The Trio created impact by influencing other organizations to create the desired impact.
- The Trio had two approaches to IP policy. AOSTRA directly influenced the sharing of IP within industry, whereas AHFMR and iCORE left the IP to be managed by the universities.

- Some of the Trio programs had unanticipated consequences such as underinvestment in environmental mitigation of oil sands development and creating a difficult to sustain funding model for skilled researchers.

1.9 Thesis structure overview

Chapter 2 surveys the literature that positions the thesis within systems of innovation and historical literature and is presented in two sections. The first section provides an overview of systems of innovation literature including the role of natural resources as a source of path dependency. The second section reviews literature about innovation agencies and institutional entrepreneurship. Chapter 3 presents the research methods used to collect and analyze the data. Chapter 4 provides the findings from the historical analysis of Alberta's sub-national system of innovation that is required to place the Trio into context. Chapter 5 presents the findings from the analysis of Trio cases. Chapter 6 discusses the findings and positions them against existing systems of innovation literature. Lastly, Chapter 7 concludes this thesis with suggestions about how and why these organizations deserve greater consideration in systems of innovation literature and discusses some directions for future research.

2 Literature Review

This chapter provides a summary of the literature relevant to understanding the instrumentality of innovation agencies in a sub-national system of innovation. The review of the literature is divided into two main sections. The first section examines the literature related to sub-national systems of innovation, the second section examines the literature concerning to innovation agencies and institutional entrepreneurship.

2.1 Systems of innovation literature review

2.1.1 Innovation

The Oslo Manual (2005) defines innovation as "the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations". This thesis adopts a similarly broad view of innovation as a phenomenon that can result in improved economic performance and can be expressed in a range of mediums (i.e. technology, governance, institutions, organizational form, household activity, etc.). The essence of innovation is that people (individually and collectively) can recognize and propose new and valuable combinations of economic elements. Additionally, with this perspective, there is a protagonist role for individuals and organizations (Malerba, 2002).

2.1.2 Schumpeterian, neoclassical, and neo-Schumpeterian frameworks

2.1.2.1 Schumpeter

Joseph Schumpeter suggested that capitalist development was the result of the long-run coevolution of elements in an economy. According to Schumpeter, innovation results elements are recombined in qualitatively different ways that add positive socioeconomic value (Schumpeter, 1942). He emphasized the coevolution of economic factors and the importance of integrating theoretical work with historical analysis (Fagerberg, 2003). Schumpeter was inspired by many economists with views as diverse as Karl Marx (who believed that technological competition between organizations drove capitalist economic evolution) and Léon Walras (who begat the 'equilibrium' principle at the core of neoclassical economic analysis). Schumpeter appreciated Marx's perspective of technological change as the primary source of industrial dynamism (disrupting the equilibrium) and suggested that new markets, new sources of supply, and new organizational structures allow industrial organizations to compete in a capitalist economy (Fagerberg, 2003; Hospers, 2005). Schumpeter viewed qualitative change in the economy as a pressing force that arose from individual entrepreneurs (and he later included organizations as a source of this entrepreneurial function). His context-rich approach to economic assessment differed from neoclassical models that underemphasized evolutionary elements of economic growth. A neoclassical economic picture illustrates an economy without dynamic forces (like entrepreneurship) causing disequilibria (Fagerberg, 2003). Schumpeter believed that some neoclassical models were useful, as they described how the economy behaved (i.e. returning to a state of equilibrium). He also suggested that competing industrial organizations would imitate and adapt to innovation, thus creating new investment and causing the economy to grow. Attempts to catch-up to original innovators would then erode the first-mover advantage that they had enjoyed at the outset. Interestingly, Schumpeter didn't have much to say in regards to why certain firms would be better able to innovate than others (Magnusson, 1994). Schumpeter applied his concept of imitation to government policy when one jurisdiction would attempt to apply policy that had been successful in another region. Schumpeter believed that copycat policy design must incorporate regional context to be successful (Hospers, 2005).

2.1.2.2 Neoclassical economics

After World War II, economic science embraced a neoclassical economic paradigm (Nelson and Winter, 1973; Nelson and Winter, 2002). Neoclassical economics is characterized by the analysis of an instant in economic time (i.e. the subject of analysis is static) with a relatively low amount of contextual analysis. For example, technological change is widely accepted in neoclassical thought as a driver of economic growth; yet is treated as external (exogenous) to its models (Abernathy and Clark, 1985; Freeman, 1994). Neoclassical economics is also characterized by economic actors all having frictionless and immediate access to knowledge (Stoneman, 2002). When it comes to appreciating the role of technology, neoclassical models require that the rate of technological growth increase deliberately for per capita growth in productivity to occur. However, the models do not include technological growth as a variable in their designs, which results in technical change being exogenous. Neoclassical models admit that the rate of per capita growth is inextricably tied to deliberate investment in technology. This technological dynamic is exogenous to the neoclassical model and addressing this exclusion is extremely challenging, due in part to the limitations of modeling knowledge development (e.g. serendipitous and unexpected research insights, R&D knowledge being only one type of innovation affecting productivity, etc.) (Solow, 1994). Technological change may be difficult to explain ex-ante or may only be explainable ex-post, however, the neoclassical model does not offer any useful insight on incorporating technological progress into models of aggregate growth (Solow, 1994).

2.1.2.3 Neo-Schumpeterian and evolutionary economics

In the 1970's neo-Schumpeterians literature used Schumpeterian concepts to explain the capitalist economy. Schumpeter's contributions, including insights on entrepreneurship, innovation, and the process of economic growth, provided a different conceptual starting point for economic analysis. Neo-Schumpeterians emphasize the dynamic ways that socio-economic systems qualitatively evolve in an open-ended process (Fagerberg 2003; Hospers, 2005). The literature emphasizes the central role of technical change in affecting economic growth. As a result, there now existed a range of economic approaches that incorporated both technological competition and evolutionary dynamics. Widespread interest in evolutionary economics faded after Schumpeter's death in 1950. Gradually, economists began to propose economic models that incorporated innovation as a factor to explain differences in international trade that could not be accounted for by contemporary equilibrium models (Fagerberg, 2003). In the 1980s, academics such as Freeman, Dosi, Pavitt, and Fagerberg proposed models that incorporated innovation as a primary driver of economic growth. Learning and a skill development are a key economic dynamic in these models.

2.1.3 Learning and skill development

Learning and skill development impact the performance of economies because 'intangible' resources (i.e. knowledge, routines, and skills) are not evenly distributed throughout economic systems (i.e. individuals, organizations, and regions) (Nelson and Winter, 1982; Lundvall, 1998; Nelson and Winter 2002; Lundvall, 2007).

Nelson and Winter (1982) describe skill as the capability to complete a smooth sequence of coordinated behavior that is ordinarily effective, relative to its objectives and within its ordinary context. Skills involve a series of steps and become internalized with practice and development. Repeated experience is a primary method for the individual development of skills with an inherently tacit nature (Lundvall, 1998). Skills that are aggregated into larger processes are referred to as routines. The total skills of individuals manifest in the overall capabilities of organizations and regional economies (Nelson and Winter, 1982). Many elements of skills are tacit (i.e. gained through experience) and are difficult to develop or transfer without the opportunity to learn through experiences and interactions. Skill (and its aggregate network of skills) may be difficult to transfer because it is challenging to communicate, either because of the inherently ineffable nature of the skill or due to a poor vocabulary that inhibits effective articulation.

Nelson and Winter portray routines are the focal point of the learning-centered approach to investigating behavioral questions into organizational behavior. Through repetition routines will become ingrained and efficient through repetition. These routines determine behavior, are inherited (through organizational culture), and evolve (since some routines may lead to organizational successes or failures) (Nelson and Winter, 1982). A central issue in innovation is that Individuals and organizations generally make decisions about their course of action by adhering to a known routine; assuming it provides a satisfactory outcome. Schumpeter (1934) discusses how difficult it can be for individuals and organizations to overcome their usual routines in search of innovative processes and solutions. He attributes this difficulty to uncertainty surrounding the implications of new routines, limited timeframes when the new opportunities are available, and inherent biases toward the status quo. Routines can, therefore, continue to be utilized even when they lead to sub-optimal outcomes due to irrationality, the perception of prohibitive expense in the development of new routines, and potential disruption to existing relationships and organizational culture (Nelson and Winter, 1982). This inertia that resists evolution in routines is a source of path dependency in sub-national systems of innovation.

When an organization is involved in the creation of another organization, there may be important knowledge transfer of routines. An organizations ability to generate incremental routines is shaped by differences in knowledge between individuals that are associated with the organization (Dosi et al, 2008). Knowledge about routines that can accessed by new organizations from external networks of advisors, stakeholders and partners; these individuals can play a key role in the establishment of new routines inside the emerging organization (Miner et al. (2011).

On a macroeconomic scale, intangible resources like knowledge are not evenly distributed throughout economic systems (Nelson and Winter, 1982; Lundvall, 1998; Nelson and Winter 2002). People, organizations, and regions are heterogeneous and possess bounded rationality about their environment and available opportunities. Knowledge empowers agents (individuals or organizations) with an understanding of available options and best practices for the optimization of their economic outcomes, however, no agents are omniscient, and all possess bounded rationality (Nelson and Winter, 2002). To make sense of their context agent rely upon ‘messages’; conceptually, messages contain a broad range of information about the environment that an individual or organization may interpret through ‘search routines’. Search routines are a process where agents demonstrate an ability to understand messages, select the appropriate routines from its repository to react to the incoming messages, and exploit situations (Nelson and Winter, 1982).

Knowledge can also be described as ‘spilling-over’ from one context to another. The creator of knowledge generally captures a portion of its economic rents; however, these benefits can ‘spillover’ within and beyond the home industry of the pioneering firm. Knowledge spillover can significantly impact the research activities of others; an industry sector ‘A’ firm can benefit from research conducted in industry sector ‘B’. The productivity of one organization is not limited by its own research efforts but by its accessibility to knowledge (Griliches, 1998). Learning, spillover and the development of knowledge and skills within a system is affected by the institutions at play in the region.

2.1.4 Institutions and institutional dynamics

‘Institutions’ are defined in the context of this thesis as the ‘rules of the game’ in society. Thus, institutions act to constrain and shape human interaction and have a significant impact upon the way that societies evolve over time (North, 1990). Institutions are conceptually crucial to the discussions within this thesis, as they shape the interactions between the system of innovation elements (i.e. organizations, natural resources, and laws). Equally important is the impact that organizations and natural resources exert on the dynamic evolution of institutions (Edquist, 2001). While it is valid to conceptualize an organization as an aggregate of institutions, this thesis presents institutions and organizations as separate concepts (Hollingsworth, 2000).

Institutions are a source of inertia in a path-dependent system. Evolution of institutions may also provide a catalyst for economic and technological change (Johnson, 1992; Freeman, 1995). The coevolution of institutions and other system elements results in the emergence of unique systems over time. When institutions take the form of rules and norms, they are durable.[1] This institutional durability contributes to longitudinal path dependency within a region (Hollingsworth, 2000). Organizations have distinct boundaries and are meant to leverage economies of scale through coalitions of elements (Tirole, 1988). Organizations that are best able to adapt their activities to their institutional environments are better positioned for success and innovation (Abernathy and Clark 1985, Hollingsworth, 2000). Interactions between organizations and their institutional environments are multifaceted processes. If organizations are empowered, they may both respond to their institutional environment and attempt to modify it (Hollingsworth, 2000).

2.1.5 Systems of innovation

The systems of innovation (SOI) approach has emerged from the field of evolutionary economics as a means from which to explore the determinants of innovation (Edquist, 1999; Edquist, 2001; Geels, 2004). In his paper examining innovation as a systemic phenomenon, Smith (2000) describes systems as possessing the following basic underpinnings:

- Economic behavior rests on institutional foundations that afford individuals and organizations reduced uncertainty.

[1] Although dramatic institutional evolutions occur frequently in the wake of events like elections and wars.

- Differences in institutional arrangements are critical to understanding differences in socioeconomic behavior and outcomes.
- Competitive advantage results from variety and specialization.
- Institutional evolutional processes are self-reinforcing and allow path-dependent specializations in socioeconomic structures.
- Technological knowledge is distributed amongst individuals and organizations within a system.

Much like the evolutionary economic approaches reviewed in the previous section, the systems of innovation approach emphasizes:

1. putting innovation at the center of the approach;
2. including all elements (i.e. organizational, political, social, available natural resources, etc.) relevant to innovation in the model;
3. exploring a historical perspective where context aids the understanding of how system elements have emerged and coevolved;
4. non-existence of an optimal system of innovation; there must be comparison between idiosyncratic systems;
5. that system elements (e.g. industrial firms) never innovate in isolation and instead rely heavily on interplay with other elements and guidance by institutions (e.g. laws, regulations, habits etc.); and
6. conceptualizing innovation beyond technological products and services in order to understand the relationship between innovation and economic growth (Edquist, 1999).

The systems of innovation approach suggest that innovation and economic performance are driven by the configuration of elements in the system (see Table 1), how optimal these elements are relative to the demands upon the system, and how effectively the system can evolve in response to demands. Knowledge is generated and applied thanks to interactive learning between individuals and organizations within the system (Doloreaux, 2002). Feedback in the system of innovation provides instability that eventually catalyzes qualitative change in the economic structure. This evolutionary feedback affects institutions at all levels; the economy of today is a product of historical evolution (Smith, 2000; Aghion and David, 2009).

Table 1: Conceptual elements of systems of innovation

Element	Description
Agents (i.e. organizations and individuals)	Perform activities and functions
Knowledge	Scientific knowledge and knowledge from practice
Institutions	Rules and norms
Relationships	Social capital and leadership
Positional goods	Natural resources and highly qualified people who are loyal to a region
Users	Impacts on society

(Adapted from Edquist, 2001; Geels, 2004)

Another approach to analyzing systems of innovation is presented in Table 2. On one axis, resources are characterized by their ease of replicability; on the other axis, the resources are characterized by their physical attributes.

Table 2: Resource taxonomy

	Easily reproducible	**Less reproducible**
Tangible	Production resources	Natural resources
Intangible	Intellectual resources	Social resources

(Based on Lundvall, 2007)

It is important to be specific with respect to the 'level of analysis' undertaken when discussing systems of innovation (Carlsson et al., 2002; Fagerberg et al., 2005). The sub-national perspective is the default system of innovation concept in this thesis, due to ability to capture the institutional context relevant to the cases. Systems of innovation can generally be conceptualized at multiple levels, as described in Table 3.

Table 3 : System of innovation levels

System of innovation concept	Description
National	The system of innovation elements bounded by national institutions.
Sub-national	Below the level of national institutions, there are sub-national regions that may also have a shared history, culture, language, territory, resource endowment, and sub-national institutions.
Sectoral	A system (group) of organizations active in the selection, development, and manufacture of a sector's products and technologies.
Technological	An integrated system oriented toward a particular technology.

(Adapted from Breschi and Malerba, 1997; Cooke, Uranga, and Etxebarrie,1997; Smith, 2000; Edquist, 2001; Doloreaux, 2002; Geels, 2004; Doloreaux and Pareto, 2005).

2.1.5.1 National systems of innovation

The idea of a system of elements embedded within a national system of relationships is quite old, with Freeman (1995) and Lundvall (1992) suggesting that this idea can be traced back to the national economies described in Friedrich List's 1841 work *The National System of Political Economy*. List's work advocated policies to protect emerging industries and encourage industrialization to catch up with the rapidly developing British economy. List recognized that investment in knowledge accumulation (versus physical capital investment) was a decisive factor in economic development (Freeman, 1995). List (1841) also foresaw the value of linking industry and university organizations:

> There scarcely exists a manufacturing business which has no relation to physics, mechanics, chemistry, mathematics or to the art of design, etc. No progress, no new discoveries and inventions can be made in these sciences by which a hundred industries and processes could not be improved or altered. In the manufacturing state, therefore, sciences and arts must necessarily be popular.

List understood the importance of many of the elements discussed in contemporary national system of innovation studies (i.e. education, science, interactive learning between producer and user, integration of imported knowledge, technical institutions, etc.) and emphasized the role of the state in coordinating activity and long-term economic development policies (Freeman, 1995). The advocacy of List and other economists, combined with the influence of Prussian institutions, induced Germany to develop one of the best technical training and educational systems in the world. List also observed the emergence of the unique American system, which promoted knowledge based initiatives, enjoyed abundant natural resources and hosted an institutional environment that encouraged development and waves of immigration (Wright 1990; Freeman, 1995).

In the 1980s, research was revealing that systematic aspects of innovation were crucial determinants of the efficacy of knowledge diffusion and associated productivity gains. Researchers and policymakers noted the astounding performance of Japan and South Korea as examples of this phenomenon (Freeman, 1985). It was hypothesized that national institutions were extremely influential on rates of technological change and economic growth and, in the 1980s, the 'National System of Innovation' approach emerged as a discrete concept.

While many of the factors affecting a system of innovation span the globe (i.e. social, technological, and institutional factors), many relevant factors are geographically linked to a specific nation. Lundvall (1998) suggests that there are strong reasons to focus on the national level when discussing or comparing SOIs:

- When examining a country, there is often a relatively reduced variation in culture, institutions, and language.
- Systems of innovation can vary dramatically due to institutional differences even when history, geography, culture, etc. are reasonably similar (e.g. Canada and the United States).
- The clear majority of economic data is very national in scope.
- The focus of many economic policies is directed at the national level.

2.1.5.2 <u>Sub-national systems of innovation</u>

National culture and institutions play an important role in the innovation process, however in a large diverse nation such as Canada, sub-national conditions heavily influence the innovation process; a sub-national perspective provides a more nuanced perspective to ground understanding of the innovation process (Holbrook and Wolfe, 2000). While a sub-national system of innovation derives much of its character from local knowledge networks[2], culture and geographic features, in this thesis it is the institutions that are born of government policies[3] that define sub-national (e.g. Alberta) systems of innovation (Doloreaux, 2002). In this thesis, a sub-national system of innovation is defined by sub-

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[2] For example, geographic proximity to advanced users, institutionalized user-producer relationships, and proximal supplies of talent

[3] For example, taxes, subsidies, R&D organizations, innovation infrastructure, financial support, regulation, procurement

national institutional boundaries that demarcate the primary impact of economic policies. Because a sub-national system of innovation is embedded within a national system of innovation it has much of its form defined by the innovation policy instruments of both national and sub-national levels of government.

Beginning in the 1970s, sub-national institutions (e.g. R&D subsidies to sectors) and sub-national organizations (e.g. research organizations and universities) began to play increasing roles in the evolutions of their respective sub-national systems of innovation (Cooke et al., 1997). In theory, national and sub-national governments should act in both informal and formal ways to coordinate inputs from government, industry, and academia to achieve innovation outcomes (Nelson, 1993; Hawkins, 2012; Freeman, 2004). In Canada collaboration is impacted by provincial institutions that demarcate the flow of economic factors in a manner like national borders (Niosi, 2005). Hence, it is important to understand the idiosyncrasies of state structures and multi-level divisions of power, particularly when studying the ways in which policy instruments have been designed and developed (Salazar and Holbrook, 2007; Borrás and Edquist, 2013).

The importance of natural resources as both causes and consequences of innovation will be explored further below. Localized natural resources, that are valuable and technically challenging to develop, can have primary evolutionary impacts on sub-national institutions and catalyze the development of the sub-national technical and scientific knowledge bases. These specialized knowledge bases emerge in regions based on the needs of one sector. As Griliches (1998) has shown, the tendency for knowledge to 'spillover' from one specialty to another is an important evolutionary economic dynamic.

2.1.5.3 Sectoral systems of innovation

Sectors are often a primary consideration when governments create policy instruments.[4] Nelson and Winter (1997) state, "Policies need to be designed to influence particular economic sectors and activities.". Malerba (2002) defines a sectoral system of innovation as "a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. Sectoral systems of innovation have a [sector specific] knowledge base, technologies, input and demand." The sectoral perspective on systems of innovation analyzes the structures of sectors, their boundaries, agents within the sectors and their interactions, learning and innovation processes, production processes, how the sectors evolve, and the factors that impact differential organizational and regional performances (Malerba, 2002).

A crucial aspect of the sectoral system of innovation is that knowledge, actors, and institutions vary significantly between sectors (Malerba and Vonortas, 2009). It is important to note that the geographic bounds of a system of innovation may differ from one sector to another (Carlsson and Stankiewicz, 1991). Griliches (1998) observed that technological capabilities spillover from one industry sector to another and, thus, the knowledge base of adjacent sectoral systems influences the general knowledge base of the primary sector.

[4] The cases discussed in Chapters 6 through 8 are government interventions focused on three sectors: unconventional oil, biomedical research, and information technology.

2.1.5.4 Technological systems perspective

The technological systems perspective takes technology not as an individual artifact but as an integrated technological system, supported by managerial and societal elements (Smith, 2000). Technological systems focus upon knowledge competence flows (Carlsson and Stankiewicz, 1999). Technological systems of innovation develop and deploy technologies, clusters of resources, and institutional infrastructures with the purpose of creating and exploiting new business opportunities. The technological system may work to integrate diverse inputs into a product (Smith, 2000).

2.1.6 Natural resources

Conventional theories of innovation have very little to say about the role that natural resources play in the evolution of innovation systems. This presents a challenge for understanding the development of systems of innovation in resource-rich regions such as Alberta. Natural resource development may create straightforward economic impact directly through extraction and use, providing limited impact upon the structure of the sub-national economy. The development of natural resources may also create valuable externalities that impact the development of the sub-national economy (i.e. affect the capabilities of organizational supply chains and technological capabilities in the region) (Hawkins, 2012). Natural resource development that requires the creation and deployment of knowledge assets in a region (e.g. new technological processes, surveys, etc.) provides opportunities for the spillovers, as described by Griliches (1998). In Alberta, a common example of these spillovers is when information technology systems that have been developed to meet the needs of the oil industry find application in other sectors, like in the development of medical devices or consumer telecommunication systems. Since natural resources are a fundamental economic asset, perceived natural resource opportunities directly influence the institutions and policies that will be introduced by sub-national governments (Boothe and Edwards, 2003). However, the sole existence of resources is certainly no promise of a well-functioning socioeconomic system (Wright and Czelusta, 2004). The socially constructed elements of an economy have as much impact upon economic development as do the resources themselves. Examples of socially constructed elements include:

- the intensity applied by industry, government, and academia in their searches for natural resources;
- the development of new innovations for extraction, refining, utilization, etc.;
- the emergence of substitutions for locally available natural resources;
- the existence of accessible markets for natural resources; and
- the legal, institutional, and political structures that govern all of the above (David and Wright, 1997; Wright and Czelusta, 2004; Sachs and Warner, 1997; Sachs and Warner, 2001).

Industrial organizations that directly develop natural resources are embedded within a system of suppliers and may be linked to innovations in exploration, extraction, and substitution. Thus, natural resource development can have a significant impact on the supply chains that are related to the extraction of the resource; drawing on an enormous range of inputs from other sectors and inputs ranging from the crude and unrefined to those that represent the edge of human technological capability (Hawkins, 2012). Innovations are often driven by fears of impending scarcity, since natural capital can not always be reproduced (Wright and Czelusta, 2004; Lundvall 2007) (see Table 2). The natural resource opportunities of a region and its development demands will influence the path of the region's socioeconomic development. The emergent ethos and network of industrial organizations and institutions create layers of 'character' in the area (David and Wright, 1997).

David and Wright (1997) describe how the perception that natural resources are nearing economic viability can induce an innovation feedback loop. There may be positive feedback between resource development savviness (causation) and the quantity of resources in a region (consequence). The creation of new knowledge (e.g. location of deposits, development techniques, and technologies) may lead to the development of widespread resource management routines which then demand further knowledge resources (e.g. scientists) (David and Wright, 1997). Since natural resource abundance can be both a cause and a consequence of the deployment of knowledge resources (i.e. social, knowledge, infrastructure, etc.), it creates what David and Wright (1997) purport to be a positive feedback loop; "The more [natural resources] you find, the closer you look, and the closer you look the more you find.". The further benefit of these knowledge resources having been established within a region is that they may then spillover into non-resource related sectors in the form of new initiatives (Hawkins, 2012).[5]

Developing institutions and policies for the development of a resource-focused economy is often a central economic goal of sub-national governments. A government may seek to improve the development of natural resources through deliberate investments in knowledge capabilities such as educating the workforce, surveying the regional geology, and developing extraction technologies that may lead to a comparative advantage. A common natural resource 'bottleneck' occurs when there is a lack of accurate knowledge about

[5] For example, computer science capabilities developed for use in natural resource assessment are subsequently applied to other sectors, like medicine.

the extent and distribution of a potential natural resource deposit (Wright, 1990; Edquist, 1999; Wright and Czelusta, 2004).[6] The belief of a poor outcome from exploration or development is a sociological factor that can cause underperformance. A lack of expectation where new discoveries are concerned (or of the perceived potential of existing natural resources) may be a more potent source of resource underdevelopment than many more conventional explanations (i.e. small population, distance to market, export factors, geological challenges, etc.) (David and Wright, 1997).

The type of natural resource, its location, its perceived value, the ability to economically harvest and distribute it, and market demand are all variables that affect the impact of the natural resource and parallel evolution of government institutions (Boothe and Edwards, 2003; Wright and Czelusta, 2004). Institutions from beyond the region (e.g. national institutions) can affect internal innovation as well by creating new demands that require technological solutions (e.g. stricter environmental regulations) and affect the economic viability of a resource (e.g. putting a resource in strategic reserve).

While a robust institutional environment is not a guarantee of success, a weak institutional environment will challenge the efficient, economical, and orderly development of natural resources (Wright and Czelusta, 2004). Large quantities of resources, whether catalyzed by innovation or not, hardly ensures prosperity. Resource abundance can lead to economic challenges such as:

- increased economic volatility arising from the interdependent nature of economic sectors;

[6] In the Alberta Context chapter, the conventional oil deposits are a relevant example.

- the sub-national government becoming dependent upon resource rents to finance ongoing operations, leading to operating challenges during lean times;
- the growth of the resource sector challenging the overall economic growth of the region, especially if the growing sector has less externalities (benefits) than the compromised sector(s); and
- the growing sector challenging the growth of other sectors by raising the cost of inputs, such as labor and capital (Wright, 1990; Mansell and Percy, 1990; Sachs and Warner, 1997; Sachs and Warner, 2001; Wright and Czelusta, 2004; Alberta Chamber of Resources, 2011; Borrás and Edquist, 2013).

2.1.6.1 Transforming natural resources into knowledge resources

Knowledge resources are crucial for sub-national resource-focused economies that want to manage the production of natural resources with a view of future success (Wright and Czelusta, 2004). An important policy instrument that a government may use to manage a resource bonanza is the creation of a savings fund financed from resource rents. This policy instrument can navigate multiple mandates such as helping to smooth government expenditures and supporting investments in economic diversification and quality of life improvements (Magud and Sosa, 2011).

2.2 Innovation agencies literature review

Innovation agencies are government created organizations that are designed to deliberately affect the system of innovation in a consequential way. Their mandated scope can be systems of innovation at the national, sub-national, sectoral or technological scale. An innovation agency will possess a mandate to address an innovation issue of perceived relevance to the government, although the breadth of the mandate can vary. To understand the concept of innovation agencies this section explores literature on the topics of the dynamic balance of authority and accountability for innovation agencies and role of organizations within sub-national systems of innovation. It also reviews the literature on government's specific role as a creator of innovation policy (i.e. institutional entrepreneurship) and the assessment of impacts attributable to innovation agencies.

2.2.1 Environmental determinism and strategic choice

There are two constructs used in this thesis to describe the extent of an organization's autonomy; 'environmental determinism' and 'strategic choice' (Hrebiniak and Joyce, 1985). 'Environmental determinism' refers to the impacts that elements outside of the organization can wield on it. Markets, technological paradigms, institutions, leaders, funding sources, users, and competitors are all arbiters of environmental determinism. In this thesis, environmental determinism arising from governance is an area of focus. 'Strategic choice' is the inverse of environmental determinism and describes the power to make independent and voluntary choices about the organizations future. The dependence of public organizations on government leads to qualitatively different levels of environmental determinism and strategic choice, when compared to market focused organizations (Joldersma and Winter, 2002).

The government determines what types of task a public organization (like an innovation agency) should execute and its organizational design. The requirements of the government mean that the organization will be unable to decide upon many of its own strategic objectives (Joldersma and Winter, 2002).

2.2.2 Organizations

Within the sub-national system of innovation, most activity is initiated between organizations. An organization is a coalition of elements (i.e. individuals and/or institutions) connected by short and long-term authority and knowledge sharing relationships that exploits economies of scale (Tirole, 1988; Nelson and Winter, 2002; Santos and Eisenhardt, 2005; Van Slyke, 2007; van der Mandele and van Witteloostuijn, 2013). An organization can perform certain activities that are meaningful to the sub-national system of innovation namely research (i.e. basic, developmental, and engineering), implementation (i.e. manufacturing), end use (i.e. customers of the product or process outputs), linkage (i.e. bringing together complementary knowledge), and education (learning and skill development) (Liu and White, 2001). Organizations have boundaries that demark an organization from its environment. Pressures and signals cross organizational boundaries and precipitate evolution (Santos and Eisenhardt, 2005; Equist, 1999).

2.2.2.1 Task, market, and hybrid organizations

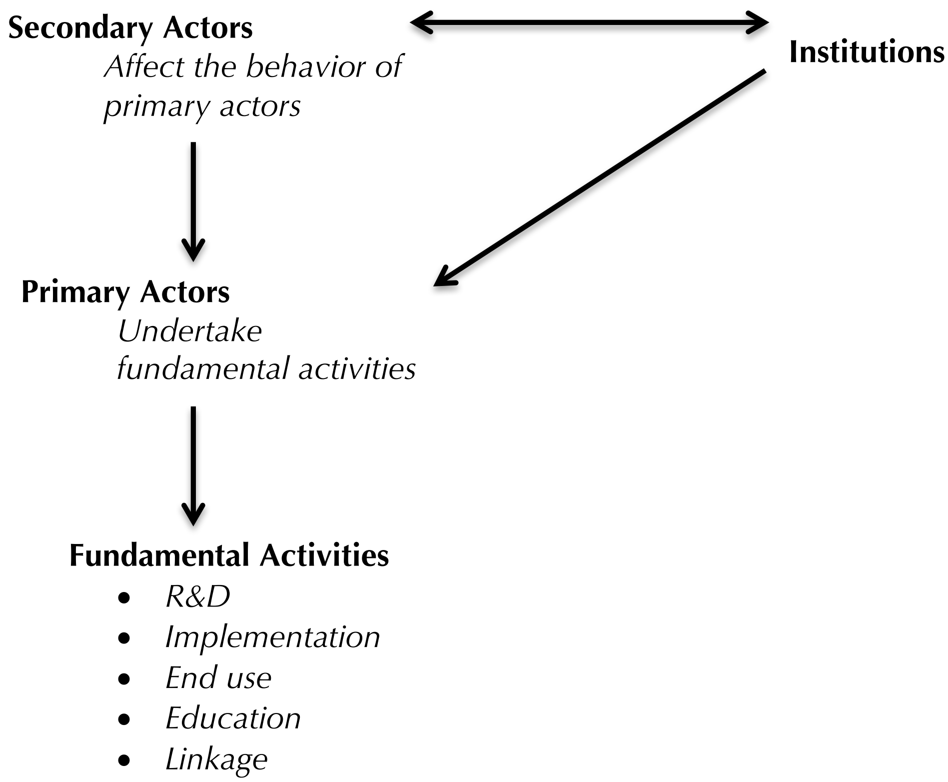
An organization can receive its funding and governance under three basic styles, that will determine much of an organization's routines: task, market, and hybrid (Joldersma and Winter, 2002).

A 'task organization' is conceptually equivalent to a public organization. They are funded exclusively by the government to provide mandated functions to the public. Task organizations require close relationships with their governments, where their governments will have significant say in their activities and operations. This influence over the task organization will affect its ability to make its own strategic choices about its operation. 'Market organizations' deliver services to clients who pay for products or services. They are basically private firms. In general, market organizations are not dependent on authorities with respect to the quantity and quality of services that they deliver (Joldersma and Winter, 2002). Innovation agencies, as defined in this thesis, do not begin as market organizations although it is possible for innovation agencies to become market organizations. 'Hybrid organizations' have characteristics of both market and task organizations. Hybrid organizations are task organizations with functions and boundaries that include contact with private industrial environments.

2.2.2.2 Primary and secondary organizations

Liu and White's (2001) organizational framework (see Figure 1) describes how an organization can affect fundamental innovation activities as either a primary or a secondary organization. Primary organizations directly perform one or more innovation activities within their organizational boundaries. Secondary organizations affect the behaviors of (or between) primary organizations directly, through governance, or indirectly, through the institutions that they create and shape.

Figure 1: Primary and secondary organizations



(Liu and White, 2001)

2.2.3 Organizational actor types

This thesis will review several key actor types and their typical role in a sub-national system of innovation like Alberta's. In a sub-national system of innovation is a broad and dynamic range of actors and the functions provided by these organizations can vary over time and between regions (Liu and White, 2001). Nevertheless, this thesis will discuss the roles of several types of actors (i.e. government, higher education (universities and colleges), and industry) who have varying abilities and mandates for generating and using knowledge and incenting other organizations to create and deploy knowledge.

2.2.3.1 Industry organizations

Industry organizations utilize production factors (i.e. labor, capital, and IP) to deliver goods and services to the market at a financial charge that covers the cost of their aggregate expenditures (Van der Mandele and van Witteloostuijn, 2013). Industrial organizations exist within a complex system of institutional, contractual, and social linkages. Capitalist organizations act as both users and producers in a co-evolutionary relationship which create clusters of technological capability in a manner that is conceptually similar to a sectoral system of innovation (Edquist, 1997; Edquist, 1999; Storper, 1995; Mansell, 1990; Smith, 2000).

In a sub-national system of innovation, industrial organizations generally dominate the deployment of knowledge into commercially viable forms within the region. According to Dosi (1988) capitalist industrial organizations are predisposed to innovate and play a dominant role in the deployment of innovation:

> In the most general terms, private profit-seeking agents will plausibly allocate resources to the exploration and development of new products and new techniques of production if they know, or believe in, the existence of some sort of yet unexploited scientific, and technical opportunities; if they expect that there will be a market for their new products and processes; and, finally, if they expect some economic benefit, net of the incurred costs, deriving from the innovations (Dose, 1988).

Industrial organizations are rarely beholden to a single (or small group of) customer(s) for their revenue (Joldersma and Winter, 2002). Thus, industrial (market) organizations experience a qualitatively different environmental determinism scenario, when compared with government (task) organizations.

By many measures the expenditures made by Canadian industry on research and development are weak by many measures (Council of Canadian Academies, 2013). The scientific techniques and technological opportunities that underlie much of Canadian industrial innovation rely on significant investments by the government. An example of this is the development of economically viable science through universities or other research organizations (Mazzucato, 2013). Industrial organizations may take advantage of these government investments to evolve their capabilities. These investments by government are made for the sake of industrial evolution. They can be more sophisticated than simply addressing market failure; a government's innovation policy may emphasize support for industrial efforts to develop and deploy more technology (Aghion, David, and Foray, 2009).

2.2.3.2 University and Colleges

The university has traditionally been viewed as a support structure for innovation; providing trained persons, research results, and knowledge to industry and academia. Recently, the university has increasingly expanded its function with respect to the formation of industrial firms based on new technologies originating in academic research (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003). Mansfield and Lee (1996) propose that top universities have a significant (and growing) proportion of their research supported by industry and that industry, in turn, does base a portion of their products directly upon university research. Thus, universities play a major role in technical change. Mansfield and Lee (1996) also noted that the quality of faculty has an impact upon the propensity for industry to collaborate with the university on research (mainly basic research) (Mansfield and Lee, 1996).

'Academic engagement' is a term used to describe the extent of university and industry collaborations, which begin via person-to-person interactions (Perkman et al., 2013). Academic engagement is characterized by the partners jointly pursuing goals beyond academic success (e.g. publication) and generating utility for the non-academic partner. Research into academic engagement has tended to focus on the roles of technology transfer offices (or similar units within the university), which has consequently led policy efforts to focus upon the technology transfer function. Academic engagement is a much broader phenomenon than what falls within the scope of technology transfer organizations; a critical distinction, from an innovation policy perspective, is that individual discretion (by the university, government, and industry) is the primary determinant and driver of academic engagement. Perkman et al. (2013) suggest that policies to encourage and facilitate individual-level engagement skills, on both the industrial and academic sides, have the potential to change behavior and improve the quality and quantity of academic engagement. It is also important to highlight that academic engagement requires both an instigator and a receptive party. Thus, individuals inside of industrial organizations are essential to catalyzing successful academic engagement. It follows that innovation policy may benefit from efforts to improve the ability of industry agents to understand and appreciate the nuances of working with individuals from the academic domain. Perkman et al. (2013) suggest a significant relationship between an individual's pedigree and academic experience and their ability to meaningfully engage industry.

In sub-national systems of innovation not all relevant post-secondary educational organizations are universities. There are educational institutions that offer programs of shorter duration than universities, are more closely linked to the labour market and have more limited or practise orientated research roles than universities (OECD, 1998); this thesis uses the term colleges to discuss these tertiary educational organizations. Many colleges are reassessing their traditional role of skill development and training and are playing an increasingly important function in Canadian sub-national innovation systems providing advanced training and applied research functionality with close ties to industry needs. (ACCC, 2010; Bélanger et al., 2005). Colleges vary in their innovation policies and structures, ranging from colleges with an undecided commitment to applied research and innovation to colleges with integrated applied research and business (Madder, cited in ACCC, 2005). One indicator of Canadian colleges increased applied research capability is the number of colleges that are NSERC funding eligible, rising to 51 in 2010 from 12 in 2005/06 (ACCC, 2005). While the colleges did not appear in the data examined in this thesis in relation to the historical narrative of the Trio, there is no doubt that they are increasingly significant actors in Canadian system of innovation in part due their increased capabilities in applied research. The role of colleges in the innovation activities related to the descendants of the Trio programs is expected to grow as Canada's innovation agenda recognizes how college contributions can blend with universities (Bélanger et al., 2005).

2.2.3.3 Government

When considering innovation policy and the role that governments play in the evolution of sub-national systems of innovation, much of the discussion focusses on incentivizing other agents and creating rules of engagement through the development of institutions (e.g. policy). It is crucial to understand that the government often undertakes an entrepreneurial function and assumes a significant amount of the risk that industry is unwilling or unable to take. By these actions, the government can create sectoral and institutional activity that otherwise would not have occurred.

Mazzucato (2013) notes that an important function of government supported research is to provide the earliest proof of viability for technological systems and processes. Without government undertaking this (largely unheralded) science-friendly behavior, industry (e.g. elite technology entrepreneurs) would have far fewer opportunities to upgrade knowledge feedstock for commercialization (or in the case of health, social purpose). Mazzucato (2013) proposes that the government has a crucial role in leading and sustaining the development of emerging opportunities (e.g. promising technological systems) up to the point that other agents in the system of innovation can take over and leverage them.

Governments may engage in activist functions where the pursuit of their goals (i.e. economic well-being, social outcomes, etc.) is achieved via context-specific economic policy instruments (i.e. programs and projects) (Etzkowitz, 2003; Borrás and Edquist, 2013). These policy interventions can bolster the evolutionary economic approach to economic development by supporting interactions in the system that create or enhance existing technical and economic opportunities (Edquist, 1999). The Government can set a direction for change, tilting the environment toward favoring certain opportunities over others (Mazzucato and Perez, 2015; Mazzucato, 2016)

Through its search routines, the government can identify opportunities to use innovation policy to address perceived innovation system failures (Nelson and

Winter, 1982). Edquist (2001) identifies four types of system of innovation failures;

- functions in the system of innovation may be inappropriate or missing,
- organizations may be inappropriate or missing,
- institutions may be inappropriate or missing, and
- interactions or links between elements in the system of innovation may be inappropriate or missing.

To address these perceived gaps, the government may choose to introduce a policy instrument. However, the role of the government may go beyond addressing failures in the system, and may extend to leading, directing and structure transformational changes (Mazzucato, 2016). There are three types of public policy instruments used by governments (and their agencies), presented in Table 4.

Table 4: Policy instrument typology

Regulatory instruments ('sticks')	The government controls many of the institutions that affect interactions between individuals and organizations in the system of innovation. These tools affect the innovation systems conditions by outlining what is and is not allowed to occur.
Economic and financial instruments ('carrots')	The government may provide monetary incentives to encourage particular activities. Thus, the government acts as a public entrepreneur and a deliberate investor in the system of innovation.
Soft instruments ('sermons')	These instruments are voluntary and provide non-binding guidance. They are not punitive and do not provide direct incentives. Generally, they are meant to be persuasive and provide information amongst actors that may encourage collaboration.

(Borrás and Edquist, 2013)

To be effective, policy instruments need to be adapted to specific social, political, economic and organizational contexts (Borrás and Edquist, 2013). Governments may attempt to copy the successful economic development policies of other regions, however, overlooking how local context affects the translation of the borrowed policy may result in sub-par performance (Schumpeter, 1942). It is challenging for governments to design effective policies because many important aspects of system behavior are emergent and can not be understood through the consideration of elements in isolation (Aghion, David, and Foray, 2009).

2.2.4 Institutional entrepreneurs

Earlier in this chapter, the role of the entrepreneurial function was discussed as a crucial factor in Schumpeter's theory of non-equilibrium. The entrepreneur can overcome existing inertia and create new value-adding combinations of economic elements. There are other motivations beyond accumulating wealth for the entrepreneur (e.g. competitive drive and the joy of creating) and entrepreneurial functions can, therefore, exist in non-capitalistic socioeconomic contexts (Schumpeter, 1934; Schumpeter, 1947; Fagerberg, 2003). This thesis believes that governments can play a directive role in the shape of a system of innovation (Mazzucato, 2016) and that an individual's agency can play an important role in shaping the institutions that they are embedded within (Battilana et al., 2009). The concept of an 'institutional entrepreneur' is an individual who promote policy ideas and articulate policy innovations onto government agendas; they engage in:

- The identification of problems and possible policy responses;
- The effective presentation of their ideas to policy makers;
- Effectively networking in and around the policy-making community to build trust and to gain an understand the policy maker's world view;

- Scanning beyond their jurisdiction for policy ideas that may be implemented in their home region (Mintrom, 1997).

These individuals must introduce policy that is at least somewhat divergent from the existing institutional environment (Battalina et al, 2009). Institutional entrepreneurs are a significant evolutionary force on the institutions of the government. The role of the institutional entrepreneur is crucial to understanding how innovation agencies emerge and manifest as important instruments of sub-national governments.

2.2.5 Agencies

Governments may undertake the provision of public services directly, as a primary organization, by utilizing the service delivery mechanisms within its organizational boundaries. However, the government may also rely on its ability to create an arm's length task organization to implement the needed activity, an 'agency'. Agencies are an important tool in the democratic government toolbox (Salazar and Holbrook, 2007).

McCrank et al. (2007) propose that agencies are organizations that:

- are established by the government but are not part of a government department;
- are responsible to perform a public function (i.e. provide a service, manage regulations and/or public trusts, or provide advice to the government on a particular issue);
- are responsible to government through a defined reporting relationship. This relationship may (or may not) encourage independence in decision-making;

- have some degree of autonomy from government, when compared with a government department; and
- are subject to government involvement in the appointment of their key individuals

VanSlyke (2007) suggests that governments create agencies primarily to benefit from lower costs, access to specialized expertise, and insulation from the consequences of innovation policy failure. A recent study of Alberta's agencies indicated that approximately 50 percent of the Alberta government's 2007 annual operating expenditures had been administered through 248 agencies (McCrank, Hohol, and Tupper, 2007). Table 5 outlines how government initiatives like agencies emerge and progress through distinct stages.

Table 5: Lifecycle of government policy

The idea	Every agency begins with an idea. Government and/or institutional entrepreneurs will have used search routines and interpreted messages from their environment to determine a need which requires policy to address. Governments can become more skilled at this function through practice and deliberate skill development. The creation of an agency requires at least one institutional entrepreneur to exert significant effort in lobbying for the design, legislation, and budget allocation of the innovation agency.
Legislation	Once the idea for an agency has gained traction with the political community, it must be given a legislative form. This legislation specifies the mandate of the agency and the terms of its governance. This thesis will examine important differences in agency routines that have arisen directly from governance and funding structures articulated in legislation.
Inception	'Inception' is the moment when the legislation for an agency wins the approval of the government and is marked by the control of a budget. An agency's funding structure has a real impact upon its operations and autonomy.
Implementation	The agency now begins operations and implements programs in pursuit of its mandate. The routines of the agency organization now become established through practice and the ongoing evolution of the organization and its portfolio of instruments will take place.
Results	The agency implements its instruments in a sincere attempt to generate the desired results. However, unless it is a primary organization, the desired results require action (and sometimes evolution) in other organizations.
Sunset	It is highly likely that an agency will eventually reach a pivotal juncture where it must either wind up or be reinvented. Governments may even

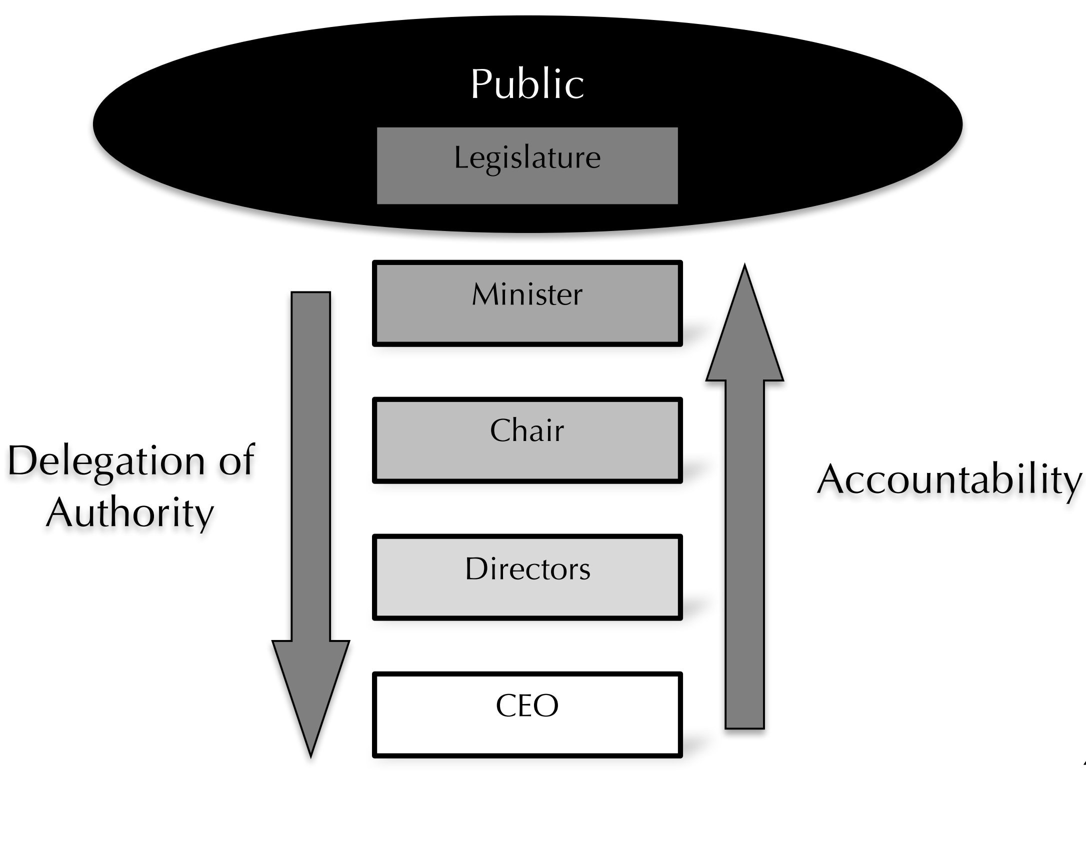
	include a 'sunset' provision in the legislation of an agency that articulates when and how the agency is to be wound down. It is common, however, for an agency to evolve or wind down in an ad-hoc fashion, where the agency is subjected to the political desires of the period (for better or for worse). The structure of the governance for the agency has a significant impact on this process.

(Adapted from Eggers and O'Leary, 2009; van der Madele and van Witteloostuijn, 2013)

2.2.6 Agency governance and accountability framework

Agencies are unique government organizations that have defined relationships between the agencies and other institutions. Between the inception of an agency and its sunset, agency individuals are awarded authority and entrusted with accountability (McCrank et al., 2007). Figure 2 provides an overview of the key individuals who are involved in the exchange of information, responsibilities, and resources.

Figure 2: Authority and accountability structure for agencies



(Adapted from McCrank et al., 2007)

This thesis uses the term 'arms-lengthiness' to describe an agencies authority and accountability.

2.2.7 Innovation agencies

The earliest innovation agencies emerged in the nineteenth century during a general shift in industrial and government behavior, as government labs and independent contract research institutes dramatically changed the ethos around how research and development were performed (Freeman, 1995).

Agencies offer the government some advantages in pursuit of their policy goals compared to managing the effort directly. Innovation agencies possess mandates to positively impact systems of innovation and enhance them through the provision of services and/or advice to government, universities, and industry stakeholders. Innovation agencies can be primary organizations, with their functions directly contributing to evolution in the system, or secondary organizations, influencing other organizations to change their behavior (Liu and White, 2001; Edquist, 2005).

2.2.8 Assessing the efficacy of an innovation agency

As an innovation agency is an expression of government policy, the assessment of the 'additionality' of innovation policy is an area of considerable importance for these public policymakers. When a government takes an activist role by using public funds to invest in innovation, it will be called upon to "figure out how … monitor and measure its economic and social outcomes." (Hawkins, 2012).

The Canadian Academy of Health Sciences (2009) suggests that evaluations of impact are performed for one of three reasons; accountability, advocacy, or learning. Accountability and advocacy evaluations are both used for the justification of innovation agency activities and for securing funding from stakeholders (see Table 6)

Table 6: Reasons for evaluation of innovation agency impact

Accountability	Governments have a responsibility to their taxpayers to show that their investments in innovation have been effective relative to their anticipated goals. However, it is tremendously difficulty to prove that an intervention has been more effective than an alternative (the counter-factual problem).
Advocacy	'Advocacy' examines the promises made with respect to what it may be possible to actually deliver. This is a consideration of future potential and differs from the concept of accountability, which focuses on examining past performance.
Learning	While the metrics of accountability and advocacy typically satisfy an assessment for external stakeholders, 'learning' delivers information for internal benefit. Conducting evaluations to determine what has been learned by the agency helps an agency to understand its strengths and weaknesses and to subsequently enhance its capabilities.

(Canadian Academy of Health Sciences, 2009)

Understanding the impacts of innovation agencies is extremely challenging, as they exist in complex networked socioeconomic systems. There are few, if any, standardized approaches to assessing the impacts of innovation agencies. No standardized approach to assessing research and development impact could adequately address the complexity of research and development outputs, describe the processes by which system of innovation impacts occur, and capture resulting economic outcomes (Tassey, 2003). The context of the system of innovation that surrounds the innovation agency can vary significantly, making cross-case comparisons of innovation agency impact challenging (e.g. the innovation agency mandated to improve oil sands technology will face a starkly different environment than the innovation agency mandated with affecting the sub-national health research and clinical delivery sector). The dynamics of the impact of research and development will also vary dramatically, depending upon sector and industry (Salter and Martin, 2001). Table 7 presents some of the most significant challenges that arise when attempting to evaluate the impacts of innovation agencies (Salter and Martin, 2001).

Table 7: Challenges in evaluation of impact

Attribution	The causal link between an outcome and an intervention.
Counterfactual	Understanding what would have happened had the intervention not occurred at all; this approach requires having established a baseline prior to the intervention.
Time lags	Understanding how time must pass before one can expect the input(s) to result in the desired outcome(s).
Quality and availability of data	The required data must be available and contain enough detail to glean the desired insights on the impact of the initiative.

(Buxton and Hanney, 1996; Tassey, 2003; Buxton et al, 2008; Canadian Academy of Health Sciences, 2009)

2.3 Summary

Innovation is broadly understood as a process that can result in improved economic performance expressed in a range of mediums such as improved products, services or organizations. Learning and skill development is crucial to the process of innovation and is not ubiquitously distributed in an economy. Institutions are the 'rules of the game' in society and help shape the character of economic evolution; they are an important source of path-dependency. The systems of innovation approach examines the determinants of innovation within a defined system; this thesis focuses upon sub-national systems of innovation which are determined by the institutions of the sub-national government. It is recognized that this focus is necessary but will exclude many complex system elements at the sub-national, national and global level. Natural resources can play a significant role in the structure of a sub-national system of innovation by shaping the industrial structure (e.g. supply chains) and technological capabilities of the region; the character of natural resources in a sub-national system of innovation is not fixed, it is largely determined by societal factors.

Within a system of innovation, organizations initiate most meaningful activity (i.e. research, end use, implementation, linkage, and education) and are subject to varying levels of autonomy. Organizations can be categorized as task organizations (funded by the public), market (funded by clients) or a hybrid of task and market. Organizations can provide a function directly to the sub-nation system of innovation, or they can affect other organization to provide the function. Organizations can deliver institutions (policy instruments) that can be in the form of regulation, incentives or advisory. Governments are viewed in this thesis as shaping a sub-national system of innovation through policy; policy that is promoted and articulated by individuals (institutional entrepreneurs). Governments may decide to create arms-length agencies to implement their policies; when these organizations are focused upon affecting the sub-national system of innovation, this thesis refers to them as innovation agencies. Investments made in innovation agencies are expected to make a discernable impact in inputs (e.g. investments from other sources), outputs (e.g. knowledge outputs) or behavioral changes in the recipient.

3 Research Methods

A combination of historical analysis and case study methods were chosen. Yin (2006) notes that mixed method design enables the researcher to collect complementary forms of data that will be richer than data collected by a single method. The approach to designing a project based in these methods was informed also by theoretical concepts relating to systems of innovation theory. Incorporating these theoretical concepts served three purposes; it placed the research within the relevant literature, helped define the unit of analysis, and informed the criteria for selecting agencies for case study.

3.1 Historical analysis

The literature suggests that history, natural resources and institutions matter a great deal for the formation of systems of innovation at the sub-national level (Doloreaux, 2002). Thus, it was decided that a detailed examination of these topics in specifically in the Alberta historical context was essential for understanding the subsequent evolution of innovation agencies.

The historical analysis utilized mainly extant secondary documentation (public records, government reports and historical literature) relevant to the industrial history of Alberta. It also examined texts pertaining to historical and institutional factors relating to the development of the oil sands, the emergence of Alberta's biomedical research capabilities, and the instrumentality of Alberta's energy sector in creating an information technology sector.

The analysis of the historical materials focused on interactions amongst elements that were theoretically relevant from a systems of innovation perspective. The historical analysis was aimed at identifying both long-term patterns in the historical narrative as well as contingent events that shaped this narrative. As Gaddis (2002) and Burgelman (2011) suggest, historical methods such as systemic perspectives and accounting for continuities and contingencies improves the quality of case study outputs.

3.2 Case study research

The case study is an empirical inquiry that investigates and contemporary phenomenon within its real-life context (Yin, 1994). It involves systematically gathering information about a group or organization to permit a researcher to understand how the subject operates or functions (Berg, 2009).
Case studies can be conducted as exploratory, explanatory or descriptive (Tellis, 1997).

This study employed a multiple case study approach. Multiple case studies resemble multiple experiments and provide more robust and valid insights into the phenomenon being explored (Yin, 2003). Accordingly, three agency cases were selected. Each case study was constructed partly on documentary analysis (mainly published reports) and partly on in-depth interviews with significant individuals in the development and operation of the agencies selected. The interviews provided a link with the historical analysis.

3.2.1 Unit of analysis

Case studies tend to be selective, focusing upon key issues fundamental to understanding the phenomenon (Tellis, 1997). Yin (1994) suggests that researcher uses their prior research experience and expert knowledge to further the analysis. In this research the 'unit of analysis' is the relationship between the innovation agency and elements of the sub-national system of innovation; a concept that can be presented in several theoretically relevant ways. The unit of analysis is not the innovation agency itself, but the emergence and instrumentality of the innovation agency.

3.2.2 Analytical categories

As the research progressed the unit of analysis became clearer and several categories of information were identified that were theoretically relevant in a system of innovation context. These categories were used to guide comparisons between cases, which is important for improving the perspective of the researcher and increase the odds of novel findings (Eisenhardt, 1989). The categories can be described as follows:

- Establishment of the agencies
- Operational models
- Organizational models
- Impacts

The last category necessarily must deal with the "additionality" of each innovation agency. This term refers to those impacts that can be attributed directly and specifically to the agencies (as opposed to random or general downstream impacts). Buisseret et al., (1995) note that additionality can occur in one or more of three forms; input additionality, output additionality, and behavioral additionality. 'Input additionality' refers to impacts related to changes in the supply of resources – e.g. increases or decreases in funding. 'Output additionality' refers to impacts created by what an organization produces. 'Behavioral additionality' refers to changes in practice, organization, networking and so forth. As Buisseret et al., (1995) note further, input additionality is relatively easy to measure whereas output additionality is more complicated, with absolute additionality attributions often impossible to determine. Behavioral additionality is often easier to observe, if not always to measure. But as Polt and Striecher (2005) argue, understanding behavioral additionality is often the key for effective policy-making, as the perspective provides rich information about the evolution of organizational routines.

3.2.3 Selection of agencies

Over several decades, dozens of innovation agencies have been created by the Government of Alberta and given various mandates to impact the sub-national system of innovation. The agencies selected for study were chosen according to the following criteria:

1. The cases should be from different sectors within the system of innovation;
2. The cases should have been in operation for a significant length of time (i.e. at least ten years) to ensure that they have had a reasonable chance for primary and secondary impacts to emerge through the system of innovation
3. They should represent a significant policy and funding commitment by the Alberta government.

Three Alberta innovation agencies conformed closely to these criteria:

- The Alberta Oil Sands Technology and Research Authority (AOSTRA) – an agency focused upon energy research, initially on the oil sands.
- The Alberta Heritage Foundation for Medical Research (AHFMR) – an agency focused upon supporting biomedical research.

- The Alberta Informatics Circle of Research Excellence (iCORE) – an agency focused upon supporting informatics research.

Table 8 describes the length of time that this Trio of organizations existed, from their legal inception until their 'sunset' phase. For AOSTRA the sunset was determined to be when operations were integrated into a Government department. For AHFMR and iCORE sunset was determined to be when Bill 27[7] came into effect on January 1, 2010 (see Appendix C: Bill 27).

Table 8: Length of operation of innovation agency case studies

Innovation agency	Inception - sunset	Sunset event	Lifespan
AOSTRA	1974 - 1993	Integration into government (reduction in funding and strategic choice)	19 years
AHMFR	1976 - 2009	Bill 27	33 years
iCORE	1999 - 2009	Bill 27	10 years

Table 9 demonstrates that over the period that the Trio were active, the Government of Alberta invested significant funds in their programs and operations.

Table 9: Government of Alberta funding for Trio

Innovation agency	Approximate funding inception - sunset
AOSTRA	~$448,000,000
AHMFR	~$1,000,000,000[8]
iCORE	$109,839,000

[7] Bill 27 (the Alberta Research and Innovation Act) was a piece of legislation that came into effect January 1, 2010. The essence of the Bill was to establish new innovation agencies and to merge or wind-up numerous Alberta innovation agencies. The purpose of Bill 27 was to improve sub-national innovation system performance (see Appendix C: Bill 27 for the complete text of the Bill)

[8] This was the value of the retained earnings of AHFMR as of 2005 (Lampard, 2008)

(Hester and Lawrence, 2010; Lampard, 2008; iCORE, 2000 - 2009)

3.2.3.1 Selection of interviewees

Interview subjects were non-randomly chosen based upon their familiarity with the case organizations or with the topic in general, due to their professional experience. There are two main categories of key informants that are relevant for this study:

1. Government officials: individuals who, in their current or past responsibilities, engaged in the creation of one of more innovation agencies and/or engaged in supervising their performance.

2. Innovation agency officials: individuals who were involved with the creation and/or management of one of more innovation agencies, generally as an executive and/or as a member of the board of directors. Thus, a part of their responsibilities would have been managing the activities of the innovation agency in pursuit of the organization's mandate. Another important responsibility for some of these individuals would have been assessing/communicating the impact of innovation agency activities.

3.2.4 Construction of the case studies

The case studies were constructed from a combination of documentary materials and interviews. The analysis triangulated information from these multiple sources to ensure the consistency and validity (Tellis, 1997, Yin 1994). Extensive review was undertaken of relevant secondary documentation concerning the Trio in the form of official publications, annual reports, evaluations and legislation. Archival information was then supplemented with interviews.

Identification of potential interviewees was accomplished largely through existing relationships or referrals. Interviewees were contacted via email to discuss recruitment and introduce the aims of the research and schedule interviews. Interviews were held face-to-face at a location of the interviewee's choosing. Interview data came from 18 interviews with subject matter experts. Interviewees were informed of the right to withdraw from the study in the consent form (see Appendix D: Consent form) and at the start of the interview.

The researcher followed a semi-structured interview format. The questions were asked in a systematic and consistent order, yet there was flexibility to probe beyond the standard questions (Berg, 2009). This format was chosen for its flexibility in exploring the topic, allowing the questions to be modified as needed to help responses with the key informants. The flexibility of the open-ended interview questions allowed interviewees to elucidate their opinions regarding expectations.

In accordance with the provisions of the University of Calgary Research Ethics board certification, where an interviewee decided to withdraw, prior to any data analysis, all data collected to the point of their decision was destroyed. With interviewee permission audio from the interviews were recorded on a password protected computer system digital device (i.e. laptop or smartphone). Recordings were stored at the home of the researcher. Interviewees participated on an anonymous basis. Provisions were respected whereby direct quotations could be used only with the written consent of the interviewee.

3.2.4.1 Interpreting interview data

The interviews were transcribed. The categories listed in Section 3.2.2 were then deployed as an open coding scheme to organize statements in a systematic manner according to the key elements of the Trio agencies to which they referred.

Analyzing case study data is one of the least developed aspects of case study methodology and relies heavily of the experience of the researchers and the literature to interpret the evidence (Tellis, 1997). This research used an explanation building approach that is built from the theoretical insights that began the research (Yin, 1994).

To increase the internal validity and generalizability of the research (Eisenhardt, 1989), the main findings of the research were enfolded in the literature pertaining to systems of innovation, evolutionary economics, natural resources, institutions, institutional entrepreneurship, agencies, innovation policy, and assessment of innovation policy impact.

3.3 Limitations of the mixed-method research

Alberta's situation results from a complex interplay between a complex set of causes which limits the predictive ability of the research. Thus, the research is limited in its generalizability and theory generating potential.

The generalizability of the findings is also limited because the innovation agency cases and the interviewees were not chosen randomly but rather with the intention of providing useful insight. There were only a limited number of interviewees that would be familiar enough with the cases to provide meaningful insight into the research questions and were accessible to the researcher. This constraint led to limitation in the ability to maximize triangulation.

A limitation from the interview data was that in some cases the interviewer was asking interviewees to recall their actions and experiences from quite a few years ago. In some cases, the Innovation Agencies used in the case studies were formed over 35 years in the past. Thus, there is a chance of selective recall.

Another limitation was the constraints on the categories of interviewees. Increased insight would have been gained if there were more interviews with key stakeholders who were the beneficiaries of innovation agency programs. By interviewing people from industrial research, deans, university department heads, CEO's, academic researchers, graduate students etc. the research could have gained rich data further triangulating insight into impact of Trio activities. However, as useful as this information would have been this data collection approach was beyond the resources available.

4 Historical Analysis

This chapter presents a historical context as a foundation for the case study research to follow and provides an overview of the complex web of non-linear social, industrial, and political causes that led to the Trio. It will consider phenomena such as institutions, natural resources, institutional entrepreneurs, and the organizations that shaped the sub-national system of innovation in conceptually important ways. For brevity, the thesis uses the term 'Lodges' to refer to the First Nations Government, 'London' to refer to the British Government, 'Ottawa' the Canadian Government and 'Edmonton' the Alberta Government. The chapter is organized around eras outlined in Table 10.

Table 10: Overview of Albertan eras

Era	Time period	Theoretically relevant events
Pre-Confederation Alberta	Up to 1867	Ancient oceans of organic matter transformed into vast fields of hydrocarbons in the Western Sedimentary Basin. The First Nations people settled Alberta and developed non-industrial institutions. Europeans explored Alberta and traded with the local peoples. Early explorers noted Alberta's oil sands, but the now familiar age of fossil fuels had not yet arrived.
Pre-provincial Alberta	1867 - 1905	Canadian settlement and its supporting socioeconomic institutions supplanted First Nations control in most of the region and over most natural resources. Alberta's economy was focused on farming and ranching.
Heritage Alberta	1905 - 1947	Alberta became a province but governance of the oil sands remained with Ottawa and, to an extent, London. In 1930, control of most natural resources transferred from Ottawa to Edmonton. Conventional oil was discovered in Turner Valley but was rapidly drained to sate the thirst of two world wars. The University of Alberta is established, playing an important initial role in energy and biomedical research.
Early modern	1947 - 1971	Major conventional oil deposits were discovered

Alberta		and transformed Alberta's economy. Commercial development of the surface oil sands grew, however, development and adoption of in-situ techniques remained elusive. Peter Lougheed's political career begins.
Modern Alberta	1971 – 2009	Peter Lougheed took office and pursued an agenda of utilizing resource revenues to prepare the economy for what he deemed the inevitable eventual resource decline. The growth of the energy sector leads to demands for ICT communication and data solutions. The Trio innovation agencies were founded and operationalized hundreds of millions of dollars of Alberta innovation policy funding.

4.1 Pre-confederation Alberta (<1867)

During the Early Cretaceous age,[9] an ancient seabed was transformed into hydrocarbon rich deposits underneath Alberta including three major oil sands deposits in Alberta; Athabasca (including Wabasca), Cold Lake, and Peace River (see Figure 3) These fossils set the stage for the possibility (not certainty) of a vast hydrocarbon economy.

Figure 3: Alberta oil sand deposits

[9] A period that took place about 135 million years ago. Other major bitumen deposits in Alberta were embedded in carbonate rocks from the Devonian period, approximately 405 million years ago.

(http://www.mining.com/wp-content/uploads/2013/09/Alberta-oil-sands-map1.png)

About 13,000 years ago, 'Albertans' settled across the province, from the woods of northern Alberta to the plains of the south. Early Albertans were nomadic, applied generalized knowledge about hunting tactics, used high quality stone for their tools (which was drawn from quarries far from where the tools were uncovered), and possessed sophisticated stone, bone, antler, and ivory technologies (Ives, 2006). After having lived in Alberta for over 10,000 years, the institutions, skills, knowledge, routines, and technologies evolved in response to the natural resources opportunities of the region of the First Nations peoples (Peck and Vickers, 2006). In 1778, an explorer, Peter Pond, noted the existence of the bituminous oil sands of Alberta and, while the oil sands remained undeveloped during this era, the vast energy potential of the area had become obvious (Chastko, 2004). In the 1700's Alberta's First Nations peoples were in control of Alberta's economic and military situations (Devine, 2006) although with increased settlement of Alberta came increasing institutionalization, which eroded the foundation of system that was 'the commons of the plains'; the impact upon hunting altered the natural resource economy of First Nations peoples' (Pannekoek, 2006).

4.2 Pre-provincial Alberta (1867 - 1905)

The British North America Act of 1867 created the Dominion of Canada and introduced the federal system which created two levels of authority; the federal government and the provincial government. The federal government handled issues like banking, trade, First Nations, the post office, national defense, and taxation in addition to the task of acquiring the remaining British colonies in North America (Hall, 2006). Provinces entering Confederation had limited taxation powers (and instead received subsidies from Ottawa) but had control over most lands and natural resources[10], civil rights, education, and health (Hall, 2006). In 1870, Canada received the British title to the former Hudson's Bay Company holdings, known collectively as 'Rupert's Land'. Alberta was then known as the North-West Territories and was governed under the 1875 North-West Territories Act which meant that Ottawa provided and exerted control of Alberta's budget. Ottawa's plan was for Alberta to gradually gain control over the placement of the federal grant, beginning with an appointed lieutenant governor and council in 1875, and eventually see an elected premiere and a cabinet in 1897 (Hall, 2006).

[10] As will be discussed later, when western provinces like Manitoba, Saskatchewan, and Alberta were established, the federal government retained control over natural resources and public lands, arguing that such control was in the interest of developing the nation. This created two tiers of provinces.

Economic development in the region required access to the land, which was still mostly controlled by First Nations peoples.[11] This tense land situation drove a need for a significant institutional transformation that this thesis considers the first building block in Alberta's modern innovation system. Canada's treaties with the First Nations have been called 'the Hidden Canadian Constitution' and brought First Nations peoples under the umbrella of federal government institutions (Carter and Hilderbrandt, 2006).

It difficult to overestimate the importance of the treaties, as they defined relationships between First Nations and non-First Nations peoples and transferred vast amounts of land and natural resources to the Dominion of Canada. In a 1975 report, the Indian Chiefs of Alberta stated "To us who are Treaty Indians there is nothing more important than our Treaties, our lands and the well-being of our future generations. (Indian Chiefs of Alberta, cited in Indian Association of Alberta, 1975). Taken together, Treaty 6 (1876-78), Treaty 7 (1877), Treaty 8 (1899), and Treaty 10 (1906) cover all of Alberta (see Figure 4). For First Nations peoples, these treaties resulted in a great diminishment of their land base, economies, and freedoms and are responsible for the seizure of control over natural resource development (Carter and Hilderbrandt, 2006). The concept of ceding land was not part of First Nations routines and the vocabulary to accurately convey the concept did not exist in many of the First Nations languages. Additionally, per the records of treaty negotiations, the Crown underemphasized the topic of ceding land. In general, this led to an unfortunate misunderstanding where First Nations peoples thought that they were lending their non-reserve territory, rather than ceding it (and its mineral wealth) forever. Siksika Chief Ben Calf Robe wrote:

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[11] In 1869-70 First Nations people had been decimated by smallpox, losing a significant amount of their population and leadership.

When I heard from the Old People about this treaty is that it was a peace treaty. They agreed to make peace, but they didn't say anything about selling the land. The treaty discussions have a lot about giving up our lands, but the Old People didn't know anything about it … There was no mention made to sell land [during the negotiations]; or to sell what was underneath the land or to sell the mountains, trees, lakes, rivers, and rocks. And we didn't say to sell the animals that fly, or the fish that swim. The Old People didn't get asked to sell these things. They were told, "the Queen will be like your mother, and she will take care of you until the sun stops shining, the mountains disappear, the rivers stop flowing, and the grass stops growing."
(Calf Robe cited in Carter and Hildebrandt, 2006)

Figure 4: The Treaties of Canada

(Natural Resources Canada, 2007)

The treaties resulted in the Government of Canada gaining control of Alberta's vast resource wealth and opening the door to increased settlement. The treaties, which acknowledge the sovereign political and cultural status of First Nations, remain central to the rights of First Nations and impact their socioeconomic development to this day (Carter and Hildebrandt, 2006).

While Alberta's territorial government had very limited capabilities there existed a growing desire to achieve provincial status, driven in part by the insufficiency of federal government funding in meeting Alberta's growing needs. In 1900, the Government of Alberta was unsuccessful (unlike Manitoba) in petitioning Ottawa for provincial status with control of its public lands and resources (Hall, 2006). In Ottawa, Alberta's energy potential was top of mind. Government reports from the 1880s suggest that territory owned by First Nations in the Athabasca and Mackenzie Valleys contained "the most extensive petroleum field in America, if not in the world." (Canada, Senate Journals, 2 May 1888). The technical challenges of economically developing these unconventional oil deposits were not appreciated. Also, the vast fields of conventional oil and gas that lay beneath Alberta's soil were unknown.

4.3 Heritage Alberta (1905 - 1947)

In 1905, the Alberta Act legally created the Province of Alberta. Alberta began with much of her best land, natural resource development, and royalties administered by Ottawa (Hall, 2006). While the Alberta act created the province and a host of provincial government institutions, Ottawa had determined that the neophyte provincial government in Edmonton simply didn't have the routines and capabilities necessary to manage its strategic natural resources. In exchange for this loss of sovereignty over resources and their royalties, Ottawa provided

Edmonton a subsidy. Since the federal government lacked the resources to invest directly in the development of the oil sands, it displayed a preference for allowing private industry to spearhead development (Chastko, 2004). This differed from the approach of Alberta's first premier, Alexander Rutherford, who was an economic protagonist who believed that governments and business should collaborate in development; Alberta's style of government/industry partnership is as old as the province of Alberta itself (Chastko, 2004).

The University of Alberta (founded in 1908) was an important organization to the early effort to develop the oil sands and biomedical research. Dr. Henry Tory, the first president of the University of Alberta, felt that the federal approach to oil sands development was inferior to Alberta's approach to public-private collaboration and would lead to sub-optimal outcomes (Chastko, 2004). Some of the earliest biomedical research in Alberta began in 1915 at the University of Alberta, when Dr. Tory, hired Dr. James Collip, who had been researching 'internal secretions' and had presented his research to the American Medical Association. In 1919, Dr. Tory formed a scientific interest group that, in 1920, would be reorganized as the Scientific and Industrial Research Council (later renamed the Alberta Research Council in 1928). In 1920, the University of Alberta was successful in receiving a $500,000 grant based on completion of the planned medical school building, implementation of a full four-year MD curriculum, upgrading the clinical faculty,[12] and the reacquisition of a hospital. In 1938, the National Research Council created the Medical Research Council (MRC) and a Calgary surgeon, Dr. John McEachern, drove the Canadian Medical Association to create the Canadian Cancer Society. The idea of government funded and university-based research became national during Dr. Tory's presidency of the National Research Council, from 1923 to 1935.

[12] Interestingly, the first professor to be upgraded was Dr. Collip, who was involved in the discovery of insulin.

Meanwhile, since Canada was a part of the Commonwealth London could exert significant influence over the development of Alberta's resources; and London viewed Alberta's oil sands as a strategic asset that was to be used to support the British Empire. Under pressure from London, Ottawa placed the oil sands in reserve in 1913. This policy put an end to the limited commercial development that had begun and even allowed Ottawa to seize assets on crown land. This policy effectively meant that Albertans had to apply to the federal government to conduct research on the oil sands. Alberta remained largely focused on ranching and farming while all oil development activity focused on the oil sands. Progress in development was slow, with many industrial stakeholders expressing that Ottawa's approach to the development of the oil sands was haphazard (Chastko, 2004).

By the 1920s, scientists from the federal government, the University of Alberta, and the Alberta Research Council had spent over a decade working to develop processes for exploiting the oil sands. One important technology system was the hot water separation process, developed by Dr. Karl Clark, that facilitated the separation of bitumen from oil sands mined from the surface (Chastko, 2004; Patton et al., 2006). However, the perceived role of the oil sands as Alberta's primary energy opportunity changed when significant conventional oil deposits were discovered in Turner Valley in 1914. This find decreased the appetite for oil sands development and reinforced the value of prospecting for conventional oil deposits (Rennie, 2006). The discovery at Turner Valley was immediately globally relevant, as World War One had arrived with its enormous energy and food demands. With the discovery of oil in Turner Valley, the conventional oil[13] economy of Alberta began to emerge. This economic activity created a culture of exploration that would pay off in the 1940s (Rennie, 2006).

In 1930, the province and federal government ratified an agreement to transfer control of Alberta's natural resources to Edmonton. The Alberta Natural Resources Act was as transformative as Treaty 6, Treaty 7, and the Alberta Act of 1905 and gave Alberta control over its crown lands and resources for the benefit of its inhabitants (a status that B.C. and the eastern provinces had long enjoyed). This act did not affect the governance of First Nations territories, whose resources were administered by the Government of Canada under the terms of the treaties. However, one important exception to the natural resource transfer existed - the largest oil sands deposit in Alberta. Critically, the federal government retained the resource management of the region around the Athabasca deposit. Chastko (2004) explains:

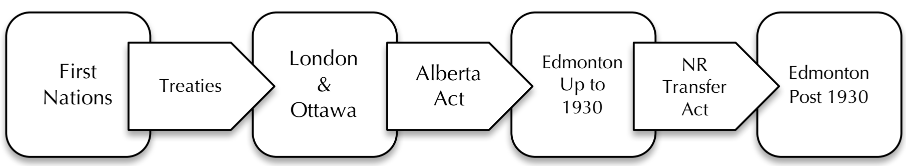
> Ottawa inserted a caveat into the Natural Resource Transfer Act that granted the Federal government control over approximately 2,000 square miles of territory in Northern Alberta, including the Athabasca deposit. Then, a matter of weeks before the agreement was to take effect, Ottawa signed a lease agreement with Max Ball that would allow Abasand Oils to develop the same area that the Federal government had held back from Alberta in its agreement.

[13] Conventional oil is distinguished in this thesis as coming from sources that do not require significantly new techniques for extraction or refinement. Unconventional oil (i.e. the oil sands) require advanced techniques for extraction and use.

Ottawa had excluded the prime oil sands deposit from the transfer and had done so without consulting the province. This action made many in Alberta suspect that Ottawa was planning to commercially develop the oil sands without Edmonton's involvement (Chastko, 2004).

Governance of Alberta's natural resources had moved from the First Nations to London, to Ottawa, and eventually to Edmonton (with limited natural resource control 1905 - 1930) and Edmonton (with almost complete natural resource control from 1930 onward)[14] (Chastko, 2004).

Figure 5: Evolutions in Alberta's natural resource governance



During this period, a pioneering research effort to develop the Alberta oil sands was primarily being led by two innovation agencies; the Alberta Research Council and Abasand Oils.

4.3.1 The Second World War

The Second World War impacted Alberta in much the same way that the First World War had, as global conflicts require enormous amounts of food and fossil

[14] The Athabasca oil sands deposit was not included in the 1930 NR Transfer Act.

fuels. During this time, the institutions related to and the governance of natural resources and industry transferred to Ottawa, through the Federal Minister of Munitions and Supply. To quench the thirst of the war, Ottawa set aggressive production quotas for the Turner Valley fields which shortened their lifespans dramatically. The policy of aggressive production from the Turner Valley fields worked against Alberta's economic interests and acted as another irritant between Edmonton and Ottawa. (Chastko, 2004).

In 1942, the Turner Valley oil fields were experiencing a marked decline in production which drove interest in Abasand (the oil sands innovation agency endorsed by Ottawa) and its potential to provide a domestic supply of oil. Abasand was successfully processing bitumen on a limited scale, albeit amid concerns regarding commercial scalability in its current facilities. Federal government assessment of the Abasand operations eventually led to Ottawa assuming its control with the goals of reorganizing operations, upgrading the facility, and piloting a more effective separation process. After the takeover by Ottawa, many of the skilled operators of the Abasand plant left and the modest relationship between the Alberta Research Council and Abasand also came to an end. The termination of this relationship meant that the Albertan government now had limited ability to gain knowledge of the oil sands. By 1944, continued poor performance at Abasand led its management to re-establish its relationship with the Alberta Research Council. At that time, Abasand also faced resistance from Ottawa on its implementation of new processes. This issue precipitated the perception in Alberta that Ottawa was mismanaging Abasand operations. This was a difficult pill for Albertans to swallow, as the oil sands represented a major development opportunity for a strategic reserve of oil. By 1945, Ottawa had decided to abandon its Abasand efforts due to a series of fires at the Abasand plants which resulted in Alberta losing both its access to federal government oil sands expertise and Edmonton's allocation of funding for its own oil sands pilot plant (Chastko, 2004).

Figure 6: Abasand refinery

(University of Alberta Archives, 2014)

Alberta's conventional oil sector was rapidly growing but the Province's overall economic character was still agricultural. With the Turner Valley fields in rapid decline, Abasand proving less than promising and conventional oil exploration efforts yet to bear fruit, it was believed that agriculture would continue to be the backbone of the provincial economy. At the time, the farms and ranches of Alberta provided almost sixty percent of Alberta's economic production. Fossil fuels were still Alberta's primary hope for economic diversification away from agriculture and, while research continued with the goal of developing the unproven oil sands, more significant industrial effort was expended on searching for conventional fields (Breen, 2006). For the preceding thirty years, major oil companies had been exploring Alberta with hopes of locating her next oil fields.

However, until 1947, success had been elusive. Beyond searching for new oil fields, Alberta's economic policy lacked serious calls for both industrial development and economic diversification (Myers, 2006).

4.4 Early modern Alberta (1947 - 1971)

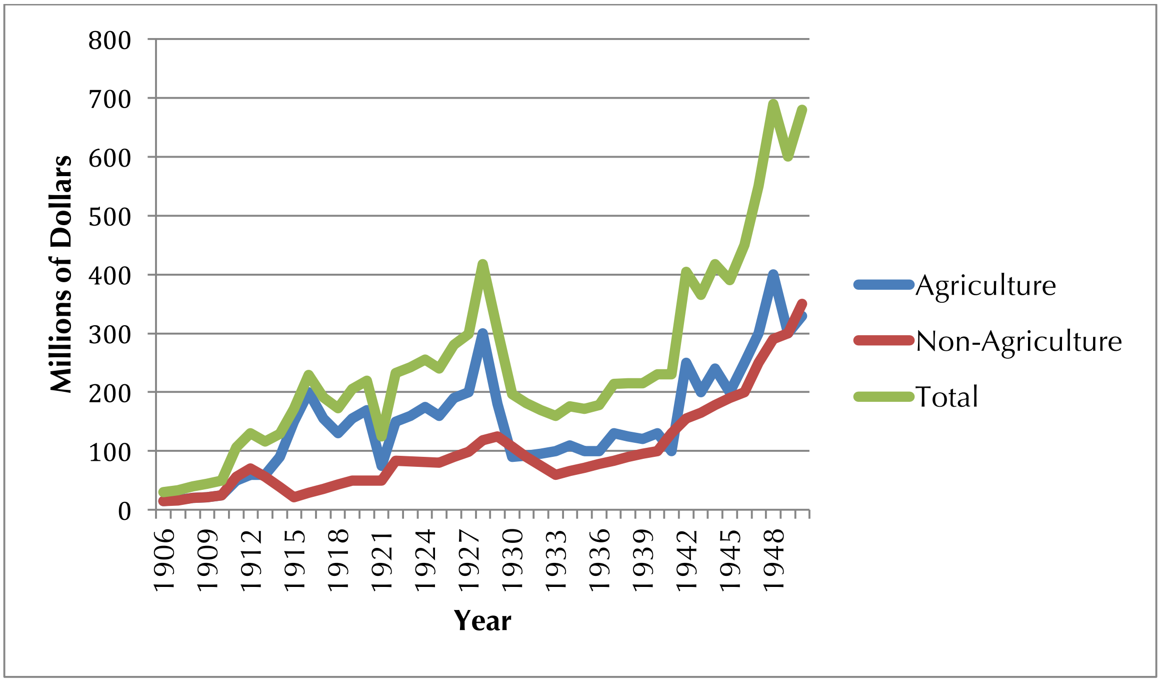
In 1947, vast conventional oilfields were discovered in Leduc and followed by discoveries at Redwater, in 1948, and at Joarcan, Golden Spike, Stettler, Excelsior, and Bon Accord, in 1949. By 1953, sixteen new fields had been added, notably, the Pembina, which exceeded all others in size. Like Turner Valley in 1914, these conventional oil discoveries began another evolution of the Albertan economy by reinforcing the importance of conventional oil resources and capabilities as the center of Alberta's economy. The epic scale of these conventional oil discoveries dramatically changed the economic case for industry and government support of the research and development of the oil sands. The vast and technically challenging oil sands were now competing against yet more extant supplies of well-understood conventional oil. To make the future development of the oil sands even more challenging, the conventional oil industry neglected oil sands development, due to its economics, and generally opposed their further development (Chastko, 2004).

There was still some activity surrounding oil sands development. A public-private partnership, Bitumount, was proposed to the province before the end of the Second World War to develop a pilot plant that would demonstrate the potential of the hot water separation process at a commercial scale (Bowman, 2008). Many felt that the initiative was underfunded and made poor use of the skills and resources located in Alberta, replicating many of the weaknesses of

Ottawa's Abasand effort. The Bitumount plant struggled towards completion in 1947 and began to produce results in 1948, to the chagrin of many individuals in the Alberta Research Council who were displeased with their lack of official project involvement. In 1947, the discovery of conventional oil deposits at Leduc dealt a blow to Bitumount research. In response to the criticisms and cynicism, its champions argued that proving commercial viability of oil sands was crucial to catalyzing industrial involvement and that the plant would not be the failure that Abasand had been. Toward the end of 1949, it was determined that the provincial effort had produced enough knowledge to prove commercial viability of the hot water separation process and the Bitumount research concluded (Chastko, 2004).

At the end of the 1940s, Alberta entered a prolonged period of healthy economic development, with personal income doubling by 1951 and a prolonged real growth rate of five to seven percent (Owram, 2006). There was an expectation that the conventional oil bonanza would be retained within Alberta and would continue to displace agriculture as the center of Alberta's economy. Farming and ranching were extremely volatile and subject to boom and bust cycles. The oil and gas sector provided much needed economic diversification. As seen in Figure 7, even though agriculture was worth more in net economic value, there was an obvious focus on exploiting conventional oil and gas and unlocking its future potential. Interestingly, the conventional oil industry was having a disproportionate effect on industrial development and job creation, negatively impacting sixty percent of manufacturing in Alberta (Foran, 2006).

Figure 7: Primary and secondary production in Alberta (1905 - 1950)



(Boothe, P. and Edwards, H., 2003)

Conventional oil had grown to become the incumbent economic sector. The struggles of the oil sands contrasted sharply with the success of conventional oil and further entrenched the latter as the foundation of Alberta's economy. Thus, it was rational for many industrialists to believe it against their interests for the government to invest in developing the oil sands a competing supply of oil (Owram, 2006). During the 1950s and into the 1960s, conventional oil interests in Alberta positioned the oil sands as an expensive and risky alternative fuel source. In the United States, however, there existed some interest in Alberta's mammoth oil sands reservoirs. The president of Sun Oil, J. Howard Pew, steadfastly believed that the oil sands had the potential to become his company's primary source of oil. Sun Oil worked to take over a significant amount of the Abasand lease and, in 1958, after eight years of development, entered an agreement with the Great Canadian Oilsands. After several false starts, Great Canadian Oilsands, in partnership with Sun Oil, received permission to develop the first commercial oil sands plant in Alberta (Chastko, 2004). By the late 1960s, only the Great Canadian Oilsands was engaged in commercial production of oil sands using mining techniques (Hester and Lawrence, 2010). Clem Bowman (2008) described Sun Oil and its decision to create the pilot plant as "displaying great courage" and described the company as "one of the heroes of [the oil sands] story".

There remained tension and conflict between conventional and unconventional energy producers over preferential institutional treatment (e.g. royalties, fiscal regimes, technological research, style of infrastructure, etc.) (Hester and Lawrence, 2010). Tremendous technological, logistical, and political challenges had yet to be overcome before the potential of the oil sands could be realized economically. Very few Albertan industrial organizations had active development plans for their oil sands leases. Syncrude had leases that it intended to develop but had been slowed by challenges in securing financing to begin operations. In 1966, Syncrude urged the government to consider the merits of allowing a second oil sands plant and, despite concerns of impact on the conventional oil sector, the government approved their final application in 1969 (Chastko, 2004).

In the late 1960s and early 1970s, modest industrial development of surface oil sands deposits using mining techniques continued under the assumption that the government would eventually deem oil sands development an economic development priority (Chastko, 2004). At this point, there was no in-situ project close to being commercial nor any on the path to commercial viability (Bowman, 2008). The large in-situ potential of the oil sands would be unlocked by technologies that were decades in the making (Hester and Lawrence, 2010).

In the 1960s, Alberta's oil industry faced the challenge of oversupply from the American market and lacked sufficient logistical resources (i.e. pipelines) to distribute its surplus. In this context, many Albertans saw the development of the oil sands as expensive and unnecessary. However, there were some individuals, such as J. Howard Pew and Roger Butler, who played critical roles in the development of the oil sands. Howard Pew was the President of Sun Oil and believed that the oil sands would be a key fuel source for his company. Dr. Butler was a scientist working to develop the steam assisted gravity drainage process. Dr. Butler would go on to become the director of AOSTRA's technical programs (Chastko, 2004; Patton et al, 2006).

The 1960s saw the beginning of Peter Lougheed's political career, which would be unmatched in its impact on modern Alberta. He had a professional background in institutions, having graduated from Harvard Law, and had practiced law in Calgary. Peter Lougheed spent the pivotal early years of his career surrounded by western regionalists and fierce free enterprisers, from whom he inherited a concern for the eventual exhaustion of conventional oil reserves. Of the ideas of his peers, Lougheed also internalized the economic necessity of diversification into industrial and petrochemical operations (Friesen, 1984, cited in Marsh, 2006). In 1965, Peter Lougheed announced his intention to lead the nascent Progressive Conservative party against the incumbent Social Credit party (who had governed Alberta with a bible in one hand since 1935). The Progressive Conservative party of Alberta had no leader, no seats, no funding, and no organization but their energetic and modern approach appealed to Albertans. Peter Lougheed and five other progressive conservatives were elected to the Alberta Legislature in 1967. In 1971, the Progressive

Conservatives defeated the stale Social Credit party and Peter Lougheed became Alberta's Premiere (Marsh, 2006).[15]

Peter Lougheed exhibited his ambition when, in 1966, he presented his vision for the future of Alberta:

1) to recognize the important leadership role that Alberta could perform in Canada;
2) to improve the public good;
3) to have a long-term plan for the future development of the province;
4) to anticipate problems and prepare for shortages; and
5) to set as an objective, a society that is not inferior to any province or state in North America (Lampard, 2011).

In this speech Peter Lougheed described how Alberta would be the long-term beneficiary of increases in oil (and gas) revenues, which would then enable the government to make long-term investments in accelerating growth and economic diversification (Lampard, 2011).

4.5 Modern Alberta: (1971 - 2009)

Peter Lougheed's victory in the 1971 election began an agenda of province building, which included preparing for the day when the resource base would inevitably decline. Peter Lougheed's view was that the government had the responsibility to steer economic and social development. He was an interventionist leader who believed that, if there existed an opportunity to add value, the government was obligated to act (Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary). The Progressive Conservative party unleashed a torrent of legislation, averaging 94 bills per session between 1971 and 1985 (Marsh,

[15] Alberta's emerging urban and secular middle class had grown impatient with the Social Credit party's blend of religious fundamentalism and agrarian populism.

2006). In 1974 he outlined his strategy to encourage economic diversification through knowledge-based industries and stated his intention to invest significant funds in science. Mr. Lougheed's vision was to position Alberta as Canada's research leader and, in doing so, prepare Alberta to weather economic downturns and develop into a region that was, economically and socially, second to none (Lampard, 2011). This vision of developing Alberta's research capabilities would eventually include significant investment in what Lougheed termed Alberta's 'brain industries'; which in the context of this thesis includes the oil sands and biomedical research.

Upon election in 1971 the government of Peter Lougheed was not satisfied with the pace of oil sands in-situ industrial development (Bowman, 2008). Alberta's industry lacked a development path for the oil sands, particularly for in-situ techniques. Peter Lougheed implicitly understood that a long-term focus was needed to develop the required advanced technological capabilities and earth science knowledge base to tilt the economics of the oil sands toward viability, a vision initially articulated in 1974 as an "Energy Breakthrough" (AOSTRA, 1990; Chastko, 2004; Hester and Lawrence, 2010). He also understood that, while the province owned the resource, the sum of the government's technical capabilities fell far short of what was needed to address the challenges of commercially developing and deploying in-situ oil sands techniques (Hester and Lawrence, 2010). The Lougheed government's vision for transforming Alberta's oil sands industry involved industry developing a deep technological focus on new recovery and processing technologies for the oil sands. The government's role would include leading investment for demonstrations of in-situ production technology (Chastko, 2004). In an interview, David Redford recalled what Peter Lougheed told him about the situation:

> Look, we've got all of this money coming in from conventional crude. We have all royalties coming in and land sales coming in from conventional crude. But, it's limited. It's going to start going down. We have this huge resource out there. Everyone knows how much is there because of the work of the Alberta Research Council. We know that we have one of the largest hydrocarbon resources in the world, if not the largest. But, it's all in-place reserves. It's not proven reserves. We don't know how to produce the in-situ material and that's the largest part of it. And, the economics for the mine material is questionable. We've got these two plants that are going. Great Canadian Oilsands only was allowed to go because it was the smallest bid, 40,000 barrels a day. And, Syncrude, we spent a lot of money, put a lot of money into that to get that project to go. So, we need to improve the economics. Now, you can prove your economics by price or you can improve the economics by better technology. Why don't we take some of this revenue that we've got coming in from the royalties and invest it the development of the technology which will make the in-situ recovery possible and make the mine material economic?
>
> (Petroleum Historical Society, 2013)

Turning to Alberta's biomedical situation during this era, economic inflation in the 1970s was 10 to 11% and, in 1974, led to a medical funding crisis when a major federal medical research funding organization was forced to curtail its biomedical research funding programs (Lampard, 2011). Thus, Alberta's medical research faculties faced the prospect of capability erosion. By 1974, biomedical research funding had reached over $3 million at the University of Alberta and the University of Calgary (see Figure 8), about 8% of all Canadian MRC funding (see Figure 9) (Lampard, 2008).

Figure 8: Alberta biomedical research funding (1974)

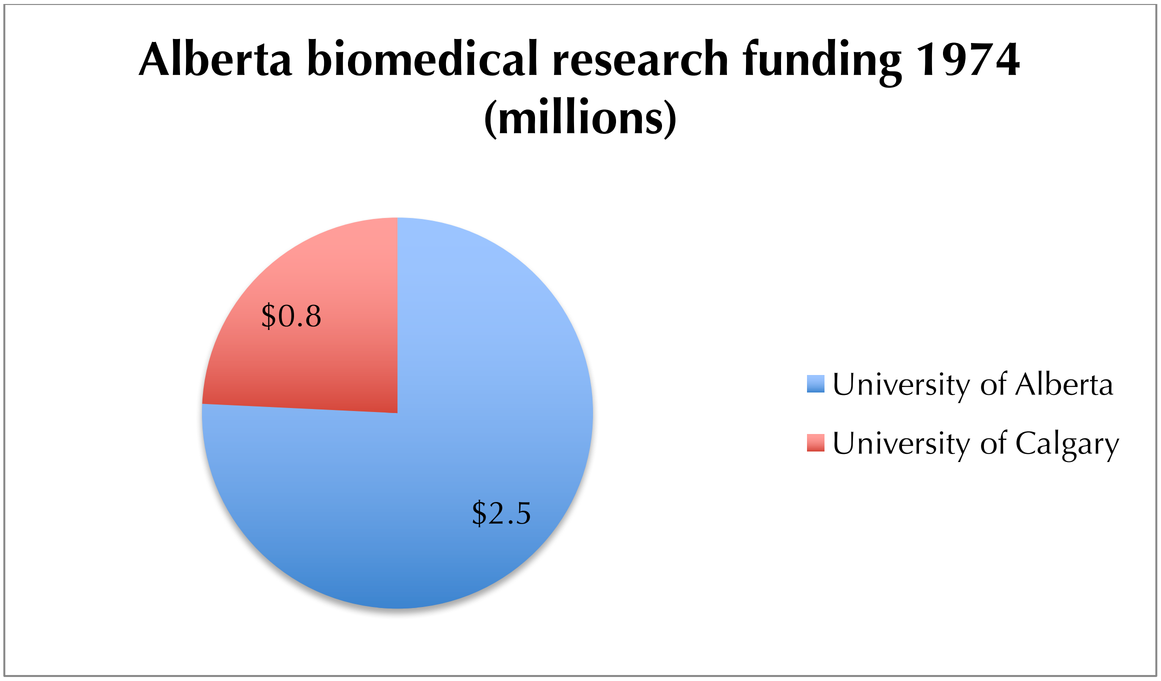
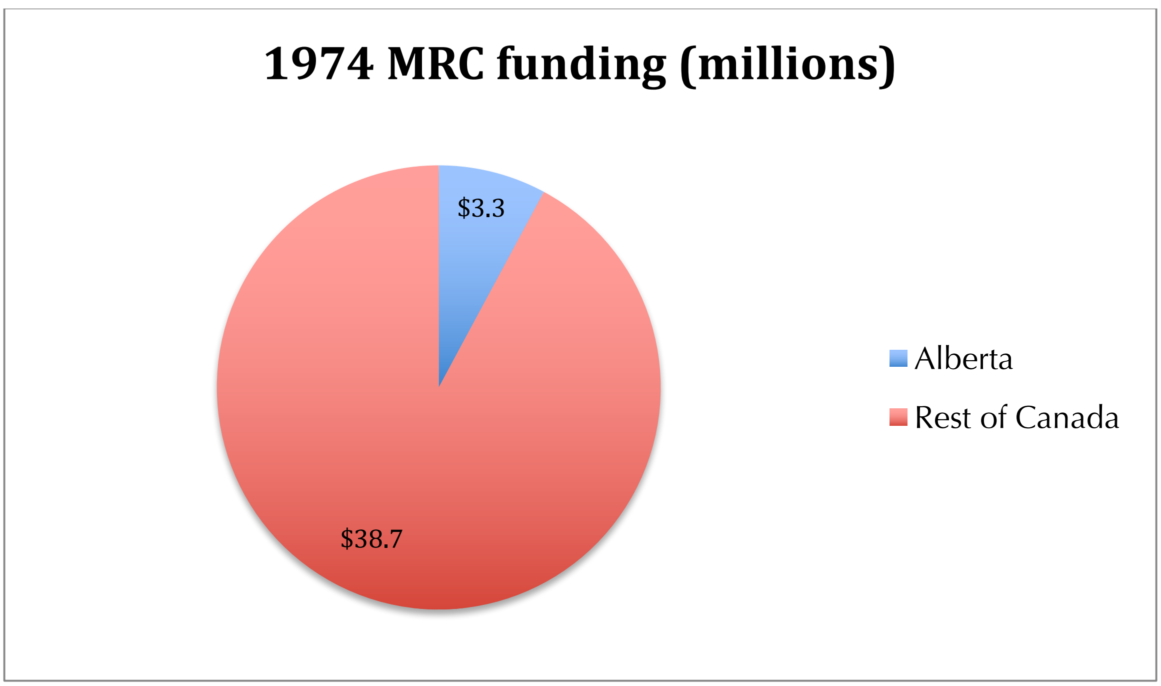


Figure 9: Alberta portion of medical research funding (1974)



(Lampard, 2008)

4.5.1 Alberta Heritage Savings Trust Fund

In 1975, Lougheed's party was overwhelmingly re-elected, taking 69 of Alberta's 75 seats. In 1976, resource related revenues filled Alberta's purse with a declared surplus of $600 million. From this solid footing, Peter Lougheed implemented policies to manage non-renewable resource rents for the continuing benefit of Alberta and announced the creation of the Alberta Heritage Savings Trust Fund (hereinafter called the AHF). This measure attempted to convert non-renewable resources into a renewable resource, a fund, and into infrastructure that would have the capacity to provide enduring benefit to the province (Warrack, 2005). AHF emerged as an instrument to manage the dynamics that significant resource revenue can have on a sub-national economy. There were concerns that a resource bonanza would induce unsustainable government expenditures, create corruption, and induce inflationary pressures, because of money directly invested into the economy that was not easily absorbed (Warrack, 2005). Warrack (2005) outlines four main drivers behind the creation of the Alberta Heritage Savings Trust Fund:

- To support future generations of Albertans via conservation of resources, increased economic opportunity, and environmental preservation;
- To strengthen the Albertan economy by supporting diversification and investment in strategic infrastructure (e.g. educational infrastructure and economic infrastructure);
- To improve quality of life through investments in culture (e.g. parks and art galleries), medical research, and innovation (which can all provide social dividends) and attract highly skilled individuals to the province; and
- To have at government disposal a source of revenue to smooth variations in tax revenue.

AHF was created with an initial contribution of $1.5 billion and an investment of 30% of future oil and gas royalties. Table 11 shows how the AHF has been resourced since its inception.

Table 11: Alberta Heritage Savings Trust Fund royalties (1976 – 2005)

1976	$1.5 billion initial allocation to AHF
1976 - 1982	30% oil and natural gas revenues (royalties and land sales) + all financial AHF yields
1982 - 1987	15% oil and natural gas revenues (royalties and land sales) but no yields allocation
1987 - 2005	No allocations and no yields allocations - this was the end of natural resource revenues being allocated to the AHF

(Warrack, 2005)

4.5.2 The emerging information technology sector

Much of the energy sector development discussed in the previous sections often required robust communication networks for its operations that would cover the vast distances and rough terrain, which makes laying the cables for communications systems difficult. Thus, the logistical and tactical needs of the Albertan energy industry became a driver for the development of informatics capabilities in wireless systems, geological data, and geospatial technologies (e.g. Novatel) (Langford, Wood, and Ross, 2003). Brian Unger was the first CEO of iCORE and talked about the information technology sector in Alberta prior to the establishment of iCORE "The needs of the energy sector led to the creation of roughly 1000 information technology companies in Alberta prior to the creation of iCORE. This information technology sector was created because of the energy sector and while it was not a large industry sector compared to the energy sector, it was still a large sector in and of itself. This information technology sector and its skilled workers were a resource that iCORE would attempt to work with" (Unger, B. 2013. Interview with Terry Ross. October 4, Calgary).

While still dominated by the energy sector's needs, Alberta's economic policy was characterized by a deliberate and focused effort to take revenue from nonrenewable sources (i.e. conventional and unconventional oil royalties and leases) and invest it in knowledge infrastructure initiatives that were physical, intellectual, and social. In the 1990s, the institutions and technologies of the global information technology economy were emerging. Government search routines suggested that informatics would be a wise economic development choice for diversification, however, some institutional entrepreneurs felt that Alberta was lacking the talent to participate in the productivity and diversification opportunities that the 'dot-com' boom could provide (Taylor, R. 2013. Interview with Terry Ross. November 8, Palo Alto). The Alberta Science and Research Authority suggested that deliberate, entrepreneurial investment in the information technology sector of the economy would lead to increased prosperity in the province:

> The industrial age has given way to the information age as technological advancements in computers, telecommunication, software, and digital information provide new economic opportunities … with the proper use and encouragement of ICT, Alberta can seize the opportunity to become more productive and more competitive in the global economy.
> (ASRA, 1998)

In November of 1997, the Alberta Science and Research Authority created the Information and Communications Technology Task Force to make recommendations on an ICT strategy for the province (iCORE, 2000). The resulting document, entitled "Information and Communication Technology: A Strategy for Alberta", recommended a four-point strategy for developing Alberta's ICT system of innovation, which focused on creating positive feedback loops in education, infrastructure, research and development, and technology commercialization (ASRA, 1998). Table 12 describes the main initiatives that resulted from the government's focus on informatics policy.

Table 12: Main informatics development policies (circa 1998)

Policies	Focus
SuperNET	Top quality data infrastructure for Albertan communities
Banff International Research Station	A top tier mathematical research institute
Education	IT training in the primary education system
The Informatics Circle of Research Excellence (iCORE)	Attraction and development of top caliber informatics teams at Albertan universities

(ASRA, 1998)

4.6 Summary

Alberta's sub-national system of innovation lies over vast fields of hydrocarbons. It has emerged from the institutional foundations of treaties with First Nations peoples, which provided institutional access to natural resources to the Federal Government. When the sub-national province of Alberta was created in 1905 governance over the natural resources remained with Ottawa. The oil sands had been recognized as a valuable resource by the federal and provincial government; however, research and development was slow and awkward. The establishment of the University of Alberta and the Alberta Research Council marked the emergence of biomedical research in Alberta and innovation agencies focused on developing the oil sands. When conventional oil was discovered in 1914, the thrust for development of the oil sands diminished. In 1930, the Alberta government received control over natural resources, with the notable exception of the most significant oil sands deposit, which remained with Ottawa. The discovery of large conventional oil deposits at Leduc in 1947 further affected the drive to develop the oil sands as the emerging energy sector focused upon conventional oil and gas. This development of the energy sector often required the development of communication and data solutions, which fostered an information technology sector in Alberta. When Peter Lougheed rose to power in the 1970's he brought an activist attitude to the Alberta government which was focused on developing institutions to manage natural resource wealth through institutions that would enhance the sub-national system of innovation (e.g. the Alberta Heritage Savings Trust Fund, the Alberta Heritage Foundation for Medical Research, the Alberta Oil Sands Technology Research Authority).

This historical analysis provides the context of the sub-national system of innovation in Alberta and an examination of the three innovation case studies that provide the data to answer this thesis' research question.

5 Case Study Findings

In this chapter the findings from the case studies are presented. All the cases are positioned relative to the historical analysis of the Alberta sub-national system of innovation presented in Chapter 4. In the case studies the analysis unit is the emergence and instrumentality of the innovation agency. The findings are presented in consistent categories to aid in cross-case comparisons. For each case study the first category presents the findings pertaining to the establishment of the innovation agency. The second category presents the findings pertaining to the funding and operations of the innovation agencies. The third category presents the findings relating to the model of the innovation agency. The fourth category presents the findings relating to the additionality (impact) of the innovation agency.

5.1 Alberta Oil Sands Technology and Research Authority (AOSTRA)

AOSTRA was an organization that arose to capitalize on a very specific innovation opportunity in Alberta's oil sands that had been underexploited by both governments and industry for decades; namely the innovation of new processes that are adopted by organizations to utilize new materials (OECD, 2005). Addressing this shortcoming in the sub-national innovation system led to dramatic economic impacts that arose from the development of capabilities to economically exploit unconventional oil.

Before discussing the AOSTRA case, a brief introduction to some specialized terminology relating to oil production techniques is required.

- 'Primary' oil recovery is usually the first technique used to produce oil from a reservoir; it uses gravity or pressure to drive oil to the surface.
- 'Enhanced oil recovery' or '(EOR)' are terms used for technologies used to produce oil after primary production is no longer economically viable (although it is possible that enhanced techniques may be applied from the beginning).
- 'Conventional' methods of oil recovery refers to both primary and EOR techniques.
- 'Cyclic steam stimulation (CCS)' is a technique where one well is used to inject steam for a period of weeks or months and is then used to draw the heated oil from the reservoir.
- 'Steam assisted gravity drainage (SAGD)' is a technique that uses two horizontal wells - one to inject steam and the other, positioned below the first, to produce water and oil.
- 'in-situ' is a term for development of oil sands 'in their original place'
- 'Mining' is a truck and shovel technology used to move oil sand to an extraction facility where it is then treated and the bitumen made ready for refining or upgrading.
- 'Unconventional' methods of oil recovery refers to CCS, SAGD, and mining techniques.

(Holly et al, 2012)

5.1.1 AOSTRA start-up

The need for AOSTRA was articulated during a government review of the roles and capabilities of existing agencies. This process determined that it would be advantageous to establish a separate organization with the sole purpose of funding and coordinating the required oil sands technological development and its dissemination (AOSTRA, 1990). Despite the obvious potential of the oil sands resource, there were early indications of considerable resistance to this proposal from the conventional oil sector. For example, in an interview, Eddie Isaacs (Executive Director, Alberta Energy Research Institute) noted that the existing producers preferred that research funding be focused upon established conventional technological systems like enhanced oil well recovery (Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary).

The mandate of AOSTRA was to create commercial in-situ opportunities in the main oil sands deposits and to get industry involved in those opportunities (Bowman, 2008; Hester and Lawrence, 2010; Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary). AOSTRA's initial mandate was limited to development of the oil sands, which essentially meant creating commercial in-situ opportunities in the Peace River, Athabasca, and Cold Lake deposits (Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary). In 1975, AOSTRA's focus would broaden to include heavy crude oil and then, in 1979, to enhanced recovery of conventional crude oil (AOSTRA, 1980). During its first two years of operation, representatives from AOSTRA met extensively with industry, academia, oil companies, and various interest groups to seek input and consensus on what its goals should be (Bowman, 2008). After meeting with stakeholders from industry and the universities, the AOSTRA Board of Directors settled on two major long term objectives:

- Work with the oil companies to field-test the most advanced technologies developed over the last twenty years in their labs.
- Harness university and institutional research capabilities in the search for new concepts in bitumen and heavy oil recovery.

(AOSTRA, 1980)

Peter Lougheed had significant involvement in the creation and formalization of AOSTRA, including its initial positioning in the sub-national system of innovation

(Hester and Lawrence, 2010). This included choosing its leadership, the leadership of the Alberta Research Council (which would be closely involved with AOSTRA's operations), and determining the composition of the AOSTRA Board of Directors. Peter Lougheed used an international executive search firm to source AOSTRA's leadership candidates and was directly involved in the interview process. Clem Bowman was selected as Chair of AOSTRA and Gilles Cloutier as Director of ARC (Hester and Lawrence, 2010; Petroleum Historical Society, 2013; Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary). Clem Bowman was recruited from Imperial Oil's research lab in Ontario and brought with him a strong reputation as a charismatic scientist alongside industrial credibility (Hester and Lawrence, 2010; Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary). Gilles Cloutier was recruited from Hydro Quebec.

Peter Lougheed was instrumental in ensuring that the initial members of the AOSTRA board all had significant scientific expertise in technology regimes relevant to the organization's mandate and significant business experience. The board helped guide the operations of AOSTRA through strategic choice and project determination (Patton et al, 2006; Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary).

> Premier Lougheed was directly involved in the appointment of the first seven AOSTRA board members, ensuring a relatively balanced public-private alliance [while] incorporating research and industrial strengths. Over the first ten years, as retiring board members were replaced, oil company presidents and vice-presidents, university presidents, and a number of Members of the Legislative Assembly (MLAs) coalesced as a team on a mission, a mission which never wavered. This was, in effect, a management board, meeting regularly to lay out strategies and making investment decisions. The board, especially in the first two years of

> planning, met extensively with industry, academia, and various interest groups to seek consensus on goals.
> (Bowman, 2008)

AOSTRA's operations began with Clem Bowman as the only full time staff member, with staffing continuing to be very light over most of the early years (Hester and Lawrence, 2010). As AOSTRA initiatives were launched, its technical and staffing needs were met by seconding technical staff from ARC, embedding staff inside of industrial partners, and hiring consultants. Thus, AOSTRA did not have its own research facilities (excluding the UTF), but utilized the infrastructure and capabilities of the Alberta Research Council and its industry partners (AOSTRA, 1990). Many of AOSTRA's programs leveraged research programs already in operation at the Alberta Research Council (Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary).

5.1.2 AOSTRA funding

AOSTRA's initial five-year budget, which covered its projects and operations, was $100 million, allocated from the Alberta Heritage Fund (AOSTRA, 1980). During the five year start up period, AOSTRA was not subject to annual reviews of its budget. Assessment of AOSTRA's impact was conveyed via an annual report to the legislature and by the chairperson's annual accomplishment reports to the executive council. Occasionally, stakeholders were surveyed but no formal independent evaluation by an outside organization was conducted (Hester and Lawrence, 2010).

In 1975, AOSTRA began to solicit interest in proposals from industry. The board chose five projects to pursue from a total of 21 applications. The cost for these first initiatives was $235 million. AOSTRA eventually returned to the government for an additional $135 million in funding. Over 18 years (1974 – 1992), AOSTRA had spent $448 million[16] on public-private projects and institutional research, making AOSTRA one of the largest research and development programs ever launched in Canada. The norm for AOSTRA was to co-finance industrial projects 50-50 with industry (Hester and Lawrence, 2010).

5.1.3 AOSTRA model

AOSTRA's operating model included collaborations with industrial organizations, the Alberta Research Council, universities, and other stakeholders. These collaborations would be supported through a range of programs. Table 13 provides a description of main AOSTRA programs and their relative shares of AOSTRA's committed funds, after 12 years of operation.

Table 13: AOSTRA program overview (circa 1987)

Program name	**Sample of program activities**	**Committed funds (1987)**	**% of total (1987)**
In-situ programs	Pilot projects testing in-situ technologies and techniques and projects to develop databases and economic studies	$216 million	44%
Underground access programs	Studying and piloting techniques for placing an array of horizontal wells in a formation to promote high recovery of bitumen from oil sands	$66 million	13%
Enhanced recovery programs	Projects, studies, and pilots to improve recovery technologies and techniques to extract a range of hydrocarbons from a wide range of conditions (e.g. using CO_2 to displace heavy oil and bitumen)	$8 million	1.7%
Produced water recycling programs	Research projects to treat the water used in bitumen extraction for re-use within the	~$3 million	1%

[16] Approximately $1.15 billion CAD, in 2014 dollars.

	production system		
Surface mining/extraction programs	Development of processing techniques (e.g. thermal Taciuk processes, solvents for bitumen extraction, adding sodium bicarbonate in the coking stage to reduce sulphur, etc.) for surface mined oil sands extraction, oil sands processing, soil remediation purposes, etc.	$27 million	5.4%
Upgrading research	Projects to implement upgrading technologies to improve efficiency, lower costs, and enhance yields	$24 million	5%
University programs	Provision of professorships (three years of research funding with a possibility of two more), graduate student scholarships, and project support	$34 million	7%
Alberta Research Council programs	A focused technology and expertise base located at the Alberta Research Council, divided into two streams: **Core Program** – regional generic problems, fundamental reservoir mechanisms, and novel concepts **Strategic Program** – mission-oriented problems, developing core supported opportunities, developing processes for field application, and evaluating exogenous technologies)	$40 million	8%
Programs at other research institutions	Opportunistic research projects with industrial organizations and research institutes on projects like thermal simulation software, enhanced oil recovery technology, and environmental monitoring software	~$2 million	<1%
International programs	Supporting delegations of subject matter experts from Alberta to aid in developing overseas (e.g. China) business opportunities and supporting international information centers on heavy oil and oil sands	$~2 million	<1%
Training programs	Engaging students with AOSTRA industrial partner projects over the summer or through year round co-op positions	$~2 million	<1%
Industrial postdoc fellowship	Two-year positions for postdoctoral fellows to conduct research at the labs of industry partners	$.1 million	<1%
Technology transfer	Technology developed by AOSTRA-funded projects is made available for transfer under reasonable terms	~$4 million	1%
Publications /conferences /workshops	Transferring knowledge through the publication of technical results in papers and by organizing conferences and workshops	$2 million*	<1%
Economic analysis	Economic evaluations conducted to guide research and technology development choices	*Included in publications /conferences	*Included in publications /conferences

		/workshops	/workshops
Library and information services	Organizing and managing AOSTRA confidential reports	*Included in publications /conferences /workshops	*Included in publications /conferences /workshops
Patents	Maintaining a suite of Canadian, American, European, Mexican, and Venezuelan patents	$500,000	<1%

(AOSTRA, 1976-1987; AOSTRA, 1990)

5.1.3.1 AOSTRA and the petroleum industry

AOSTRA's primary objective was to engage industrial organizations by financially incentivizing research and the deployment of technologies relevant to the oil sands. AOSTRA co-financed development projects with industry (firms were expected to pay 50% of the total project costs) and consequently shouldered an equal amount of project risk (Hester and Lawrence, 2010).

AOSTRA insisted that the province of Alberta, as owner of the natural resources, retain the rights to all technologies developed by AOSTRA. In practice, this meant that AOSTRA owned the rights to the technologies that it developed through its programs and industry partners received a non-exclusive license for that technology's use. This was a challenge for industry, but it conceded that ownership was not necessary if use rights were in place (Hector and Lawrence, 2010). Proprietary knowledge gained from AOSTRA effort (e.g. knowledge of the characteristics of a particular oil sands deposit) was subject to confidentiality arrangements which typically lasted for decades (AOSTRA, 1990). Since all AOSTRA-sponsored new technologies were owned by the government, the diffusion of technology was centrally managed and, thus, avoided the duplication of research between competing organizations (AOSTRA, 1990). The characteristics of typical AOSTRA and industry arrangements are described in Table 14.

Table 14: AOSTRA industry collaboration requisites

AOSTRA generally contributes half of project funding and has half of management control
AOSTRA obtains patents and, generally, owns all new technology
AOSTRA is the exclusive licensor in Canada for new technology
AOSTRA and the company may individually or jointly license outside of Canada
Licensing income is shared in proportion to financial contribution
AOSTRA licenses third parties at a fair market value, established in agreement with the participating company (or by arbitration)
AOSTRA may include a company's prior technology, as required to complete its licensing package, with recognition of that company's expenditures for the prior technology in distribution of the licensing income
AOSTRA, Alberta government agencies, the industrial parties to the agreement, and their affiliates may use project technology without payment of licensing fees
AOSTRA may place its technical representatives in the company's office, at project expense, to acquire technology and assemble it in the form necessary for licensing
AOSTRA and the company generally own all of the project's physical assets on a joint basis and share all revenue from their disposition, receiving proceeds from the sale of products
AOSTRA requires repayment of its investment in a project on a time value of money basis

(AOSTRA, 1990)

AOSTRA began a program in 1983 to support individual inventors with grants to move feasible ideas through early commercialization activities. Over seven years, the program supported 37 inventors with their projects (AOSTRA, 1990).

5.1.3.2 Role of the Alberta Research Council

Much of AOSTRA's research functionality was provided through the Alberta Research Council (Petroleum Historical Society, 2013). This led to the Alberta Research Council becoming a leading research center in three of the areas related to oil sands: geology, reservoir engineering, and upgrading.

The ARC and the Alberta Geological Survey (another agency) gained valuable knowledge about the location, magnitude, and distribution of the oil sands through their investments in geology; this information would be critical to projects like the Underground Test Facility. The second area of ARC expertise encompassed reservoir engineering and thermal recovery techniques, the understanding of which enhanced the understanding of reservoir properties (e.g. the saturation of rocks by oil, bitumen behavior, rock porosity, etc.). The third area related to upgrading bitumen and determining the best techniques for converting bitumen into synthetic crude oil (AOSTRA, 1990).

5.1.3.3 Links with Universities

When AOSTRA began, it needed to respond to the lack of specialized knowledge and training facilities for oil sands development and focused significant effort toward mobilizing university research. AOSTRA persuaded university researchers from across Canada to align their research priorities with AOSTRA outcomes and develop necessary training capabilities for technological deployment. In 1974, there were only about ten professors and ten students engaged in oil sands research in Alberta (AOSTRA, 1990; Petroleum Historical Society, 2013). By 1990, there were 80 professors and 500 students involved with AOSTRA-supported basic research programs in geology, geophysics, civil engineering, bitumen chemistry, physics, dredging, steam processes, electrical heating, and environmental science.

Furthermore, to address limited knowledge of oil sands chemistry, AOSTRA created a particularly important piece of codified knowledge; an inventory of the chemical properties of every type of bitumen molecule (Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary). AOSTRA also maintained a specialized library and published an oil sands themed journal.

AOSTRA managed a 'University Access Program' that assisted with the advancement and transformation of university research into larger scale testing, which then advanced techniques to the point where they could be deployed by industry (AOSTRA, 1990). AOSTRA also invested in financial incentive programs that encouraged the growth of a large and technically specialized workforce, to be trained in Alberta's universities and technical institutes (AOSTRA, 1990).

5.1.3.4 SAGD and the Underground Test Facility (UTF)

In the middle of the 1980s, AOSTRA programs had been operational and the results of these tests began to roll in in the 90s. While some of the tested techniques worked in some deposits (e.g. cyclic steam stimulation worked in deposits with good horizontal permeability, like Cold Lake) the large Athabasca oil sands deposit still lacked a commercially viable in-situ technology system. Exploitation of this deposit would require the development of a technique known as 'steam assisted gravity drainage' or 'SAGD', pioneered by Dr. Roger Butler.

Since the 1960s, Dr. Butler had been working on methods of upgrading bitumen mined from the Cold Lake deposit. Luckily, Dr. Butler also maintained an interest in developing new recovery methods. Based on a technique used in potash mining, Dr. Butler developed a new method of injecting steam into the Cold Lake reservoir to recover bitumen. Initially, the process received little endorsement or development but this changed when Dr. Butler was assigned to lead Imperial Oil's heavy oil research division, in 1975. The first SAGD oil sands well was piloted at Cold Lake (1978) but it soon became apparent that the technique was not well suited to the geological conditions of the deposit, as it exhibited poor heat transfer zones. In 1982, after retiring from Imperial Oil, Dr.

Butler assumed the position of Director of Technical Programs at AOSTRA where he continued his work on SAGD (Patton et al., 2006).

In the early 1980s, AOSTRA proposed the development of an Underground Test Facility (UTF) to assist in the development of in-situ processes that would open the development of oil sands deposits. Unfortunately, given the depressed state of oil markets, in conjunction with industry's lack of routines for assessing the risks associated with new technologies (e.g. horizontal drilling), industry could not be convinced to co-invest with the government in the UTF (AOSTRA, 1990). Nevertheless, in 1984, Alberta's government decided to invest $42 million, later increased to $80 million, to develop the Underground Test Facility. In 1982, the location of the UTF was scouted and the facility later began pilot studies, in 1987. Industry provided process screening and project evaluation, via a company steering committee of 16 stakeholders. The UTF was a crucial piece of infrastructure for the development of the commercially viable SAGD technique, developed after approximately six years (Hester and Lawrence, 2010).

The UTF was the only project in the AOSTRA portfolio that AOSTRA operated. In all other cases, another organization (i.e. the Alberta Research Council, industry, university, etc.) led the project with AOSTRA support (Petroleum History Society, 2013). This meant that, for the UTF project, AOSTRA acted as a primary organization[17] as opposed to its usual position as a secondary organization (Liu and White, 2001).

5.1.3.5 AOSTRA leadership

[17] See Section 2.2.2.2 Primary and secondary organizations

In 1984, the hand-picked and internationally recruited first CEO of AOSTRA, Clem Bowman, retired. After Clem Bowman left, the recruitment of AOSTRA board members was made without the engagement of an international recruitment firm and seemed to shift to determination by political consideration (Hester and Lawrence, 2010). After Clem Bowman retired as chair of the board, AOSTRA was led for a brief period by Reginald Humphries (Suncor) and Maurice Carrigy. AOSTRA's next CEO, William Yurko, came from the government domain.

Table 15: Chairs of the AOSTRA board

Name	Years on Board
Maurice Anthony Carrigy	1975
Clem Bowman	1975 - 1984
Reginald D. Humphreys	1984 - 1986
Maurice Anthony Carrigy (acting)	1986 - 1987
William J. Yurko	1987 – 1993

(Provincial Archives of Alberta, n.d.)

As time passed, AOSTRA gained a greater body of knowledge and position in the sub-national system of innovation. This meant that, on a tactical level, AOSTRA moved from reacting to needs to assessing gaps in the system of innovation with increasing sophistication (AOSTRA, 1990). In Figure 10, AOSTRA's investments are aggregated into two periods, 1976 - 1985 and 1986 - 1993. There was a much broader range of investment in the second phase than in the first, which may reflect increased organizational capabilities and a broader range of stakeholder demands (i.e. more environmental determinism). In the second period, AOSTRA also faced pressure to become more self-sufficient in regards to funding, reflected by increased investments in the technology transfer category (Hester and Lawrence, 2010).

In 1992, after almost 20 years of operation, Ralph Klein became Alberta's Premiere, leading with an ethos of fiscal austerity and streamlining the government (Hester and Lawrence, 2010). In 1994, the Alberta Energy Minister, Patricia Black, announced a reorganization of AOSTRA, "creating a leaner, more tightly integrated organization that would be better positioned to work with industry while protecting the interests of the people of Alberta, the owners of our energy resources." (Alberta Energy, 1995). This led to AOSTRA becoming part of the Ministry of Energy in 1994, which transformed its autonomy dramatically. AOSTRA went from 'arms-length' to 'within-torso'; funding decisions were increasingly shifted to the ministry (Hester and Lawrence, 2010). While technically organizationally intact (i.e. still had the AOSTRA legislation in force), AOSTRA's program budget was dropped to approximately $7 million dollars in 1994 (Isaacs, E. 2014. Interview with Terry Ross. March 3. Calgary). Interviewees described this event as the winding down of AOSTRA.[18]

In 2000, the Alberta Science, Research and Technology Authority Amendment Act was given royal ascent. The act transferred the assets and liabilities of AOSTRA to the Alberta Science and Research Authority (ASRA),[19] effective August 1, 2000 (its legislation superseded AOSTRA's) (Hester and Lawrence, 2010). AOSTRA's name was then changed to the Alberta Energy Research Institute (AERI) and it was established as an incorporated board with no independence and no long-term funding, as the budget now followed yearly provincial budget funding provisions (Ministry of Innovation and Science, 2000).

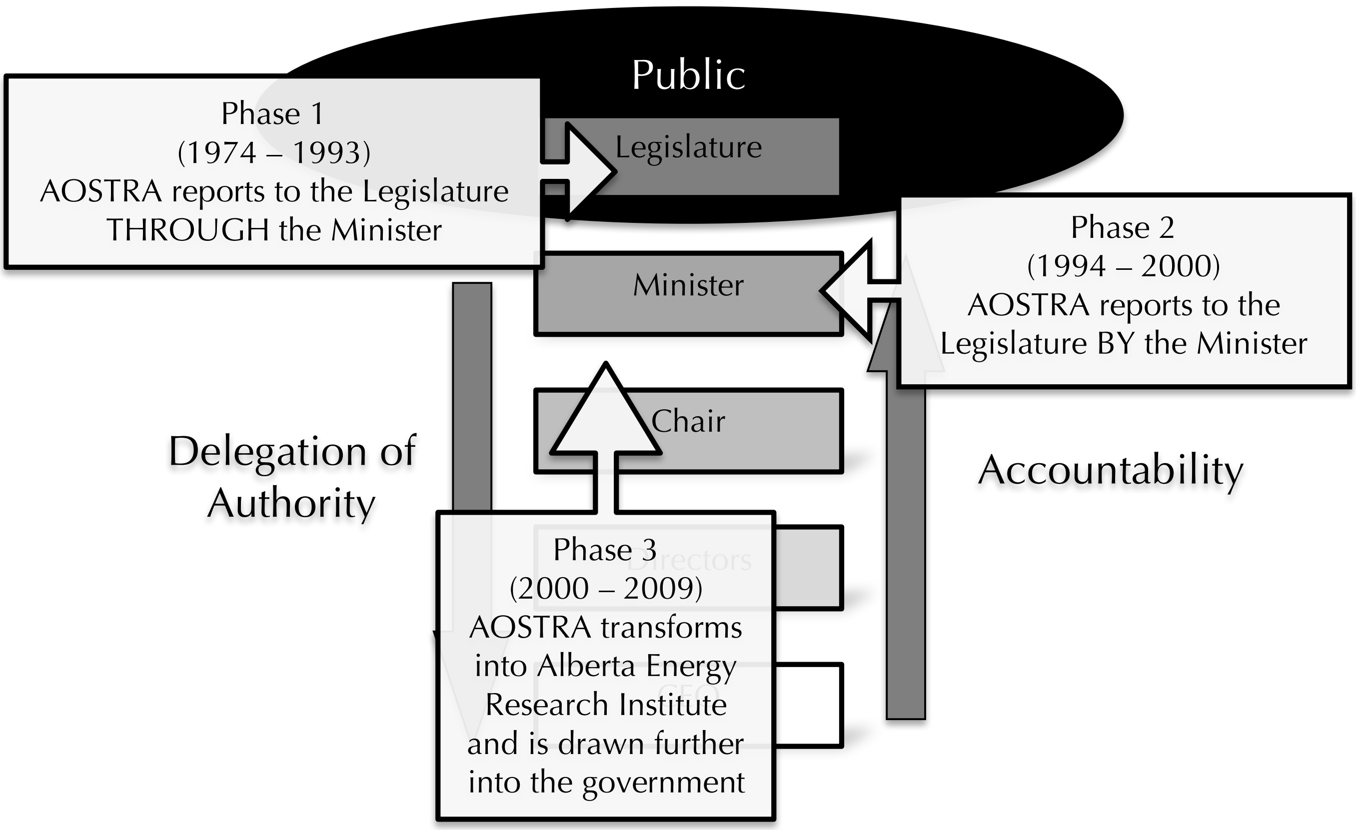
[18] AOSTRA legislation technically would remain in place until 2000. At this point, AOSTRA's organizational boundaries had been radically transformed.
[19] This is the same organization that iCORE reported to in its startup phase.

5.1.3.6 AOSTRA's evolution in authority and accountability

The first 'phase' of AOSTRA's arms-lengthiness lasted for almost 20 years and was characterized by AOSTRA reporting to the provincial legislature through various ministers.[20] As reporting was done through ministers and not by ministers, AOSTRA was effectively directly reporting to the legislature, a position of considerable arms-lengthiness for an innovation agency. AOSTRA's arms-lengthiness changed in 1994 when AOSTRA was drawn into the Ministry of Energy, had its annual budget reduced to about $7 million, and had many of its board positions filled by government employees. AOSTRA was reorganized and held accountable to a minister who then reported to the legislature. This change in agency governance represented an increase in AOSTRA's environmental determinism and a loss of much of AOSTRA's strategic choice. By this point, Clem Bowman was no longer the CEO of AOSTRA, AOSTRA had been led by Bill Yurko since 1987; this distinction is of considerable gravity, since Yurko's experience and worldview came from the government domain. 1994 marked the shift from AOSTRA as an arm's length organization to an organization within the proverbial torso of the government (even though the AOSTRA legislation was technically still in place). In 2000, the remaining parts of AOSTRA were transferred into the Alberta Science and Research Authority; AOSTRA was rebranded as the Alberta Energy Research Institute and the demise of AOSTRA was complete. Figure describes AOSTRA's evolution using the government agency model of McCrank et al. (2007).

[20] The Minister of Mines and Resources (1974), the Minister of Energy and Natural Resources (1975-1986), the Minister of Energy (1986-1994), and the Department of Energy (1994-2000).

Figure 10: Evolution in AOSTRA authority and accountability structure



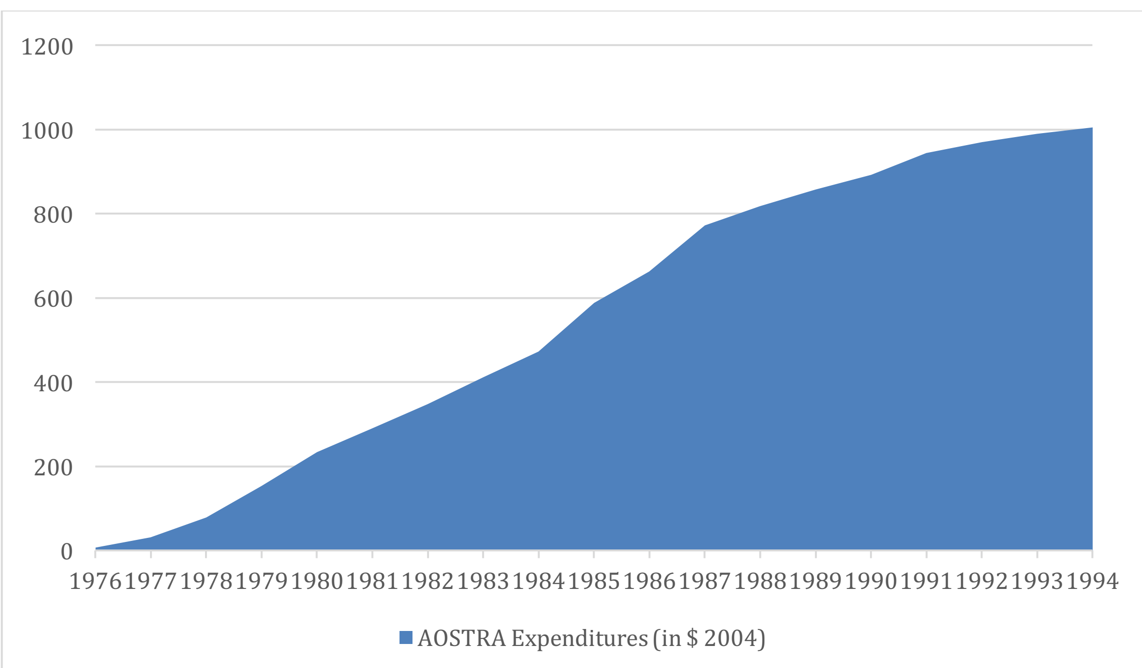
Adapted from McCrank et al. (2007)

This simplified diagrammatic representation demonstrates that AOSTRA's arms-lengthiness evolved significantly between 1974 and 2009. The next question to be answered is why the government changed the institutions that determined AOSTRA's governance. Part of the answer may lie with the mandate of AOSTRA, which centered on the development of economically viable in-situ oil sands technological systems (and supporting knowledge infrastructure, such as people trained in the systems). Perhaps, part of the answer is that AOSTRA was not designed to exist forever and, by 1994, AOSTRA had accomplished tremendous progress towards its main objective. In an interview Bob Fessendon (President of Alberta Science and Research Authority) noted that AOSTRA was not created to last forever and its evolution was impacted by the changing political and economic climate in the early 1990's (Fessendon, B. 2013. Interview with Terry Ross. December 12, Edmonton).

5.1.4 AOSTRA additionality

Applying some of the definitions and criteria discussed in Chapter 3, as assessment of the additionality of AOSTRA programs on Alberta's sub-national system of innovation. As previously discussed, AOSTRA's primary programs relied upon co-investment, with industry fostering the development of unconventional technology systems. Table 16 shows cumulative investment by AOSTRA eventually reaching just over $1 billion; of this total investment, about half was attributed to UTF or in-situ oil sands projects. Almost all of the investment funding was matched dollar for dollar by industry.

Table 16: AOSTRA expenditures (1976 – 2004)



Thus, the broadest claim of the input additionality of AOSTRA programs would be nearly $1 billion in additional industrial research and development funding, if all funding was indeed matched dollar for dollar. It is difficult to suggest that all of this industrial research and development was solely attributable to AOSTRA programs, as certainly a portion of this industrial spending would have occurred without the them. One notable exception is the industrial research and development spending focused upon SAGD in-situ techniques, since this thesis finds that commercially viable in-situ techniques largely arose from the AOSTRA investments in the UTF.

5.1.4.1 Output additionality

Output additionality infers that increased investments will result in increased innovation outputs that are attributable to the program (Buisseret et al., 1995). Estimating the complete output additionality of AOSTRA programs is beyond the scope of this thesis, however, a select example will illustrate the large output additionality of AOSTRA investment.

This thesis attributes most of the economic benefits of the SAGD production method to interventions led by AOSTRA. Of the total investment made by AOSTRA (see Table 16), about half was dedicated to in-situ oil sands projects, including the UTF. This means that, with industry leverage, nearly $1 billion was invested in the UTF and other in-situ projects between AOSTRA and industry (i.e. the input additionality discussed in the previous section). When assessing the outputs arising from this activity (beyond research outputs), Patton et al. (2006) made an economic forecast of the impacts of SAGD, presented in Table 17.

Table 17: Economic impacts of SAGD

	Direct impact on Alberta	Direct impact on Canada	Impact on Alberta with induced effects	Impact on Canada with induced effects
Increase in GDP	$155 billion	$173 billion	$194 billion	$216 billion
Labor income	$60 billion	$72 billion	$84 billion	$101 billion

(Patton et al., 2006)

The SAGD and in-situ investments supported projects that created over $155 billion (in 2005 dollars) in direct economic impact. AOSTRA did not create all of this value, but did play a critical role at a critical time within a very particular context. Nevertheless, the data provides reasonable evidence of strong output additionality from AOSTRA.

It is also important to note that AOSTRA programs created significant upgrades to the local knowledge base. In 1974, there were only ten researchers and ten students engaged in oil sands related research. By 1990, there were 80 professors and over 500 students engaged in the same (AOSTRA, 1990). AOSTRA also made important contributions to the codification of oil sands knowledge through oil sands databases, libraries, and an oil sands technology journal.

5.1.4.2 Behavioral additionality

In this context, behavior additionality refers to the change in industrial behavior that can be attributed to the AOSTRA investments.

This thesis takes the position that AOSTRA investments were largely responsible for the widespread adoption of in-situ oil sands technological systems. The behavioral additionality is macroeconomic, as investments led to the adoption of technological systems that altered Alberta's industrial structure. Behavioral additionality is especially evident in the range of specialized service companies and suppliers that emerged to meet the industrial needs of AOSTRA-enabled activities in in-situ oil sands (Isaacs, 2014). These organizations are tightly economically linked to the oil sands sector and its economic precariousness (Mansell, 2010).

The UTF provided a pathway for industry collaborators to experiment, prove that SAGD was feasible, and refine SAGD techniques (Patton et al., 2006). This AOSTRA-led project made a clear behavioral impact evidenced by industrial stakeholder engagement in the research program. Up until this initiative, industrial organizations had expressed limited research and development efforts on piloting productive in-situ extraction techniques. Without AOSTRA and the UTF, the development of Dr. Butler's SAGD processes would likely have been, at best, delayed.

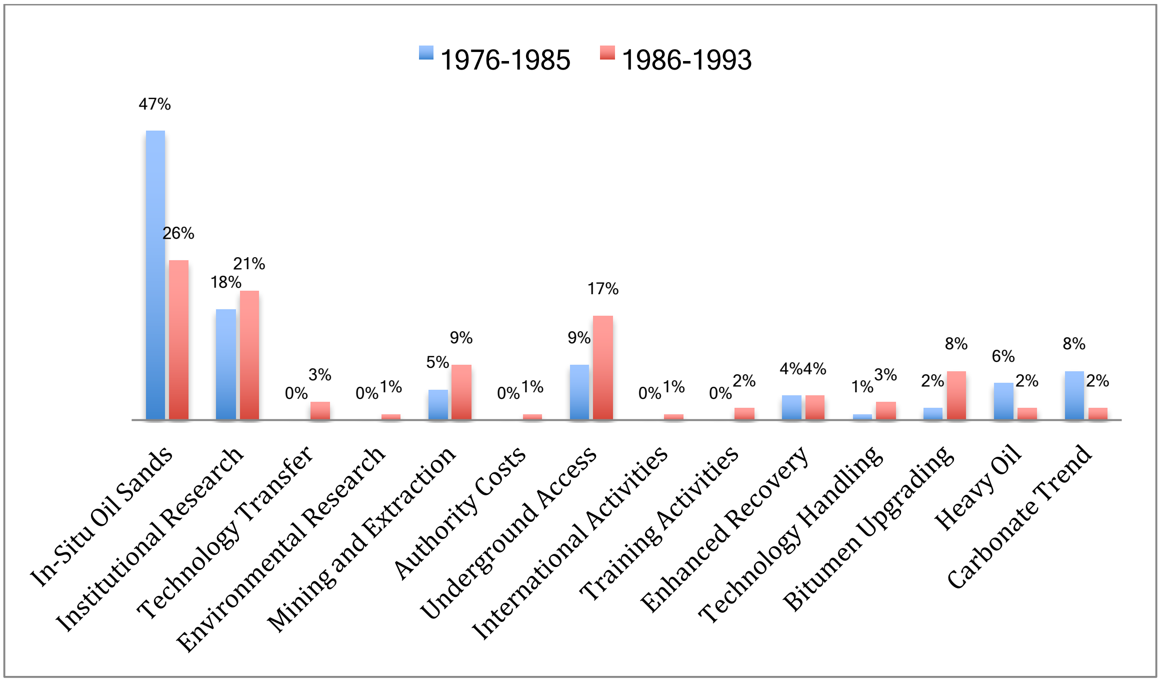
AOSTRA's intellectual property management regime encouraged widespread diffusion of knowledge amongst its industrial partners. If organizations had developed SAGD techniques on their own, these techniques would have become embedded in restrictive intellectual property regimes and organizational knowledge boundaries (Patton et al., 2006). This counter-factual knowledge management situation would have likely reduced the diffusion of useful technical knowledge within the sub-national system of innovation.

AOSTRA projects resulted in substantial skill and knowledge development, a crucial feedstock for the commercial scale viability of the oil sands. When AOSTRA began, there was very little by the way of research and scientific knowledge relating to the oil sands. In just over a decade, the in-situ oil sands research community grew many times over, a new oil sands research journal was established, and information services to assist with the diffusion of knowledge had been established (AOSTRA, 1990; Petroleum Historical Society, 2013). In addition, individuals involved with AOSTRA's industrial projects were empowered with knowledge and trained in technologies that were complex, new to Alberta (and often new to the world), and readily translatable to industry.

If there is an area where AOSTRA's behavioral additionality could be challenged, it is in the organization's focus, or lack of focus, on the environment. While the environment was heralded as an area of research focus (AOSTRA, 1980), the size of the investment in environmental research was relatively minor (see Figure 10). In an interview with Clem Bowman, he stated that AOSTRA could have put more emphasis on the environmental aspects of the industry (Alberta Oil Magazine, 2013). The meager environmental investments by AOSTRA are an anecdote for industrial indifference to environmental research. In fact, not one dollar was allocated to environmental research in the first ten years of AOSTRA operation (Hester and Lawrence, 2010).[21] The Albertan industry considered environmental research as secondary to investments that were likely to provide economic returns (Isaacs, 2013). Clem Bowman's expressed his thoughts; "If we had only paid more attention, we would be in a much better position now … there was no public awareness at that time, which meant there was no political pressure for anything to happen." (Hester and Lawrence, 2010, p.35).

Figure 10: Distribution of AOSTRA investments (percentage of total)

[21] Although, in interviews with Hester and Lawrence, Clem Bowman noted that some environmental monitoring activities occurred but were not recorded as environmental research.



(Hester and Lawrence, 2010)

5.1.5 Conclusions

AOSTRA emerged from a historical climate where oil sands research was an awkward initiative managed between London, Ottawa, Edmonton, and a range of industrial organizations (including the entrenched conventional oil sector).

The need for an organization like AOSTRA arose from several preconditions. There was an enormous hydrocarbon deposit under the institutional control of the Government of Alberta and a significant perceived demand for oil while conventional deposits and oil sands accessible by mining were in decline. Complicating this issue, industrial organizations operating in Alberta were not set on a trajectory to develop the in-situ technology systems (including personnel) required to develop the oil sands. There was an existing innovation agency, the Alberta Research Council, with significant research capabilities to support future initiatives. There was also the existing research of Dr. Roger Butler on the SAGD process for oil sands extraction. The catalyst for all of these conditions to coalesce into AOSTRA was the leadership of Peter Lougheed, who was enthusiastic about the need for an organization to lead a breakthrough and empowered as the Premier of Alberta to facilitate its creation.

When AOSTRA was created, Peter Lougheed was deeply involved in its design, the leadership of its board, ensuring its long-term funding, positioning it in the sub-national system of innovation (under the leadership of the Alberta Research Council), and approaching the challenge of engaging Albertan industry with an innovative IP policy. Once in operation, AOSTRA was lauded for having a strong board and CEO alongside a clear purpose. AOSTRA activities were primarily focused on the development of techniques for the commercialization of oil sands and heavy oil, the piloting of new in-situ processes, basic research, the accumulation and distribution of technology, and the training and support of HQP. AOSTRA operated in its inaugural form from 1974 to 1993 and, although it technically remained in operation until 2000, its programs continue to this day. Notable AOSTRA accomplishments include leading the Underground Test Facility initiative, which led to advancements in SAGD processes, and the growth of oil sands research capabilities across universities, industry, and research institutions. In addition, there were copious AOSTRA industry technology development projects and significant codification of oil sands knowledge resulted from them. However, AOSTRA may be seen as having failed in its mandate to adequately address the intense environmental challenges presented by the oil sands processes.

AOSTRA arose from a clear opportunity that presented in a natural resource based system of innovation. It transformed the behaviors of industry, academia, and government toward the transformation of boutique technology platforms designed to upgrade the local resource.

5.2 Alberta Heritage Foundation for Medical Research (AHFMR)

The Alberta Heritage Foundation for Medical Research (AHFMR) was mandated to build an elite biomedical research system in Alberta[22]. The resources required to fund this development came from the Alberta Heritage Fund (from revenue generated by the energy sector). Unlike AOSTRA, the need for AHFMR did not arise from a latent economic opportunity locked behind research and development challenges; it was driven instead by the leadership of universities and the governmental desire to redistribute natural resource wealth into biomedical research capabilities.

> Our province is rich in talented people and we have outstanding scientists working in our universities. This permanent commitment to medical research on a very major scale will attract truly outstanding research-orientated staff members … It is a part of a commitment made by the government to invest in the future of health care … [it] will provide an opportunity for leadership in health research in Canada … [and] will assist in the diversification of the provincial economy through the creation of a science industry.
> (Peter Lougheed, 1979)

AHFMR arose in Alberta due to; investment capital from natural resources, perceived challenges to regional biomedical research capacity, and institutional entrepreneurship by the universities and Peter Louagheed. This section discusses the creation of AHFMR, how its programs affected the regional system of innovation, how it evolved, and its discernable impacts.

[22] AHFMR programs expanded from biomedical research to include clinical and population health research. While these programs led to positive impacts on the range and quality of services available in Alberta they are deemed largely out of scope of this thesis.

Before exploring AHFMR, some quick definitions of specialized terminology are required:

- 'Biomedical research', in this section, is a global term that refers to the search for new knowledge about the maintenance of health and treatment of disease. It encompasses the continuum of research from basic laboratory research to population-based research.
- 'Basic research' is concerned with fundamental biological questions relating to basic functions and mechanisms in areas such as anatomy, biochemistry, chemistry, mathematics, pathology, pharmacology, and physics.
- 'Clinical research' is conducted on the maintenance of health and the treatment of disease.
- 'Health research' generates and tests hypotheses related to the promotion of health and the prevention of disease in the community.
  (AHFMR, 1992)

5.2.1 AHFMR start-up

AHFMR was conceived of in 1975 when Peter Lougheed was asked whether the newly announced Alberta Heritage Trust Fund would support basic medical research. Two doctors, Dr. Neil Madson (University of Alberta) and Dr. Bill Tatton (University of Calgary), were concerned that the level of accessible medical research funding in Alberta had been eroding and decided to contact Peter Lougheed. The Lougheed government responded that this would be considered if requests came from both the University of Calgary and the University of Alberta (Lampard, 2008).

Dr. Tatton and Dr. Madson's proposal to the Lougheed government led to the identification of three shortfalls in Alberta's medical system of innovation:

- there was a lack of continuity in Canadian research funding;
- there was a lack of career opportunities for investigators within the university system, due to budget cutbacks; and
- there was a lack of enthusiasm in youth for the pursuit of a research career (Bradley, 1993).

Over the next two years, a special advisor to Peter Lougheed, Dr. Bradley, would continue to develop the proposal with the help of international experts. Dr. Bradley was a physician with considerable experience in hospital administration, had served as chairman of the board of governors for the University of Alberta, and was serving as the chairman of the Alberta Hospital Services Commission. The proposal was to establish an arms-length government foundation for the support of biomedical research (Bradley, 1993).

The progress towards the creation of AHFMR took a major step forward in 1976, when the Alberta Heritage Fund was formed. Only eight days later, the deans of the of the faculties of medicine presented a 28-page report to the government which recommended the establishment of an 'Albertan Heritage Health Research Fund'. The government accepted the proposal for a $75 million medical research fund and the kernel for AHFMR was born. Peter Lougheed supported the vision of a biomedical research agency and entrusted its development to carefully selected groups from its startup through to its ongoing operations (Dyck, R. 2013. Interview with Terry Ross. December 13, Edmonton).

Next, a committee was curated to develop the best framework to support medical research in Alberta (Lampard, 2011). After the original proposal was thoroughly assessed by the government, the endowment was modified to $300 million, which was determined to be more capable of providing sustainable funding than an operating fund (Keough, K. 2014. Interview with Terry Ross. March 6, Edmonton). By 1977, the concept for AHFMR had evolved into a foundation positioned at arms-length from the government with guaranteed funding of $50 million over its first five years. With this framework in place, work began on establishing an Albertan Health Research Foundation (Lampard, 2011). By November 1977, the details of the new initiative had become clearer and the refined agency was re-named the 'Alberta Heritage Foundation for Medical Research' and was made responsible for funding medical research, rather than the previous scope of general heath research. It would also coordinate with the government's innovation policy and would be large enough to allow operating costs to be met through interest revenues (Lampard, 2011).

The university proposals were included in the draft AHFMR legislation. In 1978, Peter Lougheed collected feedback on the proposal and concluded that Albertans would support the idea of a health-focused innovation agency (Lampard, 2011). By 1979, Peter Lougheed had met with the Dean of Harvard Medical School, an Albertan named Dr. Joseph Martin,[23] to discuss AHFMR. Lampard (2011) reviews a personal letter that Dr. Martin had written to the dean of The University of Calgary, Lionel McLeod.

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[23] Dr. Martin joined the scientific advisory committee in 1982 and chaired the international board of review in 2004. (Lampard, 2011)

> [Lougheed] considers this endeavor to be a major part of the heritage that he will leave to the province and that he wants to do it right … The administrative organization is sound … and there is a genuine effort on his part to hold the whole endeavor at arm's length from government, to 'de-politicize' it and to allow academic freedom.
> (Lampard, 2011)

AHFMR officially began with the proclamation of the Alberta Heritage Foundation for Medical Research Act, on March 19, 1980. After almost six years of development, AHFMR began with an endowment of $300 million, an enormous amount even today. The endowment would support the delivery of all of AHFMR's proposed medical research programs at $30 million, annually (Lampard, 2011; Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).[24]

Peter Lougheed wanted this innovation agency to operate with significant autonomy from the government (Keough, K. 2014. Interview with Terry Ross. March 6. Edmonton). Lougheed had catalyzed the emergence and development of AHFMR under the guidance of trusted and capable stakeholders (Dyck, R. 2013. Interview with Terry Ross. December 13, Edmonton). His approach to AHFMR's capabilities, its autonomy, and his support of the initiative are reflected in his concluding statements from the first board of trustees meeting. He concluded with congratulations, a wave, and the comment, "I'll see you in six years,[25] but my door is open if you need any advice." (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton; Magnon, J. 2014. Interview with Terry Ross. July 4. Edmonton; Lampard, 2011).

[24] Approximately $840 million in 2014 dollars.
[25] At the first International Board of Review meeting.

Soon after the establishment of AHFMR, Alberta's economic environment changed drastically, as interest rates climbed sharply to 12% and the price of oil dropped, leaving Alberta with billion dollar deficits by the mid-1980s. AHFMR was fortunate to have been established prior to this economic downturn, as it would have been unlikely to receive funding if its intended inception had followed the downturn (Lampard, 1980).

In the late 1990s, the government considered reintegrating AHFMR into its operations and, thus, would have effectively ended AHFMR in a way not dissimilar to AOSTRA. However, there was no significant change made to AHFMR's operations during this period and AHFMR continued until it was dissolved through Bill 27, in 2009 (Lampard, 2008).

5.2.1.1 AHFMR boards and committees

The proposal for AHFMR included a governing Board of Trustees, a scientific advisory committee to adjudicate grant requests, and an international board of review to evaluate the entire organization, its mandate, and its programs.

5.2.1.1.1 AHFMR Board of Trustees

Several noteworthy roles were undertaken by the AHFMR Board of Trustees. The board was responsible for providing guidance on AHFMR's strategy to increase biomedical research and innovation capabilities, and their dogged determination to fulfill this mandate has been noted as a key driver of AHFMR's success (Dyck,

R. 2013. Interview with Terry Ross. December 13, Edmonton). They also played an important role in maintaining the collaborative balance between the government and AHFMR and were responsible for generating calls on the Heritage Fund.

The AHFMR Board of Trustees reported to a committee of the legislature once every two to four years. It had nine trustee positions appointed by the government, five trustee positions appointed by the universities, colleges, and foundations, and a trustee nomination. The board of trustees appointed Dr. John Bradley as executive director, appointed an ad hoc scientific advisory committee (July 1980), and began the search for a president (Lampard, 2011).

The board of trustees was responsible for creating calls on the endowment used to fund AHFMR programs and operations. The AHFMR funding model provided additional stability for planning operations (although funding was exposed to market risk) and was, generally, empowering:

> You had a funding stream that you could plan on. When I say you could plan on, I mean we also had to face the exigencies of the market. If there was a sharp downturn you would take that into account and ramp down your spending.
> (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

The CEO and the board of trustees needed to make strategic decisions about the size of the calls and how each may affect future opportunities.

> Some years you overspent and other years you underspent. In the average, you sort of came back so you were building the endowment. And the endowment grew over the time I was there and we did that very

> deliberately because we recognized the fact that we were going to need more and more funds in the future so we would need a vehicle that could generate more and more funds.
> (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton)

Through the 1990s, as the endowment grew[26], it became challenging for the AHFMR to effectively distribute its funds (Magnon, J. 2014. Interview with Terry Ross. July 4, Edmonton). The sheer amount of funds to be distributed sometimes led to challenges in finding enough quality investment opportunities to meet the AHFMR mandate.

The board of trustees maintained an important role by mediating between the government (and the adjacent political ecosystem) and the CEO of AHFMR. An interviewee stated that:

> [the Board of Trustees provided] a layer of advice between the government and the actual operation of the organization … I can not stress enough; the strong and committed board of trustees that is respected within the political system is critical in providing the interface that keeps the arms-length relationship and maintains it. When that goes, then it becomes much more difficult to maintain that kind of organization.
> (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

In the early days, the board played an important role in supporting the CEO, aided significantly by "the quality of the board of trustees. They were people of

[26] Although the endowment grew, some felt its growth was too conservative. An AHMFR interviewee noted frustration at the conservative investment strategy utilized by the fund managers, suggesting that investment returns were often in the bottom quartile of comparable investments. This perceived underperformance of the fund led to opportunity costs of approximately $10 million per year.

stature, clearly respected … a dedicated, talented board of trustees can be really helpful too because they're out there in the community and picking up [strategic information]." (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

5.2.1.1.2 AHFMR Scientific Advisory Committee

In 1979, Dr. Bradley proposed the draft terms of reference for the scientific advisory committee (SAC) and the first official SAC was later appointed, in 1982. The committee was to consist of 13 Nobel Laureates, or equivalents, with the mandate to develop an adjudication system for the awards and grants. Applications for programs were approved only after successful peer review and recommendation by the SAC (Lampard, 2011).

AHFMR also developed other adjudication bodies for the evaluation of awards, with top awards reviewed by international level experts and more junior awards, awarded to postdoctoral fellows and graduate students, by local individuals. Without elite reviewers, AHFMR instruments would have not been perceived as legitimate by the scientific community (AHFMR, 1998; AHFMR 2004).

> One of the things that allowed AHFMR to do so well and have high credibility was that it had a number of advisory bodies. These were arranged in rank order … the highest order advisory body dealt with the highest recommendations and with the most senior scientists … the committee members were all from outside of Canada and that kept a high standard of science.
> (Keough, K. 2014. Interview with Terry Ross. March 6, Edmonton).

When AHFMR broadened its research scope into the health research domain, it created the Health Advisory Committee which had some overlap with the existing basic research advisory committee. A former AHFMR CEO explained:

> To get the health research going, we created a secondary scientific advisory council to handle the health research side because at that time, internationally, there was sort of a battle for resources in the country between … basic science fundamentals and … the more health-related areas of the spectrum. And so we got good advisors in both, we had people cross between them; sit in both so you get cross-fertilization. (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

5.2.1.1.3 AHFMR International Board of Review

When it came to evaluating the entire AHFMR body and its programs, the board of trustees organized international experts to form their International Board of Review (IBR). Approximately every eight years, the IBR would review AHFMR's programs and operations and provide advice to the board of trustees through AHFMR's CEO (AHFMR, 1998; Lampard, 2011). The IBR reports provided codified suggestions and recommendations to the board of AHFMR, which could then be used to improve its operations and strategy. However, it was often tacit and informal information, shared through the IBR process, that proved most valuable to the leadership of AHFMR. A CEO of AHFMR shared his thoughts about the value of the IBR:

> The IBRs were perhaps more helpful than that; the reports are bare bones, there was a lot of information in terms of comments and the verbal stuff and so on - very helpful in terms of things that were bothering them, things that you hadn't really looked at or thought much about that surfaced again and you thought and worried about… they were helpful, no two ways about it. I really found their comments and their insights just enormously helpful.

(Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

In 1998, consideration was given by the Alberta government to reintegrate the AHFMR's endowment into the provincial balance sheet. The IBR met one year early, in 1997, to address this concern and the AHFMR's performance. As events unfolded, no changes were made to the structure, reporting mechanism, or financial framework (Lampard, 2008). While it is not known whether the outputs of the review had any direct impact on the government's choice of action, it is certain that the IBR report were presented to the government to justify the continuation of AHFMR.

5.2.2 AHFMR funding

AHFMR's board of trustees managed calls for funding the operations and programs. As mentioned earlier, there were challenges in the disbursement of funding when returns were high. AHFMR's endowment grew significantly in the 1990s, which resulted in challenges regarding investing the growing pool of capital effectively. There was also a feeling by members of the Board and the CEO that, for certain periods of time, the investment strategy of the endowment was too modest. This cautious investment strategy led to perceptions that the endowment was underperforming and providing a lower level of funding to the organization than was otherwise possible. Concurrent to these concerns was an evolving health research funding landscape (i.e. CHSRF and CFI) that Alberta could move to take better advantage of. Evolutionary pressure emerged to develop additional instruments (beyond HQP support) in support of the innovation mandate (while abstaining from providing programs that would replace federal government programs) (Magnon, J. 2014. Interview with Terry Ross. July 4. Edmonton).

5.2.3 AHFMR model

AHFMR designed and managed a suite of programs for universities (and colleges) to increase their activities in medical research by funding graduate students, postdoctoral fellows, and visiting fellows. The grants to these researchers were to be for as long as possible; in the case of top elite researchers, up to 20 years, with applicants renewing their applications every five to seven years. Appropriate working space for these research groups was also attended to by the AHFMR model. AHFMR committees estimated that a senior researcher would require $150,000 per year and 1,500 square feet of lab space (Lampard, 2011). Support for expensive university lab space and provision of the appropriate funding term would both prove to be important evolutionary forces in AHFMR's future.

Table 18 presents some of the key evolutions in the AHFMR instrument portfolio; of particular note is the growth of instrument scope over time.[27] AHFMR programs began with a focus on pure medical research and later expanded into the area of general health (i.e. closer to direct medical interventions), due to a desire to conduct research that may most directly benefit the Albertan public (as fundamental research has a longer path to application). AHFMR, therefore, had to find a way to balance the need for fundamental biomedical research with support of research that was more directly applicable to the operation of the health system and programs "to provide vehicles to get the knowledge that was being generated into the system for the benefit of the health of Albertans." (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

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[27] AOSTRA also experienced a creep in the scope of their activities.

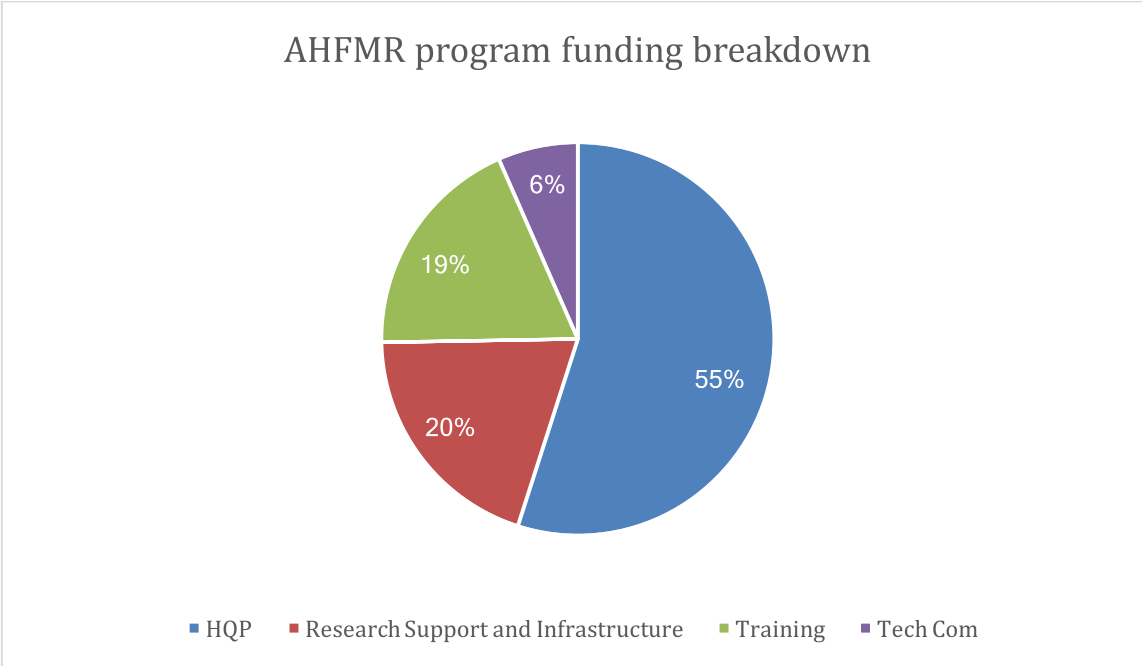
Table 18: AHFMR instrument milestones

1981	First grant competitions
1986	Acceptance of applications from clinical medical investigators
1987	Technology transfer program
1994	Population health program
1996	Health research grant requests
1998	Supplementary research allowances
1999	Recruitment fund to fast-track future researchers
1999	Meritorious research prizes ($1 million per year)
2000	Heritage research summer program
2003	Management of other health research funds
2006	Collaborative Research Awards

(AHFMR, 1987; AHFMR, 1993; AHFMR, 1998; AHFMR, 2004; Lampard, 2011; Keough, K. 2014. Interview with Terry Ross, March 6, Edmonton)

AHFMR programs can be placed into four categories: personnel establishment programs, research support and infrastructure programs, training programs, and technology transfer programs (AHFMR, 1986; AHFMR, 1992). The funding distribution is broken down in Figure 11.

Figure 11: AHFMR program funding (1992)



(AHFMR, 1992)

5.2.3.1 Personnel establishment programs

AHFMR's Highly Qualified Personnel (HQP) programs focused upon the development of research communities at Albertan universities through the provision of salaries and fringe benefits to researchers of various pedigrees for periods of five years, renewable after the first term of award had elapsed (AHFMR, 1986). An important element of the program's design was that AHFMR subsidized a very high proportion (if not all) of researchers' salaries as they progressed through their careers. The University of Calgary and the University of Alberta were eager to utilize AHFMR funding to grow their departments and the programs became well established within the structure of their medical faculties. Another important AHMFR goal is to increase the capacity of the health system as a whole for utilizing health research, although it is was a relatively small investment compared to the HQP programs (AHFMR, 2006).

The HQP programs successfully enriched the capabilities and pedigrees of the university biomedical systems (see 'output additionality', below). However, the programs also embedded a funding model with unanticipated consequences. The AHFMR HQP funding programs became an entrenched part of the university research development routines and, due to some design choices, this led to significant problems. Over time, AHFMR funding for HQP salaries became an expectation of the universities and they began to allocate funds normally earmarked for researcher salaries to other parts of the university. This led to a situation where a hypothetical withdrawal of AHFMR funding would induce repercussions (budget reallocation to cover AHFMR funds) that would be felt beyond the boundaries of the biomedical research community. Complete AHFMR support also meant that, at any point along their career path, a researcher could lose all their salary if they were no longer supported by AHFMR; a situation that led to high stress among some researchers. In practice, few researchers had to grapple with full salary loss because they remained competitive throughout their careers or the universities found other means to support their salaries. (Keough, K. 2014. Interview with Terry Ross. March 6. Edmonton)[28]. AHFMR introduced a researcher funding method that, had they been unsuccessful in their AHFMR renewals so that

> [the researchers] had a couple of years to figure out a way to either wind down or transfer to something else (e.g. administration) … it recognized the exigencies of life and created an opportunity for people to move off to other activities, very important activities. I mean if you look at some of the senior administration in both universities and elsewhere in this country, they are AHFMR alumni.
> (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

[28] Of course, highly skilled researchers may have been able to find other career opportunities beyond Alberta as well.

The AHFMR HQP program was designed to be increasingly difficult to secure, as a researcher career progressed. An AHFMR senior researcher award was "really a highly-prized thing, they were harder than hell to get" (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton). Nevertheless, the AHFMR HQP program created inflationary pressure on itself through its continuous reward of research excellence from early career through to the top levels of research; the problem was in increased expenses (e.g. salary, research program inputs, etc.) associated with career advancement. As more and more researchers advanced through their careers with AHFMR support, the AHFMR program budget was disproportionately allocated to senior researchers and the proportion of the budget available for early-career biomedical researchers shrank.

In 1998, the Canada Research Chairs (CRC) program was introduced across Canada and eroded the uniqueness of AHFMR's HQP program for certain types of biomedical researchers. On the positive side, the CRC program provided Alberta biomedical researchers with another important source of funding stability and gave Albertan universities an additional recruitment tool. However, it also provided medical research organizations outside of Alberta with a program to target top talent and lure biomedical researchers out of Alberta. In response to this, the CEO of AHFMR, Matt Spence (1991 - 2004), introduced research salary prizes for top AHFMR talent. Starting in 1999, 100 prizes were given out per year, with junior faculty receiving $10,000 awards and senior faculty receiving $20,000 (Lampard, 2011).

5.2.3.2 Medical research buildings

AHFMR had designed a suite of programs to aid the universities in increasing their activities in medical research through the funding of graduate students, postdoctoral fellows, and visiting fellows. The researcher grants were for terms that were as long as possible; up to 20 years and renewable every five to seven. The committees estimated that a senior researcher would require $150,000 per year and 1,500 square feet of lab space (Lampard, 2011). Growth in the successful attraction and retention of AHFMR researchers led to increasing demands for physical space in which to conduct the research. Scarcity of research space created a burdensome bottleneck in the research development efforts of AHFMR.

The 1986 International Board of Review noted that:

> In 1984, the AHFMR Scientific Advisory Council concluded that new multidisciplinary medical research groups could not be established in the absence of new and appropriate laboratory space. As neither of the Universities of Alberta or Calgary were able to generate funds for the construction of new space and as the foundation would have to consider the payment of substantial rental costs for commercial space, the [AHFMR] trustees agreed to provide funds for 5,000 net square meters of research space at both the University of Alberta and the University of Calgary. The facilities would be connected to the principal teaching hospitals and would house major multidisciplinary research groups based upon existing or readily developable basic science strengths …. The foundation would retain the right of approval of space allocation for ten years. Both the University of Alberta and the University of Calgary named the building 'Heritage Medical Research Building'.
> (AHFMR, 1986)

With the AHFMR funding in place, the construction of two commissioned research buildings, one at the University of Alberta and one at the University of Calgary, began in 1983 and was completed in 1988. This was the first of two attempts made to address the research space bottleneck (Lampard, 2011).

The 1998 IBR gave its approval for AHFMR to develop and maintain a policy for partnering with other organizations for funding required infrastructure.

> In the late 1980s, AHFMR funded the construction of researching buildings at the University of Alberta and the University of Calgary. These two buildings have had a very beneficial effect on the establishment and expansion of biomedical research initiatives in Alberta … In addition, CFI is a new federally funded initiative directed at research infrastructure support and development. The CFI program has a requirement for partnership funding which [is] bound to [have] impact on AHFMR. (AHFMR, 1998)

In 2000, AHFMR made a second major infrastructure investment of $40 million toward two additional biomedical research facilities at the University of Alberta and University of Calgary, respectively. AHFMR leveraged its investment with funding from Ottawa and the facilities were completed by 2007. In 2004, as AHFMR continued to invest in research facilities, the IBR commented that research space was no longer a crucial matter.

> [The IBR recommends] the Foundation henceforth limit its contribution to capital construction only to those construction projects demonstrated to be highly transformative and that are consonant with the Foundation's strategic plan. Consideration for an AHFMR involvement in capital construction projects should therefore provide a rationale for a clear competitive advantage for the researchers and/or permit the undertaking of research endeavors by the Foundation that would not be possible otherwise.

> (AHFMR, 2004)

5.2.3.3 Technology transfer programs

An important evolution in the focus of AHFMR programs occurred when technology commercialization instruments were added to the AHFMR program portfolio, in 1987.

> [The technology commercialization program] was another way of getting information out to the benefit of the health of Albertans, if we can get new and better products … to get an economical return to the province etc., this all plays to that thrust to improve the socioeconomic status of the province.
> (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton)

The goal now was to create a category of people with both the research skills and business skills necessary to progress their ideas through technology readiness levels and into the industrial domain.

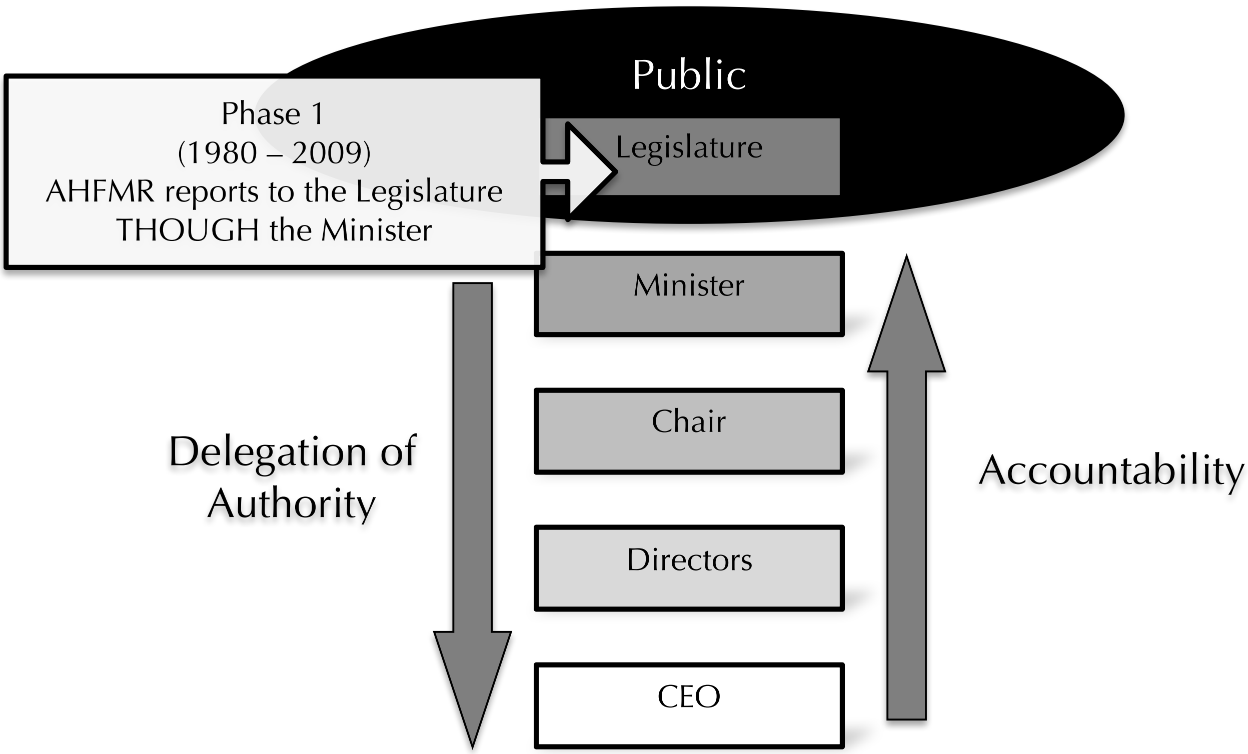
> I used to say that our trouble was not brains, we had lots of brains but they didn't know how to run a company. What I needed was a density of early stage managers and so on who could partner if you like and take this thing forward … [we discussed] how we could create a category of people with those sorts of skills that could take things forward.
> (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton)

This moved AHFMR from an organization focused on the university environment to considering issues from the industrial domain as well. AHFMR's 2004 IBR strongly advised that the technology commercialization function was, at best, an unwelcome distraction from the core mandate and, at worst, made AHFMR prone to criticism on its ability to meet the complexities and challenges of technology commercialization (AHFMR, 2004; Magnon, J. 2014. Interview with Terry Ross. July 4. Edmonton).

5.2.3.4 AHFMR's evolution in authority and accountability

When examining AHFMR's arms-lengthiness, this study did not find that AHFMR experienced a significant change during the period of study. The closest AHFMR came to a change in arms-lengthiness was the 1997 - 1998 review conducted by the government. This review focused on AHFMR's performance and led to government consideration of changes to its structure, reporting mechanism, and financial framework. AHFMR then conducted its internal review process with its IBR a year early, to allow the resulting insights to inform the government and, in the end, no material changes to AHFMR's arms-lengthiness were made (Lampard, 2008).

Figure 15: Evolution of AHFMR authority and accountability structure



Adapted from McCrank et al. (2007)

The AHFMR example shows that considerable unrealized changes to arms-lengthiness are possible; it is also possible for an innovation agency to provide important information about its impact to the government that may influence the trajectory of its arms-lengthiness.

5.2.4 AHFMR additionality

5.2.4.1 <u>Input additionality</u>

In AHFMR's context, input additionality refers to additional inputs to biomedical research (e.g. incremental research funding flowing from other organizations) that arose because of AHFMR investments. AHFMR's investments in developing researchers and infrastructure are expected to have culminated in research teams highly capable of securing additional research funding from non-AHFMR sources. Matthew Spence describes this dynamic:

> … we were creating pirates, because what we were doing was basically helping them build a ship, whether this was their lab or whatever their research was. We were providing their basic salary support and then were saying to them "get out there and get money" … we were pointed right at the federal granting structure and everything else and you could see it in the funds coming into the province that just shot up as AHMFR invested. (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton) [29]

Examples of AHFMR input additionality include:

- Total research funding from all non-AHFMR sources increased from under $10 million to over $70 million in 1996 (AHFMR, 1998).

- Total funding for biomedical research at the University of Alberta went from $20 million during the period from 1983 to 1984 to $53.8 million from 1996 to 1997 (AHFMR, 1998).

- Total funding for biomedical research at the University of Calgary went from $2.5million in 1979 to $47 million during the period from 1996 to 1997 (AHFMR, 1998).

[29] AHFMR investment totaled over $540 million between 1980 and 1998, which gives some idea of the proportion of input additionality.

- University of Calgary awards from the MRC (a federal funding agency) rose from $3 million in 1982 to $11.8 million from 1996 to 1997 (AHFMR, 1998).

- In 1979, the total MRC/CIHR funding allocated to biomedical research in Alberta was about $5 million (or 7% of all MRC/CIHR funding). By 2004, the amount of funding had risen to $70 million (or 12% of all MRC/CIHR funding) (AHFMR, 2004).

- The National Institute of Health is an American biomedical research funding agency that provides funding to Canadian biomedical research opportunities. In Appendix B, an overview of the total funding provided to Alberta and other Canadian provinces between 1992 and 2006 is presented. Figure 12 describes the NIH biomedical funding awarded to Canadian provinces, per capita. While it is not possible to attribute this increase in per capita funding to AHFMR without more research, Appendix B and Figure 12 infer that this increase occurred in Alberta to make applications to NIH more successful. The increase in attractiveness to NIH with respect to funding is both absolute and relative to every other Canadian jurisdiction.

Figure 12: NIH funding per capita

	1996	2001	2006	% Difference 96 - 01	% Difference 01 - 06	% Difference 96 - 06
Canada	$0.61	$0.81	$1.92	32%	118%	214%
Nova Scotia	$0.12[30]	$0.15	$0.29	25%	46%	145%
Quebec	$0.24	$0.70	$0.98	184%	122%	298%
Ontario	$0.69	$1.09	$2.82	57%	117%	308%
Manitoba	$0.11	$1.13	$1.10	931%	-43%	900%
Alberta	$0.04	$0.55	$2.71	1150%	226%	6005%

[30] To allow for a percentage comparison, 1997 NIH funding was used for Nova Scotia.

British Columbia	$0.27	$0.95	$1.98		253%	112%	634%

(Adapte from NIH, 2010)

5.2.4.2 Output additionality

Output additionality assumes that increased investments will result in increased innovation outputs that are attributable to the program (Buisseret et al., 1995). Ideally, additional outputs are attributable to the program and not other factors, an ideal that is often extremely difficult to prove. The following are examples of possible AHFMR output additionality.

- There are numerous examples of AHFMR investigators and biomedical research groups having earned international recognition.

- AHFMR (2004) claims that Alberta's biomedical research universities attract $250 million in total research funding, which translates, directly or indirectly, into up to 15,000 jobs in the province (AHFMR, 2004).

- AHFMR's recruitment led to increased leadership capacity within the management of Alberta's biomedical research community. "When I look at the leadership at the University of Alberta and the University of Calgary, a lot of AHFMR people filed through there. Whether they would have been here anyway… I doubt it, quite frankly." (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton).

- There were significant additions of medical research space and infrastructure to Albertan universities.

- An analysis of health research funding across sub-national regions in Canada (Zwicker and Emery, 2015) proposed that regions with significant investments in health research have increased health outcomes (as measured by changes in mortality by avoidable causes). The suggestion made is that medical knowledge can be better applied in regions where there are more health professionals supported by investments in biomedical research. While this proposition intuitively makes sense from a knowledge management perspective the data presented on Alberta's performance does not make a strong case that AHFMR's investment resulted in reduced mortality for Albertans.

Biomedical research outputs are difficult to quantify, let alone aggregate, in qualitative and quantitative manners. AHFMR reports are filled with many rich qualitative narratives around the progress made; reference is made to literally dozens of notable research and technological advances, each meaningful to one or more of the basic, clinical, and health domains. Through the lens of these reports, the perceived values of specific research outputs often have qualitative, subjective, and personal dimensions to them. One interviewee noted that, when discussing the performance of AHFMR, it was common for Alberta MLAs (Members of the Legislative Assembly) to be most engaged with topics relating to streams of biomedical research that affected members of their friends or families. Matt Spence noted, "Interestingly enough, what was more of an interest to them [MLAs] were the diseases that were pressing in their family and what were we doing about those.". The output additionality of AHFMR's biomedical research endeavors is not easily deduced, quantified, or assessed without personal bias. These research outcomes are extremely unique and difficult to aggregate in any quantitative manner. However, AHFMR did expend significant effort on the evaluation of leading impact-assessment methodologies.

AHFMR's technology commercialization program's output additionality is challenging to assess. The outputs from the 65 investments were tricky to aggregate and summarize. The 1992 report on the technology commercialization program summarizes the impact thusly, "Some projects have attracted additional funding, some have been patented and licensed and some have generated new companies. Most are still in the lengthy commercialization process." (AHFMR, 1992). The tone of the 2004 IBR report was appreciative of the capabilities of AHFMR, however, the IBR felt that technology commercialization was a function that other specialist organizations in the regional system of innovation should manage.

> AHFMR should reconsider its decision to continue its efforts in this field despite the recommendation of the previous IBR to discontinue them. AHFMR should work hard to transfer management, review, and responsibility for financial support to a different organization with greater high-tech management and financial expertise.
> (AHFMR IBR, 2004)

While some of the above outputs would have certainly occurred without AHFMR managing the allocation of funding, there is a case to be made for the rigor applied to the biomedical research selection process having led to improvement in the quality of output. Building an institution like AHFMR is an investment in the improvement of the search routines of the regional research funding agency. Thusly, AHFMR was able to bring scale and focus to inputs that likely translated into positive impact on the scale of the outputs.

5.2.4.3 <u>Behavioral additionality</u>

Behavioral additionality refers to a change in behavior that (ideally) can be attributed to AHFMR investment. The following list highlights some of the most important examples of behavioral additionality that were discovered in this research.

- The most significant AHFMR success came from the recruitment of elite talent into Alberta's biomedical research system which eventually culminated in the cultivation of a 'superlative scientific community' (AHFMR, 1998). This increased the profile of Alberta as a location of world class medical research. "This enviable profile is widely acknowledged to be directly attributable to the foundation's [AHFMR] support of personnel of great promise … in the broad area of biomedical research." (AHFMR, 2004).

- AHFMR investments were the catalyst for incremental biomedical research groups such as: The Membrane Group, the Protein Engineering Networks of Centres of Excellence, the Department of Medical Genetics, the Canadian Bacterial Diseases Network, and numerous other research groups (AHFMR, 1998). While it is possible that these research initiatives would have been organized without AHFMR, the reality is that AHFMR had been involved in their launch and ongoing operations.

- AHFMR investments affected the behaviors of organizations beyond Alberta, because of its success in attracting, developing, and retaining elite biomedical research talent. Regional governments from outside of

> Alberta saw that AHFMR was 'eating their lunch' and, in response, designed instruments to compete with AHFMR's offerings
> (Keough, K. 2014. Interview with Terry Ross. March 6, Edmonton).

5.2.5 Conclusions

AHFMR emerged from institutions and visions that had their roots in the institutional entrepreneurship of Peter Lougheed. This included the support that the Lougheed government had provided for the elite a biomedical research institution, but also included the institution that supported natural resource development (e.g. AOSTRA) and that organization that managed the revenues of the latter (i.e. the Alberta Heritage Fund).

> What one has to appreciate is the real imagination and vision of Lougheed. I think without Lougheed's vision and the support he got from a number of other visionaries at the time, both within government and outside in the community, I don't know that this thing would have taken the shape and form that it did.
> (Spence, M. 2014. Interview with Terry Ross. May 2, Edmonton)

The need for AHFMR arose from the perception that Alberta's biomedical research funding was atrophying and that early career biomedical researchers did not face a bright future in Alberta. Additionally, Peter Lougheed was enthusiastic about the potential of knowledge-based industries in Alberta.

The Government of Alberta spent considerable time and effort in the design of AHFMR so that it would be effective in the pursuit of its mandate. This led to a thorough and consultative design process which involved the universities, international experts, and the public. The thoughtful design of AHFMR's funding structure, its autonomy from government, and the careful consideration that was paid to its governance, adjudication, and advisory bodies were all factors that contributed to its positive performance.

AHFMR had a range of investment programs that focused largely on the development of biomedical research talent; providing for infrastructure needs and supporting activities that would facilitate meaningful impact on the health of Albertans. Over the next 25 years, the AHFMR granted over $800 million to the system of innovation in Alberta (Lampard, 2011). One interviewee summed AHFMR up thusly, "AHFMR was about solving big, hairy, medical issues" (Lougheed, S. 2014. Interview with Terry Ross. September 19. Calgary). Another interviewee commented, "What was the purpose of AHFMR? It was to build the excellence in the medical faculties. It was not defined in what I would call a social outcome or an economic outcome. It was implicitly understood that if you have excellence, good things will happen. So it was never anything more than making these schools the best in the world. That was the point." (Fessendon, B. 2013. Interview with Terry Ross. December 12, Edmonton).

Data collected from interviews suggests that the impacts of AHFMR investments were significant, resulted in the transformation of Alberta's biomedical research system, and garnered international recognition for contributions to the field of research. There may be a somewhat intangible benefit from the attraction and development of physicians that could deploy leading techniques into the health care system, although this thesis did not uncover direct evidence of this outcome. It appears that, through strategically directed investments of a significant size, AHFMR catalyzed the creation of an exceptional research community. Data from the MRC/CIHR and the NIH suggest that the Albertan biomedical research community could attract significant funding from sources outside of the AHFMR and attracted a relatively high proportion of funding, compared with other Canadian provinces.

AHFMR was an organization that arose from a confident innovation system that was well funded by the energy sector and led by a strong institutional entrepreneur. AHFMR was able to upgrade skilled researchers and biomedical research spaces at Albertan universities into highly productive biomedical research initiatives.

5.3 Alberta Informatics Circle of Research Excellence (iCORE)

The Alberta Informatics Circle of Research Excellence (iCORE) was an organization mandated to build an elite informatics research system within Albertan universities, primarily in the departments of computer science and electrical and computer engineering. The functional need for iCORE arose in response to the perceived necessity of assisting the diversification of the Albertan economy. The desired primary outcome of iCORE was improved university research capabilities and its method of action was like that of AHFMR (programs supporting the recruitment and development of elite research talent).

The need for iCORE was predicated on a perceived economic development opportunity related to the emergence of information technology (IT) as a potential economic driver. This unrealized economic value arose from talented research teams who supported the development of IT companies and through the propensity for IT to bolster existing economic sectors in Alberta. iCORE was driven by the leadership of universities and the governmental desire to invest wealth (largely from natural resources) into informatics research capabilities. Dr. Lorne Taylor, Minister of Innovation and Science, articulated as much in a 1999 speech:

> iCORE put Alberta in the major leagues of ICT research. This initial $30 million commitment would attract some of the world's top technology researchers to Alberta universities, accelerate new knowledge and innovation, and provide the cornerstones for both knowledge-eased economic growth and a healthy and prosperous quality of life (Taylor, 1999).

iCORE differs from AOSTRA and is similar to AHFMR in that it is an innovation agency underwritten by natural resource wealth, focused primarily upon building university research capacity. iCORE arose in Alberta due to widespread enthusiasm for a perceived paradigm shift in the economic potential of information technologies, existing industrial IT capabilities (driven by natural resource development, particularly in wireless communications), and institutional entrepreneurship from the universities, industry, and key individuals.

A quick introduction to some specialized terminology relating to iCORE's research focus areas is required:

- 'Information and communications technology' ('ICT') is a term used to refer to research in computer information systems and other closely related systems (e.g. geomatics).
- 'Nanotechnology' ('nano') is a term referring to material science research that is typically conducted at the atomic or molecular scale.
- 'Omics' is a term used to refer to broad areas of ICT-enabled research which include genomics, metabolomics, proteomics, regulomics, metagenomics, epigenomics, and other emerging pillars of systems biology.

5.3.1 iCORE start up

5.3.1.1 Copying the AHFMR model

The Alberta Heritage Foundation for Medical Research had been in operation for well over a decade. Its instruments raised the caliber of university research and were viewed as successful with the caveat that the funding model had caused some problems. Thus, AHFMR's experience provided some guidance for the design of iCORE.

> [The idea was to] build off of the AHFMR model, which was successful (especially in the early days) at attracting top scientists. This would make the institution more competitive than average when applying for funding from the Tri-Councils, NIH, etc. and that is what attracts the students, they come for the reputation and for the funding opportunities. So that was the iCORE logic.
> (Fessendon, B. 2013. Interview with Terry Ross. December 12, Edmonton).

> The learnings from this situation [AHFMR's challenges from soft-funding positions] spilled over into other funding models. You can not have iCORE researchers on that funding model; you have some researchers that have been funded for 25 to 30 years by AHFMR. But that was something was learned; even when iCORE was being founded, ASRA[31] knew what was going on with AHFMR funding.
> (Dyck, R. 2013. Interview with Terry Ross. December 13, Edmonton)

5.3.1.2 Institutional entrepreneurship

There are two individuals who were instrumental in championing the idea of iCORE to the government, Bob Church and John Roth.

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[31] ASRA is the Alberta Science and Research Authority, an innovation agency that provided advice to the government and was sometimes accountable for other innovation agencies.

Dr. Church is a rancher,[32] third generation Albertan, expert biological scientist (molecular genetics and embryo transfer in cattle), and institutional entrepreneur. He was a founding member of the University of Calgary's Faculty of Medicine and served as the university's associate dean of research for most of the 1980s. Dr. Church was involved in discussions surrounding the use of AHFMR instruments as a jumping off point for a successive agency, and successfully championed the conceptualization of iCORE to key individuals in the Government of Alberta (Fessendon, B. 2013. Interview with Terry Ross. December 12, Edmonton).

John Roth (originally from Lethbridge), was the CEO of Nortel, one of the world's largest telecommunications equipment companies. Mr. Roth was involved in the Alberta Science and Research Authority subcommittee on information technology and was responsible for the general outline of the precursor to iCORE, which he brought to the Government of Alberta (Church, B. 2013. Interview with Terry Ross. October 8, Calgary). There were many other individuals (e.g. Brian Unger and Bob Fessendon) who helped to incubate the idea of iCORE into the eventual formal initiative. Dr. Church and Mr. Roth were identified by interviewees as playing the key roles of the critical institutional entrepreneur protagonists.

5.3.1.3 Structuring iCORE as a not for profit corporation

The development of the first legal elements of the iCORE organization necessitated important decisions surrounding the structure and governance model of the organization. In iCORE's case, there were two main options for corporate structure; it could be established as a not for profit company (under Part 9 of the Companies Act) or it could be established as a crown corporation. The legislation that applied to not for profit corporations was considered to be more modern than the crown corporation legislation and provided for more autonomy, less bureaucracy, and less direct evolutionary feedback from the government domain. If the government chose to create iCORE as a crown corporation (i.e. the same as AHFMR and AOSTRA), it would then be subject to a significantly different set of institutions relative to if it were a not for profit corporation. If iCORE were a crown corporation, it would require an Order in Council to be created and the government would have deeper involvement in iCORE activities. iCORE also may not have been allowed to carryover funds or accrue interest and it might have been exempt from GST. In addition, iCORE staff would be considered government employees (Sustriuk, G. 2014. Interview with Terry Ross. January 30, Calgary).

The perception amongst relevant institutional entrepreneurs was that business corporation legislation enabled a more efficient organizational format and better positioned iCORE to succeed (Sutherland, L. 2013. Interview with Terry Ross. December 20, Calgary; Sustriuk, G. 2014. Interview with Terry Ross. January 30, Calgary). However, this organizational arrangement was outside of regular Albertan institutional routines and, thus, at the edge of the contemporary institutional framework. There were complicated legal questions about the structure of iCORE and how it would work in managing innovation policy with its incentive instruments (Sustriuk, G. 2014. Interview with Terry Ross. January 30, Calgary). One such question arose due to iCORE having had three shares, with the governance of iCORE determined by their controller. The solutions discussed for this situation included having the two universities and ASRA take ownership of the iCORE shares, having iCORE owned in entirety by the two universities, positioning iCORE under private ownership (government control would then come via an annual contract with ASRA), or allocating one share each (worth one dollar each) to the three founding owners and directors.[33] The ownership of iCORE was decided when, on March 23, 2000 via Order in Council 105/2000, iCORE became a not for profit corporate entity wholly owned by ASRA[34] - there was no university ownership of iCORE (ICORE, 2000).

In March 1999, an endowment of $10 million per year for three years was approved for an ICT research program in the ASRA. This kernel would eventually grow to be iCORE (iCORE, 2000). At the time of launch, iCORE lacked routines or processes. It was technically a funded start up innovation agency, however, many important decisions were yet to be made about its organizational structure and its prototype programs. Dr. Church approached Dr. Brian Unger to help with the building and definition of iCORE and its programs, as he had a genuine commercialization track record and an academic pedigree.

Dr. Unger's role as the first CEO of iCORE was to create iCORE's operational routines, develop its board, and initialize a program portfolio. Dr. Unger would collaborate with Dr. Church on the design of the programs and would then run them by the board of trustees (Church, B. 2013. Interview with Terry Ross. October 8, Calgary; Unger, B, 2013. Interview with Terry Ross, October 4, 2013).

When iCORE was established, it had five areas of focus; broadband networks, software engineering, high performance computing, terabyte database systems, nanotechnology, and quantum computing (iCORE, 2000).

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[33] Dr. Roger Palmer, Deputy Minister of Innovation and Science; Dr. Roger Smith, Chair of the Board; and Dr. Brian Unger, President and CEO.
[34] The structure was between that of ASRA and the Alberta Research Council Inc.

> The business to be carried on by the corporation shall be limited to activities, programs and undertakings that seek to attract, encourage and fund the growth of world-class research in the fields of computer science, computer engineering, physics, mathematics and related disciplines that encourage the growth of the information and communications sector of the Alberta economy.
> (iCORE, 1999)

5.3.1.4 iCORE boards and committees

The main committees that supported iCORE activities were its board of directors, international research advisory committee, and two committees established for the review of applications for awards.

The initial iCORE directors were largely drawn from academic and scientific backgrounds, including Richard Taylor a Nobel Laureate and James Gosling the creator of the Java programming language. The functions of the board of trustees were to help establish the organization and to approve the instrument designs proposed by the CEO.

The initial iCORE Board found it very challenging to integrate discussions relating to organizational design and government relations with the design of programs to catalyze scientific research. A decision was then made to divide the board into two groups, the board of directors, which was to focus on iCORE's governance and operational issues, and the International Research Advisory Committee (IRAC), which focused on recruiting top talent and ensuring that

Alberta remained current in its global scientific awareness. The new structure allowed board members to be chosen for their scientific pedigrees and to focus on scientific and program design topics instead of operations (Taylor, R, 2014, Interview with Terry Ross, November 8, Palo Alto; Unger, B, 2013. Interview with Terry Ross, October 4, 2013).

When iCORE launched, it focused on scaling its operations to fulfill its mandate, defining its instruments to attract and develop elite research teams. This meant that, at launch, iCORE had no instruments ready to deploy.

In 2005, after five years of operation, management of iCORE was moved from the Alberta Science and Research Authority to the Ministry of Innovation and Science (iCORE, 2005). The same year, Dr. Unger retired from the position of CEO and was succeeded by Dr. Randy Goebel. At this point, iCORE's activities for managing programs and operations had developed into stable routines that had been reviewed to the satisfaction of the government each year. The challenges facing Dr. Goebel as iCORE's second CEO centered on the integration of iCORE into the sub-national innovation system as a mature organization. These challenges included 'small "p" politics', largely resulting from competition with other organizations (e.g. Alberta Ingenuity[35]) whose mandates and programs partially overlapped with iCORE's (Goebel, R. 2013. Interview with Terry Ross, November 4, Calgary).

[35] Alberta Ingenuity (technically, the Alberta Heritage Foundation for Science and Engineering Research) is another innovation agency inspired by AHFMR, not included in this study.

One of the other challenges that iCORE faced was that the structure of the Albertan system of innovation was perceived as “fragmented and overcrowded” with “a large number of players with overlapping mandates, occasionally conflicting roles, and sub-optimized goals that link weakly with the province’s stated needs” (Wahlster, 2008). This perceived state was a significant factor in the introduction of Bill 27 (see Appendix C: Bill 27).

In 2009, the Government of Alberta focused on the deliberate recalibration of the sub-national system of innovation through the upcoming Bill 27. There was certainty that the upcoming recalibration would fundamentally affect iCORE; most stakeholders knew that there would be some institutional aggregation, though specifics were very difficult to ascertain at the time.[36] iCORE stakeholders were extremely concerned about the prominence of informatics in presentations by the Albertan government, “clearly, enabling technologies such as ICT were not adequately considered.” (iCORE IRAC, 2009). The IRAC report stated that iCORE was in “transitional jeopardy” and could be affected in a way that would also impact the portfolio of research chairs. Members of IRAC were also concerned that the transition would impact the upcoming implementation of a recruitment program for young up and coming elite ICT research talent that was meant to leverage the challenging economic times by attracting and supporting motivated research talent (iCORE IRAC, 2009).

As a result of Bill 27, as of January 1, 2010, iCORE ceased to exist as an arms-length institution. The operations of iCORE programs and staff were officially transferred to the newly formed Alberta Innovates Technology Futures (AITF).

[36] The reorganizations of the organizations affected by Bill 27 will continue through 2016.

5.3.2 iCORE funding

There were various funding models proposed for iCORE, with each suggesting that funding could stem from multiple sources (i.e. federal government, industry, etc.). However, when iCORE was incorporated, it was solely funded through an annual allocation from the Government of Alberta (first through the Ministry of Innovation and Science and then through to the Alberta Science and Research Authority). The government provided an initial financial commitment to iCORE of $10 million per year for five years. Afterward, the allocation for iCORE was determined on an annual basis but remained between approximately $11 million and $12 million per year.[37]

While $10 million per year for five years may seem a significant endowment, many scientific advisors felt that the amount fell well short of enabling the required impact. These experts believed that three to ten times as much funding would be required to adequately fulfill expectations. Comparing iCORE's funding to AOSTRA's and AHMFR's average funding (see Table 9), it is noticeable that iCORE's average unleveraged investment was less than half of its peers. Despite this, supporters of iCORE felt that even modest investments were of tremendous value and provided a great return; "$10 million is so cheap and the impact is so big compared to the investment." (Unger, B. 2013. Interview with Terry Ross. October 4, Calgary).

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[37] The Graduate Student Scholarship program was worth up to $7 million per year, but did not show up on iCORE's balance sheet.

5.3.3 The iCORE model

iCORE designed financial incentives to increase the appeal of Albertan universities to elite researchers in informatics fields (e.g. computer science, mathematics, electrical engineering, etc.). iCORE's programs were expected to be unique within Canada and uncommon within North America (Unger, B. 2013. Interview with Terry Ross. October 4, Calgary). iCORE's economic hypothesis was that the attraction of elite informatics scientists would have a multiplier effect on the attraction of additional high caliber talent (i.e. faculty, junior faculty, postdocs, and graduate students). The attracted talent would then enter the local workforce and aid in the attraction of new, and the growth potential of local, high technology organizations (Fessendon, B. 2013. Interview with Terry Ross. December 12, Edmonton).

iCORE was inspired by the experiences and challenges of AHFMR's soft-funding of HQP.

> The learnings from this situation [AHFMR's challenges from soft-funding positions] spilled over into other funding models. You can not have iCORE researchers on that funding model; you have some researchers that have been funded for 25 to 30 years by AHFMR. But that was something learned; even when iCORE was being founded, ASRA[38] knew what was going on with AHFMR funding.
> (Dyck, R. 2013. Interview with Terry Ross. December 13, Edmonton)

[38] ASRA is the Alberta Science and Research Authority, an innovation agency that provided advice to the government and, at certain points, was accountable for other innovation agencies.

An important part of the iCORE model was the flexibility given to awardees in the pursuit of their proposed research agendas.

> If an iCORE chair has been funded at $3 to $5 million over five years, and, during this five-year period, the chair decides to change direction, even significant direction changes, iCORE would not consider this a problem, not try to interfere with such changes. Every funded iCORE chair will have had a stellar past track record and is deemed the right person to direct his or her research efforts. The iCORE Chair will be judged on what is actually achieved not only with respect to the original proposal.
> (Unger, B. 2013. Interview with Terry Ross, October 4, Calgary)

Table 19 provides an overview of iCORE programs and their relative shares of iCORE funds, circa 2008.

Table 19: iCORE program overview

Program name	**Sample of program activities**	**Expenditures (2008)**	**% of total (2008)**
Chair grants	Provide support for exceptional researchers in the top 5% of their fields. Award mid-career researchers with outstanding potential, whose records may not yet justify top level chair awards. Chair grants are awarded for five years, represent up to one half of the total budget, and are renewable once, on a competitive basis.	$9.2 million	73%
Industry Chair grants	Support researchers undertaking high caliber internationally competitive research. Industry Chair grants require the applicant to have an NSERC IRC award before application. Industry Chair grants are normally awarded for five years, represent up to one third of the total budget, and are renewable, on a competitive basis.	$1.5 million	12%
Visiting Professor grants	Bring internationally recognized researchers to Alberta for terms of six months to two years to	$232,000	2%

	develop partnerships and, possibly, be recruited.		
Graduate Student Scholarships	Recruit exceptional graduate students in computer science and electrical and computer engineering.	N/A[39]	N/A
Other research grants	Provide funding for networking and system of innovation support (e.g. workshop sponsorships).	$205,000	2%
Communications and outreach	Supporting marketing, communication collateral, and networking events.	$335,000	3%
Secretariat	Funding for staff compensation, professional services, travel, and office operations.	$1 million	8%

The main instruments that iCORE designed to achieve its mandate were its Chair, Industry Chair, and Graduate Student Scholarship programs.

5.3.3.1 The Chair program

The Chair program (CPE) began in 2000 and was designed to provide financial incentives to informatics-compatible university departments[40] to offset the costs of tenure positions (and often included a stipend to make the position internationally competitive). The initial CPE program provided five year grants to Albertan universities to entice elite informatics academics to relocate their research programs.

A key feature of the program, designed to ensure additionality, was that funding was only available to elite talent from outside of Alberta. This led to several challenges for iCORE's CEO in this first year of operation (Unger, B. 2013. Interview with Terry Ross, October 4, Calgary; Goebel, R. 2013. Interview with

[39] While iCORE provided operational support for the Graduate Student Scholarship, in collaboration with Alberta Ingenuity, the approximately $6 million in annual funding for the program did not fall within iCORE's budget.
[40] Interestingly, the Alberta Research Council was originally considered a receptor for iCORE chairs.

Terry Ross, November 4, Calgary). The first challenge for the chair program was that worthwhile local scientists were be ineligible for iCORE chair funding, through no fault of their own. Understandably, local informatics researchers found this unacceptable. iCORE's logic was that its limited funding was focused where it offered the best chance of overall impact. Supporting researchers already in Alberta would be less effective overall, as some of the research would have occurred anyways (i.e. imported talent results in more output additionality). Imported research would be completely additional and would result in a more favorable return, all else being equal[41]. The second challenge was that attracting talent from abroad was a process that could take a substantial amount of time. This meant that iCORE could not expect results until into its second year at best and it would be politically advantageous to show progress sooner rather than later. As a response to these challenges, the board and CEO of iCORE agreed to allow elite Alberta researchers to receive Chair grants. In 2001, iCORE introduced the Research Grants (RG) program, a one-time round of CPE awards for Albertan researchers.

5.3.3.2 Industrial Chair program

Under iCORE's Industrial Chair program, a researcher would propose a research project in collaboration with a Canadian industrial organization.[42] If the application was successful, the research project would be funded equally by industry, iCORE, and the federal government (NSERC). Leverage provided a

[41] Unless the incoming person is filling a gap resultant of the departure of an equally talented Albertan.
[42] The industrial organizations were typically connected with the researcher prior to the Industrial Chair application.

measure of risk mitigation for iCORE, as the other partners were providing reassurance that the research undertaken was viewed as useful by industry.[43]

> The Industrial Chair program was initiated during the third year of my tenure. The program was [a] strategic win for two reasons: it was funded by NSERC, industry, and iCORE, at, thus, a much lower cost to iCORE; and it directly contributed to industrial development within Alberta. (Unger, B, 2013. Interview with Terry Ross, October 4, 2013).

Initially, iCORE's main instruments (i.e. chair and professor establishment programs) were targeted at the most accomplished informatics researchers. Soon the programs expanded to support researchers at various stages of their careers and, while the programs always supported research in informatics, the research domains supported by iCORE expanded over time (e.g. medical informatics).

Potential applicants for iCORE programs were first located through the personal networks of the CEO, committee members, and board members. As the university leadership developed a deeper level of familiarity with iCORE, the small network of relevant department heads (i.e. computer science, electrical engineering, etc.) began to nominate researchers (Goebel, R. 2013. Interview with Terry Ross, November 4, Calgary).

A significant evolution of iCORE routines occurred when iCORE entrusted their community of existing chairs to bring forward candidates from their respective disciplines for recruitment through iCORE programs. The community of chairs

[43] This validation is similar in relevance to most AOSTRA programs.

was also occasionally used to provide informal feedback on the quality of university submissions to iCORE (i.e. they served as an informal ad hoc peer-review body). According to Unger, "the best way to recruit stars is to have other stars be the lead" (Unger, B. 2013. Interview with Terry Ross, October 4, Calgary; Goebel, R. 2013. Interview with Terry Ross, November 4, Calgary). Recruiting and relocating individuals with esoteric scientific research skills is a significant challenge that can be compounded by a lack of adequate receptor capacity in the region. By 2009, iCORE had been unable to adequately develop Alberta's research capabilities in two scientific research areas, cyberinfrastructure and advanced robotics (Goebel, R. 2013. Interview with Terry Ross, November 4, Calgary).

In 2009, the first iCORE chairs had been funded for nine years. Under the governance of the iCORE programs, the funding limit was for a total of ten years and, thus, these researchers were nearing the end of their iCORE funding. One of the iCORE program assumptions was that after ten years the researchers would have been able to onboard other funding sources to continue their research programs. However, many iCORE chairs had been enquiring about funding beyond ten years to continue their research programs with minimal disruption. A concern was voiced by the IRC that allowing "special deals" for chairs to receive an additional five years of funding (and, thus, going beyond the ten-year limit) could lead to the establishment of "difficult precedents". On one side, there were concerns that non-extension would limit the additionality of iCORE investments. IRAC wished to ensure enough financial flexibility to invest in the development of new chair opportunities and didn't want too much of the budget allocated to research initiatives that were already in place. Lessons from AHFMR's experience in soft-funding were not lost on the IRAC or the iCORE Board of Directors (iCORE, 2009).

> We strongly endorse iCORE's ongoing recruitment of new chairs and thus recommend a maximum of ten years of iCORE support for an iCORE CPE chair in order to free up iCORE money for new CPE chairs.
> (iCORE, 2009)

5.3.3.3 The Graduate Student Scholarship (GSS) program

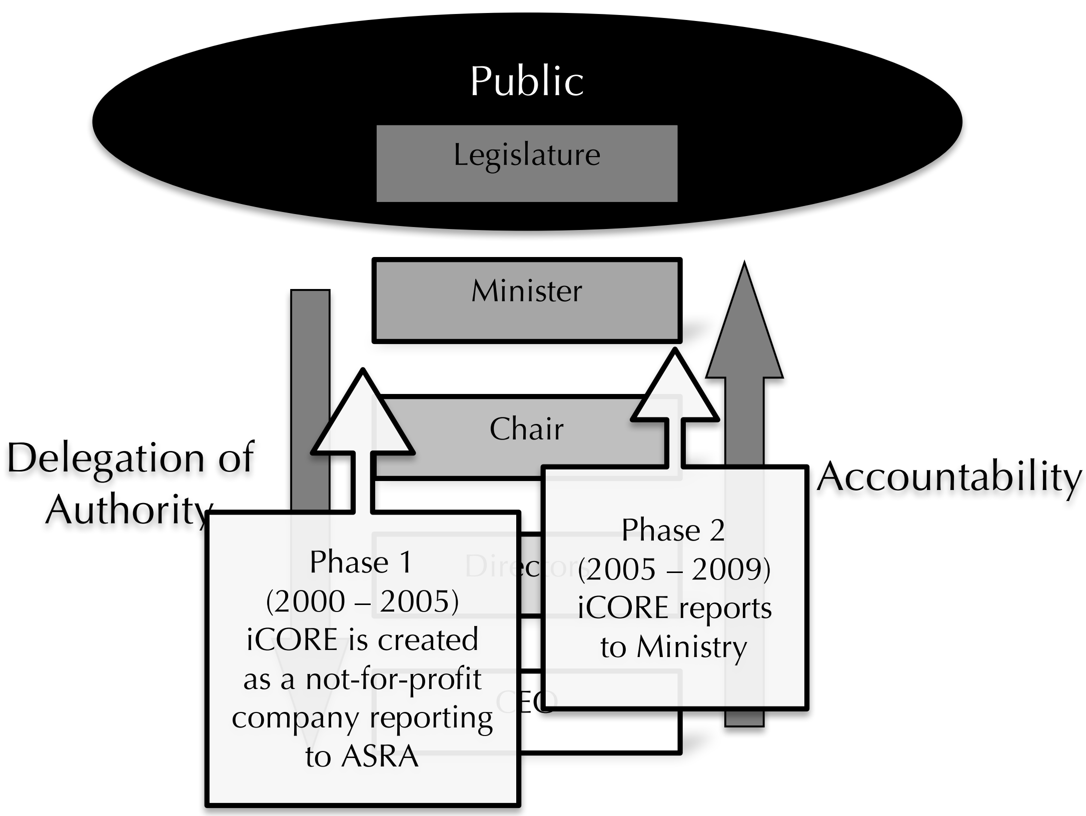
In 2001, iCORE introduced its Graduate Student Scholarship (GSS) program that operated as a straightforward funding top-up to students who had received a federal government (NSERC) student award. When it was introduced, the iCORE GSS top-up was the only program of its kind in Canada and enjoyed success in attracting a high proportion of NSERC scholarship recipients to Alberta.

> The third element was the funding of grad students, which came in concert with Alberta Ingenuity. We topped up the NSERC awards and it was so successful, we got the best students in the country. Because if you're [a] student and you can get an extra 12,000 or 24,000 [dollars] a year, that's got to be very attractive. So when we showed the government the statistics, we said, 'Look, we're getting this percentage of the cream of Canadian talent and some of these students are going to meet local people and some of them might get married.'. That last change was made when I was transferring iCORE over to Randy. We had to change a program because we needed to fund students who were not Canadian and NSERC only funded Canadians, which missed superstars from places like China, etc.
> (Unger, B, 2013. Interview with Terry Ross, October 4, 2013).

5.3.3.4 iCORE's evolution in authority and accountability

iCORE arose as a not-for-profit corporate entity that was held accountable to another innovation agency, the Alberta Science and Research Authority (ASRA) (ICORE, 2000). In 2005, after five years of operation, iCORE was moved from management under ASRA to the Ministry of Innovation and Science (see Figure 13).[44] This institutional change did not affect the strategic choice of iCORE in any way that could be determined in this study.

Figure 13: Evolution of iCORE authority and accountability structure



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[44] ASRA had been evolving from an organization that utilized soft instruments (elite policy advice to government) and financial incentive instruments toward the sole provision of soft instruments.

Adapted from McCrank et al. (2007)

5.3.4 iCORE additionality

From its inception in 1999 to its sunset in 2009, iCORE was held responsible to the government and to the public to create results to justify its investment and meet its mandate to expand the ICT research capacity of Alberta.

5.3.4.1 Input additionality

In iCORE's context, input additionality refers to the additional inputs to informatics research (e.g. incremental research funding flowing from other organizations) that arose as a result of iCORE's investments.

Table 20 and Figure 14 summarize the (self-reported) sources of chair funding that were concurrent with their iCORE funding.[45] These results allude to the wide range of funding sources beyond iCORE that supported iCORE initiatives.[46]

Table 20: Total active funding for iCORE chairs (2001 – 2008)

	Active Funding (in millions CAD)								
Year	**iCORE**	**Other GOA**	**University**	**CFI**	**CRC**	**NSERC**	**Industry**	**Other**	**Leverage**
2001 - 2002	20	5	1	10	7.5	2.5	5		**1.6**
2002 - 2003	28	11	2.5	19	7.5	2.5	22.5	8	**2.6**
2003 - 2004	35	20	2.5	24	8	10	25	12.5	**2.9**
2004 - 2005	41	18.5	5.7	22	8.3	13.5	29.3	24	**3.0**
2005 - 2006	42	21.7	5.6	5.9	9.5	16.9	33.4	38	**3.1**

[45] Thus, under this methodology, if a research program had a total five-year funding allotment of $10 million, it would be counted as $10 million in each of the five years that the contract was active.
[46] Similar to AHFMR's input additionality, if a chair had been recruited from abroad into an Albertan university (i.e. not replacing an existing researcher), then all of that research funding is purely additional in nature.

2006 - 2007	40	24.1	4.8	15.4	9.9	19.1	13.1	39.9	**3.2**
2007 - 2008	49.6	4.6	5.1	4.9	10.5	30.1	12.8	37.9	**2.1**

(iCORE, 2008)

Figure 14: iCORE researchers total sources of funding (2001 – 2008)

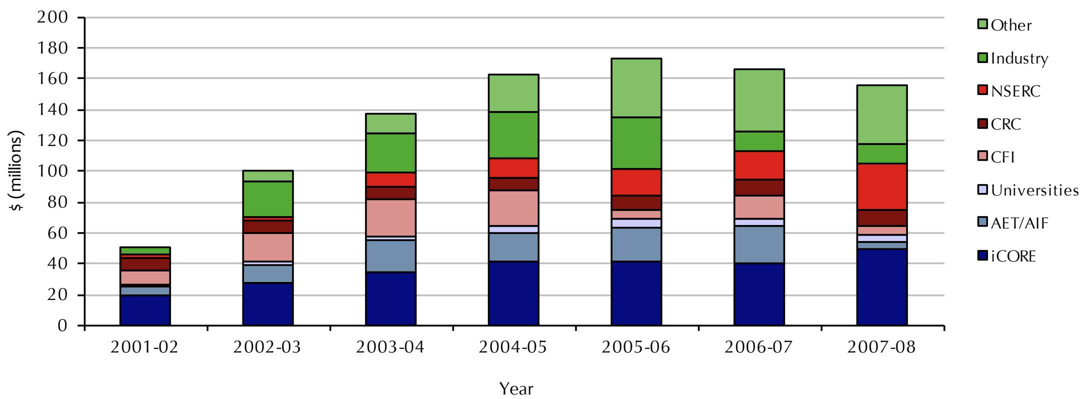


Table 20 and Figure 14 suggest that, for every dollar of iCORE funding, there was between $1.60 and $3.00 of funding allocated to the research programs by other sources. This does not, however, prove that the iCORE funding caused the attraction of other funding sources, unless the chair was recruited to Alberta and did not displace an incumbent research initiative.

The argument for the input additionality of iCORE chairs already in Alberta (i.e. most industrial chairs) is less strong, due to the reality that the researchers may have attracted much of their outside funding without the additional draw of iCORE involvement. Furthermore, the timing of iCORE support was subsequent to NSERC eligibility (or a successful NSERC award).

5.3.4.2 <u>Output additionality</u>

Output additionality infers that increased investments will result in increased innovation outputs that are attributable to the program (Buisseret et al., 1995). Ideally, the additional outputs are attributable only to iCORE investments and not to any other factors, which is often extremely difficult to determine with certainty. This is especially true for investments in researchers that were already embedded in an Albertan university, as the iCORE investment may support research that was already imminent regardless of iCORE's investment. Examples of possible iCORE output additionality include:

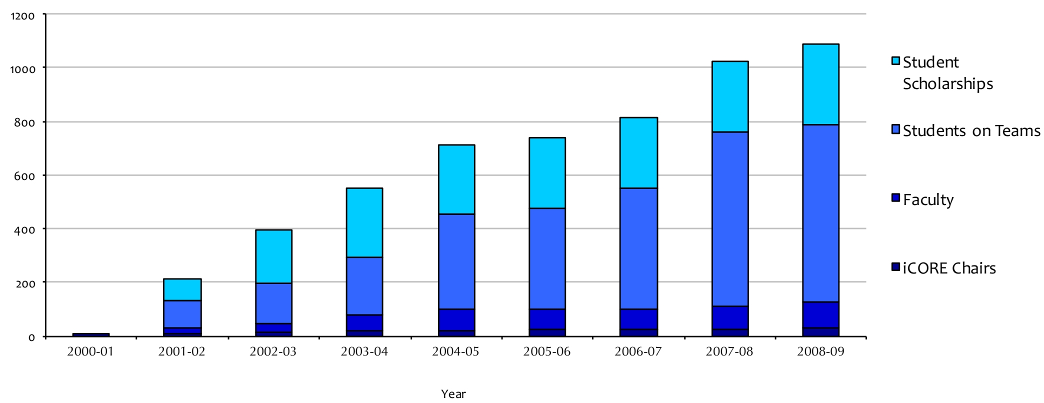
Table 21: Active HQP supported by iCORE

Year	iCORE chairs	Faculty	Students on teams	Student scholarships
2000 - 2001	6			
2001 - 2002	10	20	100	80
2002 - 2003	13	33	153	195
2003 - 2004	17	59	219	255
2004 - 2005	21	80	355	256
2005 - 2006	24	78	376	261
2006 - 2007	26	73	450	268
2007 - 2008	27	82	652	263
2008 - 2009	29	98	661	300

(iCORE, 2008)

These quantitative measures suggest that iCORE's programs had a positive impact on aggregate inputs (i.e. more research teams in the iCORE portfolio, more funding that can be considered as input additionality, etc.). In terms of outputs, the same linear growth logic applies; the size of the iCORE research portfolio was growing and, with that growth, research activities that led to publications, patents, etc. also grew. However, attributing the additional inputs and outputs solely to iCORE investments is tenuous, especially when locally established research teams are funded.

Figure 19: Active highly qualified personnel (HQP) supported by iCORE



(iCORE, 2008)

Table 22 describes the number of student scholarships that were awarded in a particular year, the active awards, and the cumulative number of awards.

Table 22: iCORE Graduate Student Scholarships (1999 - 2008)

Year	New	Active	Cumulative
1999 - 2000	16	16	16
2000 - 2001	60	60	60
2001 - 2002	50	107	110
2002 - 2003	86	172	196
2003 - 2004	81	212	277
2004 - 2005	100	253	377
2005 - 2006	106	264	483
2006 - 2007	77	268	560
2007 - 2008	104	271	664
2008 - 2009	63	238	727

(iCORE, 2008)

Table 23 describes the self-reported intellectual property and bibliometric outputs of the iCORE Research Chair program.

Table 23: iCORE chair IP and bibliometric output measures

Year	Patents	Cumulative granted patents	Books	Journal papers	Conference papers
2001 - 2002	2	2	5	40	60
2002 - 2003	5	7	16	164	196
2003 - 2004	6	13	11	184	282
2004 - 2005	8	21	25	279	344
2005 - 2006	9	30	29	314	395
2006 - 2007	10	40	19	350	456
2007 - 2008	9	49	19	340	580
2008 - 2009	10	59	36	404	488

(iCORE, 2008)

Quantitative indicators do very little to convey the breadth and depth of the skills, capabilities, and impacts that iCORE's investments in basic research provided. Thus, much of iCORE's reporting was in the format of case studies. Research program activities and outputs were qualitatively described and provided a nuanced glimpse of the impacts that the investments had on the Alberta system of innovation.

5.3.4.3 iCORE behavioral additionality

Behavioral additionality refers to the change in behavior that can be attributed to the iCORE investment. After ten years of recruitment and investment in chairs and their research teams, iCORE had invested in a group of about 30 accomplished informatics researchers at Albertan universities. A major output from this effort was the training of the next generation of researchers; the hope was that many of these researchers would stay and influence the Albertan economy. By 2008, iCORE had established three areas of research focus;

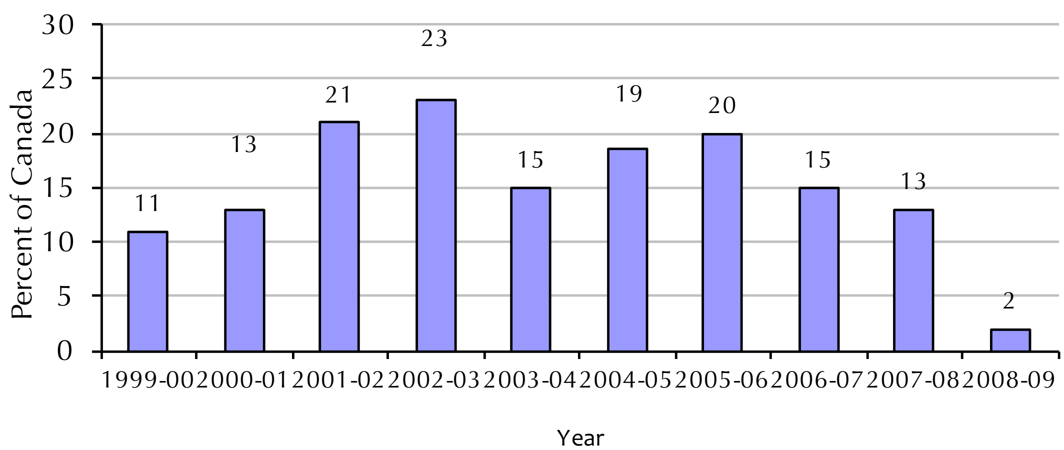
networks and wireless, intelligent software systems, and new architectures (e.g. nanotechnology and quantum computing). iCORE had also targeted three additional areas for future growth and focus; cyberinfrastructure, systems biology and sensor networks, and integrated resource management (IRM) (iCORE, 2008).

According to the CEOs of iCORE, the reported behavioral impact of iCORE was a qualitative change in the culture at Albertan universities and, thus, in the sub-national system of innovation. With the attraction of elite researchers from outside of Alberta in areas such as nanotechnology, a university department would subsequently find itself able to attract qualitatively different types of students, those interested in the respective research areas and the reputations of the iCORE chairs (Unger, B. 2013. Interview with Terry Ross, October 4, Calgary; Goebel, R. 2013. Interview with Terry Ross, November 4, Calgary).

iCORE attempted to find simple communicable narratives surrounding the rationale behind its investments and the areas where the impacts were accruing; this was approached as a continual communication exercise to help justify iCORE expenditures to the government. Ministers, deputy ministers, and assistant deputy ministers were often in flux and iCORE executives believed it valuable to present a simple narrative to these ministers that they would later be able to corroborate, as needed, through the research community. iCORE's board also believed that their stories of success should be leveraged for the benefit of their political sponsors, which meant producing events and communications that were highly artistic and of a superior quality. As one CEO said, "Creating the buzz was what iCORE was all about … the [iCORE] brand did attract people." (Unger, B. 2013. Interview with Terry Ross, October 4, Calgary).

Figure 15 describes the percentage of NSERC funded students in computer science and electrical and computer engineering that were enrolled in Alberta universities. The first model of the iCORE scholarship program 'topped up' NSERC award recipients if they came to study in Alberta, it was effective and attracted elite students. The performance of the program, in terms of its ability to attract proportionally more students to Alberta, was negatively affected when other provinces offered comparable incentives and when it was modified from operating as a 'top up' to an individually adjudicated scholarship.

Figure 15: Percentage of NSERC PGS awards in CS and ECE held in Alberta



(iCORE, 2008)

5.3.5 Conclusions

iCORE emerged from the vision of institutional entrepreneurs in an environment characterized by enthusiasm for economic opportunities driven by information technology. The recent success of the AHFMR programs in developing and recruiting elite research talent to Albertan universities was also top of mind and played a part in iCORE's successful emergence.

The need for iCORE arose from the perception that Alberta was in need of a process for developing highly skilled people in the latest informatics platforms; these individuals would then support the emergence of strong informatics based companies.

> You're not going to have economic impact without an advanced knowledge base. If you don't have excellence going on and creating grad students, in fact, it is the grad students that are important. Economic growth lies with the students and you are looking at the future. A lot of the students came from the United States or from Thailand [and] China. They're going to [do] great work here and a lot of them are going to stay there to marry somebody from here. We track that at iCORE as one of our deliverables. To achieve this kind of economic development, you need these kinds of people with the talent and the training.
> (Unger, B. 2013. Interview with Terry Ross, October 4, Calgary)

The Government of Alberta set up iCORE as a not for profit corporation, which had been determined to be a better structure for meeting its objectives than a crown corporation, like AHFMR or AOSTRA, would have been. iCORE had investment programs that focused upon recruitment and development of elite informatics research talent and, by the end of 2009, iCORE had invested approximately $77 million through its Chair and Industrial Chair programs.

The impact of iCORE investment was notable and catalyzed the creation of a strong research community across a broad range of informatics related domains. There is evidence that iCORE chairs were able to attract significant funding from other sources (input additionality).

6 Discussion

The thesis has approached the research topic of the instrumentality of innovation agencies by conducting a selective historical analysis of Alberta and then examining the Trio innovation agencies to see what could be discovered about their emergence and impact. The analysis was conducted with the aim of interpreting findings through the lens of systems of innovation theory.

The overall objective of the thesis is to answer the simple question: Have these three innovation agencies been instrumental to the development of Alberta's sub-national system of innovation? This main question is explored using three sub-questions: How did the Trio emerge and evolve? How did the Trio attempt to create impact? and did the Trio have a discernable impact? The key findings can be summarized as follows:

- How did the Trio emerge and evolve?
    - The perceived value of a specific natural resource, the oil sands, combined with the knowledge required for the economically viable development of this resource, was an important influence on how a sub-national system of innovation evolved in Alberta.
    - The actions of an institutional entrepreneur decisively shaped the sub-national system of innovation.
    - Innovation agencies possess varying degrees of authority and accountability. Although an institutional entrepreneur strategically positioned the Trio to have a deliberate amount of 'arms-lengthiness', the degree of innovation agency authority and autonomy changed over time.

    - Each successive Trio agency was to some extent patterned upon a previously established agency, important knowledge relating to effective program design was transferred by government staff.
- How did the Trio attempt to create impact?
    - The Trio acted as secondary organizations; influencing others to create the desired impact. In the Trio, it was common for economic incentives to be used to leverage industry or universities to engage in skill development or technology pilot projects.
    - Innovation agency programs were designed specifically to facilitate knowledge transfer relating to technology systems within a sub-national region. There were two patterns found in Trio IP policy. AOSTRA focused on sharing IP within industry; all while managing the IP in the government's interest. iCORE and AOSTRA supported research into a broad range of technology systems while leaving the IP management to the university. AOSTRA's approach was key to its qualitative impact on the industrial system.
    - Innovation agency programs often follow the investment opportunities supported by other stakeholders. Innovation agency programs that lead investment are important examples of the government sending signals.
    - The Alberta innovation agency programs had unanticipated consequences. The design of the programs meant eventually that important research topics, such as environmental mitigation of oil sands development, were sidelined. Also, the funding process was unfavorable for new initiatives.
- Did the Trio have a discernable impact?
    - The nature of an innovation agency's impact will vary based upon what part of the sub-national system it is mandated to affect.
        - AOSTRA made an impact upon both the industrial and academic domains; primarily through development and

diffusion of in-situ oil sands technologies and skills. This technical change enabled significant additional economic activity.

- AHFMR made a qualitative difference in the biomedical research capabilities by developing skills and infrastructure. Discernable impact on research outcomes was unquestionable, although very complicated to aggregate and assess. A proxy for impact would be to note that Alberta's ability to attract significant outside sources of research funding increased dramatically once AHFMR was operational.
- iCORE was also able to impact the informatics research capabilities of Alberta universities. iCORE's impact was significant although limited compared to AOSTRA and AHFMR due to a smaller budget and shorter period of operation.

6.1 How did the Trio emerge and evolve?

6.1.1 The perceived value of a specific natural resource, the oil sands, combined with the knowledge required for the economically viable development of this resource, was an important influence on how a sub-national system of innovation evolved in Alberta.

In Alberta's case the global demand for oil the value of the oil sands was compelling, but the technological challenges were significant. Edmonton and Ottawa decided to invest in scientific and technological initiatives like the Alberta Research Council, Abasand and the University of Alberta. However, the positive impact of these investments was stunted by moderate collaboration between initiatives, particularly between national and sub-national organizations (Chastko, 2004). Meanwhile, industry had focused upon development of the abundant conventional oil deposits. This focus on conventional oil was one reason why Alberta industry was tepid (and sometimes hostile) in efforts to address technological issues with in-situ technological systems (AOSTRA, 1990; Hester and Lawrence, 2010). Despite the potential of the oil sands Alberta industry was largely unwilling or unable to develop the required technological processes to make the in-situ oil sands economical for many decades (Chastko, 2004).

During the late 1960's early 1970's the government began to see the underdevelopment of the vast and valuable in-situ oil sands as a gap in knowledge and capabilities that merited targeted action. This would eventually contribute to the development of institutions that become relevant in a systems of innovation context. For example, elements such as AOSTRA and its initiatives such as the Underground Test Facility and other measures that would catalyze knowledge transfer to industry (e.g. AOSTRA's IP policy) (AOSTRA, 1990; Chastko, 2004).

In an examination of the late nineteenth century American mineral development boom David and Wright (1997) argue that natural resource abundance is not necessarily simply the result of a geological endowment but rather are the result of a development process. Against a background of demand for natural resources there was a complex institutional and technological dynamic that affected the supply conditions for mineral products. Institutional, organizational and technological adaptations impacted the abundance of mineral resources (David and Wright, 1997). This is exactly what was found in Alberta, the findings from Alberta reinforce this concept, and suggest that natural resources can play an integral part in the emergence of a sub-national system of innovation. Alberta's situation illustrates that valuable natural resources that are technically challenging to develop can play a primary role in shaping the system of innovation. There is also an important institutional aspect to this situation since institutional control over a significant natural resource will affect the actions that lead to the development of the sub-national systems of innovation.

Literature on systems of innovation (Freeman, 1995; Edquist, 1999; Smith, 2000; Edquist, 2001; Aghion & David, 2009), institutional analysis (North, 1990), and natural resources (David and Wright, 1997; Boothe and Edwards, 2003; Lundvall, 2007; Hawkins, 2012) alludes to the role that institutions and natural resources play in the emergence of systems of innovation. Alberta's changing institutional control over natural resources has been a core narrative in the history of Alberta's economy (See Figure 5: Evolutions in Alberta's natural resource governance on page 66). The trailhead to the Alberta system of innovation was the transfer of natural resources by the treaties. The treaties essentially transferred epic amounts of natural resources to the government and thus were a contingency in the foundation for the development of the Alberta system of innovation. In the early 20th century, the governments in London and Ottawa held control over access to the oil sands deposits; this dynamic repeatedly affected Alberta's efforts to develop the natural resources (Chastko, 2004). Some examples of these affects include: Ottawa withholding mineral rights from the Alberta Act of 1905, London and Ottawa placing the oil sands into strategic reserve during global wars, Ottawa withholding the Athabasca deposit from the 1930 Natural Resource Transfer Act, and the general squandered opportunity to have effective collaborate on oil sands research between Federal and Provincial Alberta agencies. These are examples of significant institutional that events repositioned Alberta's natural resources and way they would interact with other sub-national system of innovation elements. The historical analysis of the institutional control over Alberta's natural resources shows how central the issue was in the emergence of the Alberta economy and is relevant to understanding the character of Alberta's scientific and technological capabilities.

6.1.2 The actions of an institutional entrepreneur decisively shaped the sub-national system of innovation.

The literature on institutional entrepreneurship highlights how key actors can shape policy and the institutional environment (Mintrom, 1997; Eggers and O'Leary, 2009; Battalina et al., 2009). One such key actor was Peter Lougheed who was directly involved in the establishment of AHF, AOSTRA, and AHFMR; thus, his actions were a contingent factor for the emergence of the Trio. Many interviewees noted that Peter Lougheed's efforts defined the some of the character of the current sub-national system of innovation.

The awareness of the Lougheed government (which was partially influenced by the efforts of individuals such as Dr. Tatton and Dr. Madsen) allowed it to conceptualize policies to address perceived deficiencies in sub-national knowledge and capabilities. Part of the desired outcome from these policies was to mitigate the impacts of abundant natural resources and the strains they had the potential to create for the local economy (e.g. Dutch disease, volatility in government revenue, poor government investment choices, etc.). The justification for AOSTRA was economically straightforward, as its mandate was related to managing and developing natural resource wealth. Less straightforward was the establishment of AHFMR as an economic development initiative that was undertaken in somewhat economically challenging times.

AHFMR is perhaps amongst the most dramatic examples of Peter Lougheed's institutional entrepreneurship (Lampard, 2011). There was no 'gap' in the Alberta biomedical research system, per se, but, given the government revenues from oil and gas, there was an opportunity. This opportunity was to pursue a vision of developing Alberta's biomedical research infrastructure to a high level and support the creation of an industry built on that biomedical research.

Mazzucato (2016) has suggested that the state can pursue an entrepreneurial agenda; actively pursuing policies that can lead to innovation-led growth (Mazzucato, 2016). The actions of Peter Lougheed suggest that the agency of an individual can disrupt the institutions of a region and be a discrete and material element in the sub-national system of innovation. The role of institutions in the system of innovation is well understood. The Alberta case illustrates the role that key individuals can play in getting initiatives started in sub-national systems of innovation. This can apply to situations where there is an obvious innovation issue to address (e.g. in-situ underdevelopment) or in situations where there is a less obvious opportunity to create new capabilities (e.g. biomedical research capabilities).

6.1.3 Innovation agencies possess varying degrees of authority and accountability. Although an institutional entrepreneur strategically positioned the Trio to have a deliberate amount of 'arms-lengthiness', the degree of innovation agency authority and autonomy changed over time.

Lougheed's decisions regarding the autonomy of AOSTRA and AHFMR led to a finding about agency governance. The autonomy of an organization can be conceptualized as being determined by elements outside the organization and by its ability to make its own strategic choices (Hrebiniak and Joyce, 1985). Public organizations like innovation agencies have their tasks and organizational structure determined by the government (Joldersma and Winter, 2002). Lougheed purposefully and deliberately placed AOSTRA and AHFMR at relatively great arms-length from the government; this provided a barrier to petty government influence. This would insulate strategic decision making from those who were less capable of appreciating the nuances of implementing mission-orientated innovation policies. As a direct result of Peter Lougheed's strategic choice, AOSTRA and AHFMR emerged in a deliberately favorable position of arms-lengthiness and AOSTRA reported directly to the legislature. Lougheed created AHMFR to be at arm's length from the government and de-politicize and allow it academic freedom.

Interviewees characterized the government as sometimes finding the 'arms-lengthiness' of agencies a challenge and hard to maintain. An analysis of the Trio's autonomy showed that during the period of study the autonomy of AOSTRA was decreased and the autonomy of AHFMR was almost decreased. Bill 27 (see Appendix C: Bill 27) overhauled the governance of a many innovation agencies and had the effect of reducing the Trio's autonomy even further. This provides another example of the dynamic nature of innovation agency autonomy. In summary, the strategic choice of an innovation agency within a sub-national system of innovation may be affected by its autonomy from the government.

6.1.4 Each Trio agency was to some extent patterned upon a previously established agency, important knowledge relating to effective program design was transferred by government staff.

When innovation agencies are established, they may pattern their operations based upon knowledge of previous innovation agencies. Organizational routines represent knowledge of the organization that can be transferred between organizations, especially through individual advisors (Miner et al., 2011). For example, AHFMR guided the design of iCORE's personnel programs. This dynamic was enhanced by some individuals (e.g. Deputy ministers in the government) being involved with both the oversight AHFMR and the design of iCORE. The Alberta government understood what benefits could accrue to university departments if they could attract top scientists. They could incorporate this knowledge in their efforts to build the capabilities of the computer science, electrical engineering, and related departments at Alberta universities.

The government knew the AHFMR model could be useful in other areas, but they also knew that the AHFMR funding model would need to be adjusted when designing iCORE programs to avoid a funding problem. AHFMR faced a challenge from their programs being designed to funding the entire salaries of the growing portfolio of researchers were not forgotten during iCORE's program design (see section 5.3.1.1 Copying the AHFMR model). This is an important example of valuable organizational knowledge, embedded in routines, being transferred into a new organization (Miner et al, 2011). Often the replication of innovation policies can falter since the implementers fail to account for the nuances of local particularities (Hosper, 2005). In this case, the 'cut-and-paste' of AHMFR routines into iCORE seemed to be successful. The individuals (e.g. deputy ministers, senior managers, government advisors) that were directly involved with the government side of AHMFR and iCORE founding and operations were instrumental in this knowledge transfer on innovation policy design.

6.2 How did the Trio attempt to create impact?

6.2.1 The Trio acted as secondary organizations; influencing others to create the desired impact. In the Trio, it was common for economic incentives to be used to leverage industry or universities to engage in skill development or technology pilot projects.

Innovation agencies can directly provide their desired functions to the system of innovation (primary organizations) or they may act to influence other organizations to provide the required functions (secondary organizations) (Liu and White, 2001). AOSTRA's programs focused upon supporting industry-led projects to de-risk technologies with smaller research support programs conducted with universities and the Alberta Research Council (AOSTRA, 1990). In these cases, AOSTRA acted as a secondary organization, encouraging universities, industry, and the ARC to engage in strategic activities. An important exception to AOSTRA's role as a secondary organization was the Underground Test Facility (UTF) initiative. The UTF was a crucial effort to develop in-situ oil sands techniques and systems, however, industry had been unwilling to lead the project or even to co-invest in it at its start. AOSTRA led and funded the project, acting as a primary organization, taking a position that would be unique through its history (AOSTRA, 1990). AHFMR and iCORE focused almost all their programmatic efforts on a range of programs that, generally, incented universities to improve their ability to conduct research in strategic areas. Both AHFMR and iCORE acted exclusively as secondary organizations. It was found that AOSTRA was unique amongst the Trio in having played a primary role in the system of innovation with the UTF.

This brings up an important thought about the potential that the Trio had to impact universities and firms. Innovation policies can not create the ultimate outcomes that are desired (e.g. job creation, economic growth, improved health outcomes) (Borrás and Edquist, 2013). By definition, the primary organization conducts the desired innovation activity (e.g. research, financing, network development) which supports the achievement of the desired innovation outcome (Liu and White, 2001). However, this means that the primary organization, with its culture, institutions, and competencies, will influence the delivery of the activities, for better or worse. Thus, attributing additionality to secondary organizations must be cautiously approached with this caveat in mind.

The Trio used economic incentive instruments to increase research and development activities in their target organizations. These instruments acted to subsidize university and industry participation in pilot projects, skill development, and basic research (see Table 24).

Table 24: Trio research and development approaches

Approach	Description	Typical impact on system of innovation	Utilized by
Technology pilot projects	Project based technology deployment initiatives undertaken in close collaboration with helix stakeholders	New methods and instruments Increased stock of useful knowledge Increased capability for technological problem solving	AOSTRA programs (dominant approach) AHFMR and iCORE (could occur as an activity within an individual research program associated with a basic research investment, like a chair)
Direct skill development	Recruitment and/or development of highly skilled researchers at various career stages	Changed organizational behavior (e.g. supporting individuals engaging in research programs) Scaled the pool of individuals with desired technical and scientific skills Changed Individual behaviors re; entrepreneurship	AHFMR and iCORE (dominant approach) AOSTRA
Basic research initiatives	Direct funding of a research program, typically led by an individual researcher	New methods and instruments Increased stock of useful knowledge	AHFMR and iCORE (dominant approach) AOSTRA

		Increased capability for technological problem solving	
Regulatory	Ensured AOSTRA had an ownership position in sponsored industry research	Increased use of technology systems in industry Increased technology management capabilities	AOSTRA utilized this approach heavily for technology developed under its programs with its IP regime
Commercialization	Instruments supported commercial deployment via technology transfer into existing industrial organizations and creation of new organizations	Transfer of new scientific and technological knowledge into practice	AOSTRA (significant extent) AHFMR developed some capabilities in this area. iCORE had no direct instruments or technology commercialization programs (although chairs did engage in commercialization activities)

Adapted from: AOSTRA, 1990; Salter and Martin, 2001; Borrás and Edquist, 2013

All the Trio initiatives outlined in Table 24 deal with the development and transfer of knowledge, skills and capabilities. However, there is one AOSTRA initiative that had an instrumental impact upon the Alberta sub-national system of innovation. AOSTRA's bold intellectual property policy established government ownership of AOSTRA IP and provided non-exclusive licenses to stakeholders; this instrument was uniquely material to how oil sands knowledge emerged in Alberta's sub-national system of innovation.

6.2.2 Innovation agency programs were designed specifically to facilitate knowledge transfer relating to technology systems within a sub-national region. There were two patterns found in Trio IP policy. AOSTRA focused on sharing IP within industry; all while managing the IP in the government's interest. iCORE and AOSTRA supported research into a broad range of technology systems while leaving the IP management to the university. AOSTRA's approach was key to its qualitative impact on the industrial system.

One goal of innovation policy is to regulate social and market interaction (Borrás and Edquist, 2013). AOSTRA's intellectual property requirements (see Table 14) were the only instruments found amongst the Trio program portfolios that acted in this manner. This regulation amongst participating industrial organizations transformed the knowledge transfer process and facilitated industrial adoption of technological systems across organizational boundaries. Smith (2000) notes that a systemic approach to innovation policy may call for actions such as facilitating knowledge flows between firms (Smith, 2000). The IP approach used by AOSTRA was unique amongst the Trio for its ability to directly affect the institutions involved in the market. If AOSTRA had not insisted upon a non-exclusive IP regime for research partners, it is possible that there would have been significantly less knowledge sharing within the sector and reduced impact from the investment in developing the oil sands. Promising techniques would have been entangled in the IP regimes of individual firms and, the overall diffusion of knowledge within the system of innovation would have been impeded.

AHFMR and iCORE had a different approach to IP, they basically left the IP issues with stakeholders to be resolved under university terms. AHFMR and iCORE research agreements did not aim to directly facilitate knowledge transfer. There were some conditions in these contracts that affected university routines (e.g. an iCORE researcher could be relieved of typical teaching obligations to maximize focus upon iCORE supported research) and while these effects were important in the AHFMR and iCORE context they did not have the instrumental impact on knowledge transfer than AOSTRA's policy did. However, a hypothetical 'cut-and-paste' of AOSTRA's IP policy into AHFMR and iCORE programs could hardly be expected to have comparable impact given the difference in the domains that AOSTRA operated in compared to AHFMR and iCORE (see Section 6.3.1 on page 179).

6.2.3 Innovation agency programs often follow the investment opportunities supported by other stakeholders. Innovation agency programs that lead investment are important examples of the government sending signals.

The design of several Trio economic incentive programs required co-investment by the other stakeholders for eligibility (e.g. AOSTRA and iCORE Industry Chairs). By requiring other organizations to commit to funding prior to engagement, the innovation agency draws greater inputs into the initiative (although greater inputs are not a guarantee of increased outputs or behavioral changes). Designing programs with co-investment as a precursor to program eligibility also enables innovation agencies the advantage of simpler routines to administer their instruments, since some of the adjudication routines are offloaded to the organizations making the first investments. When a trusted industrial organization (or a federal government funding organization like NSERC) has determined through their adjudication routines that a research opportunity has merit, the innovation agency may decide they needn't expend as much effort on the task of validation. However, the flip side of this is that programs structured to require support by another funder forfeit of some their strategic choice, as the selection of worthwhile investments is initiated externally. In these cases, an innovation agency can only participate in investments that other organizations deem worthy and bring to the innovation agency to support. As an example, AOSTRA followed industry's lead in selecting research themes; following industry priorities led to a major underinvestment in environmental technologies (Hester and Lawrence, 2010).

Trio organizations sometimes assumed greater risk by leading investment decisions and forgoing the requirement of co-funding. In these cases, the Trio were exercising their strategic choice and determined that the benefits of the investment were sufficient regardless of the willingness of other organizations to co-invest before approval. In these cases, the Trio would rely on their expert adjudication capabilities and routines; interviewees suggested that, without the external expert (and primarily international) adjudication of potential investments by the innovation agency, the legitimacy of the innovation agencies' efforts may have been weakened. There was a straightforward logic in leading certain investments in skilled researchers (e.g. iCORE CPE researchers and AHFMR HQP) since it is likely that the investments made would attract additional funds post-establishment. These decisions by innovation agencies to lead investment add an interesting entrepreneurial dimension to government contributions to the sub-national system of innovation. However, it appears that unleveraged investments are not within the normal routines of government, as unleveraged opportunities were extremely rare based on the data collected. Mazzucato noted that the government could act as both a risk taker and signal maker and provide a clear statement of government priorities (Mazzucato, 2016). It may be the case that instruments that enable unleveraged investment require greater leadership and institutional entrepreneurship than leveraged investments, due to undiluted downside risk and increased adjudication effort.

6.2.4 The Alberta innovation agency programs had unanticipated consequences.

There were unexpected situations that emerged with Trio initiatives that created impacts with unforeseen and undesirable consequences. The first example was the slow start to environmentally focused research and development projects for AOSTRA. AOSTRA and its industrial collaborators chose to underinvest in environmentally focused projects. Literally zero dollars were invested over the first ten years of AOSTRA operations in environmental initiatives (Hester and Lawrence, 2010). Environmental investments were seen by industry as tertiary to investments that provided direct economic benefit. The oil sands sector may have benefited from earlier direct investments in research with environmental outcomes. Clem Bowman noted in an interview with Hester and Lawrence that "If we had only paid more attention [to environmental issues], we would be in a much better position now … there was no public awareness at that time, which meant there was no political pressure for anything to happen." (Hester and Lawrence, 2010). The firms and AOSTRA had little social pressure to allocate resources explicitly to environmental research themes. Meaningful investment in environmental technologies from the beginning may have impacted future market access problems arising from social perceptions of the environmental impact of the oil sands.

A second outcome is that AOSTRA contracts that were signed in the 1980's involved millions of dollars and the firms wanted legal protection to keep their information confidential. The IP requirements of AOSTRA did not include provisions for managing proprietary information (such as the characteristics of an oil sands deposit) after contract expiry; as the original contracts are nearing their sunset, this is creating some contemporary challenges. Because of this choice by AOSTRA the organization managing these contracts as they expire (Alberta Innovates Energy and Environment Solutions) have an unintended legal task to deal with.

A third example is the design of AHFMR's highly skilled people programs led to an unsustainable and undesirable funding structure. The successful career progression of researchers led them to become increasingly expensive and the economic burden of these placements fell almost exclusively upon AHFMR rather than the host university. This meant that over time AHFMR would have a greater proportion of its funding supporting existing investments and a diminishing portion of its funds available to invest in new opportunities (such as early career researchers).

6.3 Did the Trio have a discernable impact?

6.3.1 The nature of an innovation agency's impact will vary based upon what part of the sub-national system it is mandated to affect.

When creating new knowledge by investing in research and development, there are ranges of outcomes affected by the variations between sectors and the characteristics of users (Malerba, 2001; Geels, 2004). The Trio varied in their focuses, with AOSTRA primary focusing upon industry needs (although university and Alberta Research Council engagement was important) while AHFMR and iCORE focused upon the universities. Industrial organizations play the primary role in the deployment of innovation due to the nature of competition in a capitalist economy while universities are primarily focused upon the development of skills, knowledge and techniques (Dosi, 1988; Fagerberg, 2003; Salter and Martin, 2000). Those in the university domain are often encouraged to engage with industry through institutionalized technology transfer routines or individual engagement (Perkman et al., 2013). The Trio had different approaches to engaging with industry but had similar approaches to university engagement, albeit at different levels of prioritization. AOSTRA's programs were highly focused upon meeting industrial needs while providing support to de-risk new knowledge and prepare the knowledge assets for adoption. AOSTRA did significant work with the universities on skill development and worked closely with the Alberta Research Council to operate many of its research initiatives (AOSTRA, 1990). With their primary focuses of basic research capability development, AHFMR and iCORE had different desired primary impacts, given their differing knowledge domains and the natures of the universities as users. When it came to engaging with industry, AHFMR had a separate technology commercialization program that would support the transition of research outcomes into market focused opportunities. iCORE had the industrial chair program, which allocated iCORE funding to research teams that had demonstrated industrial relevance and relevance to federal funding programs (NSERC).

6.3.1.1 AOSTRA's impact

There is no question that AOSTRA had significant economic impact, particularly if the successful development of in-situ oil sands techniques is considered attributable to AOSTRA's efforts. Regarding inputs, a rough estimate places AOSTRA investment at about $1 billion (2004 dollars), most of which was matched by industry, dollar for dollar (Hester and Lawrence, 2010). It is impossible to determine how much of this investment would have occurred by industry without AOSTRA, although, given the lethargic pattern of industry investment in in-situ oil sands techniques, it is likely that aggregate industry investment would have been much lower without the organization. The emergence of large-scale oil sands operations (assumed to be largely attributable to AOSTRA) created a market for a range of specialized suppliers and service companies and the impact (in terms of induced effects) on Canadian GDP of SAGD-related projects has been estimated at up to $216 billion (Patton et al., 2006). The impact of SAGD technological systems has been transformative for the Canadian economy, and it's unlikely that these systems would have been developed and deployed in industry on the same scale without AOSTRA's initiatives. AOSTRA was focused on industry, however, AOSTRA's leadership was cognizant that the universities would have an important role in research and training and, thus, AOSTRA had a significant impact on the size of the oil sands research community, moving from about 20 individuals in 1974 to almost 600 in 1990. These research efforts were largely based in Alberta, although AOSTRA actively developed research initiatives across Canada (AOSTRA, 1990; Petroleum Historical Society, 2013). Through AOSTRA's IP policy, its knowledge sharing functions (e.g. oil sands chemistry library), and its training and research programs, it accelerated the development and deployment of oil sands techniques, creating significant behavioral additionality in the Alberta system of innovation.

AOSTRA's underinvestment in technological systems for pollution mitigation is considered a missed opportunity to create impact and mitigate the effects of the oil sands operations on Alberta's reputation. Contemporarily, there are many who perceive the impact of the oil sands on the environment as negative. The desired impact of AOSTRA's industrial programs was to de-risk the technological systems to the point of economic viability; technological systems with the primary purpose of pollution mitigation were not considered to have been a priority of industry. Earlier investment in environmental technology systems that were led by the government may have proven valuable to Alberta's system of innovation. This is an example where forfeiting strategic choice on investment led to problems for an innovation agency.

6.3.1.2 AHMFR's impact

To determine whether AHFMR had a significant impact upon the Alberta system of innovation the focus is on the impacts on biomedical research capabilities at Alberta universities (there is an expectation of clinical knowledge spillover, however it is difficult to quantify and treated as out-of-scope for this thesis). The data suggests that, over time, Alberta universities became much more capable of conducting biomedical research and attracting non-AHFMR funding. An enhanced ability to attract additional funding is considered a useful proxy for the caliber of research (although it may also simply reflect alignment with priorities of the funding agency or an increase in relative competence due to lower capabilities at competing research organizations). The data from the National Institute of Health and the Canadian Institute for Health Research shows that the amount of biomedical research funding from non-AHFMR sources grew at a healthy rate. The per capita National Institute of Health funding to Alberta-based biomedical teams grew over 6,000%, from \$0.04 per capita (the lowest rate in Canada) to \$2.70 (the second highest in Canada) between 1996 and 2006 (NIH, 2010). In 1979, Alberta universities were attracting about 7% of MRC and CIHR funding, which further rose to 12% by 2004 (AHFMR, 2004). This suggests that something was happening to the biomedical research system that was increasing its success in attracting funding from other organizations. This thesis' data can not prove that AHMFR was solely responsible for this impressive increase in the ability to attract NIH funding, however, as a leading investor in Alberta's biomedical research capabilities, it is likely that it had much to do with this outcome. When describing the outputs of AHFMR investments, there are numerous cases of AHFMR researchers receiving international recognition for the quality of their research, catalyzing the formation of biomedical research groups, and of research efforts leading to idiosyncratic health outcomes. Given the rigor that was undertaken in selecting research initiatives, it would be surprising not to see these outputs. There is also ineffable value in the biomedical research leadership that was drawn to Alberta because of AHFMR. AHFMR also had an impact on the funding of incremental biomedical research spaces at the universities, as a result of two major efforts. Although the first investment in infrastructure was unquestioned, the review of the second investment in infrastructure by AHFMR's International Board of Review suggested that it may have been unnecessary (AHFMR IBR, 2004). What about the impact of AHFMR on the industrial domain? While AHFMR was primarily designed to be an agency focused on building research capacity, one of its additional desired outcomes was to build additionality in the biomedical industrial sector in

Alberta. The latter goal is elucidated in Peter Lougheed's 1979 speech, "AHFMR will assist in the diversification of the provincial economy through the creation of a science industry." (Lougheed, 1979). AHFMR's investments certainly created a significant labor market impact, with a number of jobs directly (and indirectly) related to its research initiatives; the $250 million of biomedical research funding at Alberta universities (from all sources) is estimated to have led to up to 15,000 jobs (AHFMR, 2004). AHFMR managed a technology commercialization program that supported over 65 initiatives, most of which were 'still in the lengthy commercialization process' (AHFMR, 1992). AHFMR's International Board of Review described AHFMR's technology commercialization efforts as a distraction and recommended that the function of commercializing biomedical research be supported by another organization that could leverage specialized capabilities in high technology management and finance (AHFMR IBR, 2004). At the end of the day, AHFMR was successful in developing Alberta's biomedical research capabilities to a level where they were able to attract top quality research funding at a much higher level than the pre-AHFMR period and other provinces in Canada.

6.3.1.3 iCORE's impact

iCORE invested about $110 million over ten years in Alberta, which is significantly less money over less time than AOSTRA or AHFMR. When it comes to inspecting iCORE's additionality, there was evidence that iCORE Chairs attracted between two to three dollars in funding from other sources for every dollar of iCORE funding received (iCORE, 2008). Research program outputs such as patents, publications, presentations, etc. were assessed and deemed acceptable by iCORE for the caliber of the individuals that they involved. The growth in research personnel supported by iCORE is another important output and Table 21 summarizes steady growth in the number of researchers, faculty, students on teams, and students supported through scholarships. The key issue with iCORE input and output additionality is determining out how much of this activity would have occurred regardless of iCORE. There is a very strong case to be made that any research team attracted to Alberta by iCORE (e.g. most of the early chairs) could claim that their inputs and outputs were completely additional. However, the iCORE research investments that involved extant Alberta-based research teams would only be able to claim the incremental research activity that iCORE investment enabled. Assuming that incoming research teams were not displacing existing research capabilities, this group would have the greatest additionality. However, attracting and developing research groups from abroad is much more expensive and difficult to achieve than investing in their local counterparts.

iCORE was implemented on a different financial and temporal level than AOSTRA and AHFMR were. The average annual funding for iCORE was less than half of AOSTRA or AHFMR. Similarly, iCORE had much less time to establish impact, since it was in operation for about ten years compared to AOSTRA's 19 years (more if you include the AERI era) and AHFMR's 33 years. The resources allocated to iCORE in terms of time and treasure were fractional compared with the rest of the Trio and consideration of its impact, therefore, must be wary of this reality.

iCORE was like AHFMR in terms of the nature of its desired impact (i.e. improving the research capabilities of university based research teams) and its method (recruitment and development of HQP), which led to iCORE being a direct analogue to AHFMR. Like AHFMR, iCORE did not rely on industrial engagement as its primary requirement, although its Industry Chair program was only available to research projects conducted by industrial company, one of the universities, and NSERC. Even in the cases of industry engagement through the Industry Chair program, investments were made into the universities and were only for projects that had been vetted to fit into the respective university's research routines. It is also interesting to note that a good number of iCORE investments were related to informatics research projects that worked to improve natural resource development processes (e.g. computer process control research to improve the economics in oil sands processing) and, eventually, biomedical research processes (e.g. medical informatics).

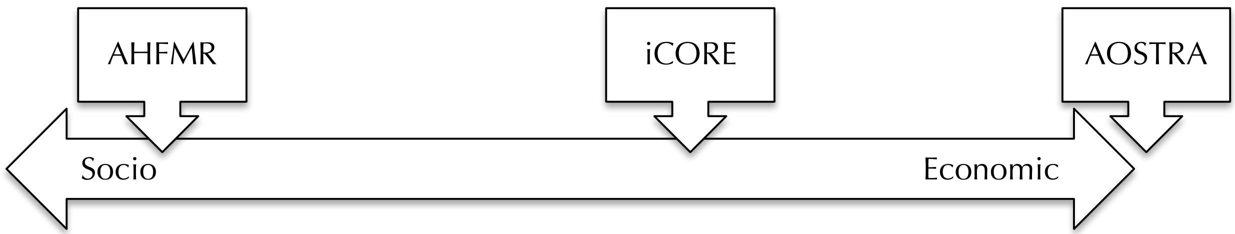
iCORE's main impact was on the culture and capabilities of the computer science and engineering departments at Alberta universities. When an elite researcher who focused on a new-to-Alberta research challenge was attracted to an Alberta university from abroad, that researcher brought capabilities that were new to the university and expanded the local knowledge base. These researchers would then act to attract high-caliber students which were hypothesized to eventually join the Alberta workforce and transfer their knowledge to industry.

6.3.2 General impacts

It is confirmed that AOSTRA, AHFMR, and iCORE investments in research resulted in a range of impacts that increased the stock of useful knowledge, resulted in trained graduates, created new scientific and technical methodologies, stimulated interaction within the system, and increased capabilities for problem-solving (Salter and Martin, 2001). Evolutionary economic literature suggests that these outcomes are important factors in driving the evolution that emerges from learning, skill development, and technological competition (Nelson and Winter, 1982; Smith, 2000). AOSTRA had a staggering impact on industrial capabilities and a meaningful impact on university research relating to the oil sands. AHFMR resulted in Alberta's biomedical research capabilities rising to sit amongst the highest in Canada, although its impact on Alberta industry is unclear. iCORE was successful at incrementally attracting and supporting elite informatics research talent.

Without as direct a relationship with industrial organizations, it was more challenging for iCORE and AHFMR to present evidence of their economic impacts, compared to AOSTRA. AHFMR and iCORE were mandated to develop world-class capabilities in domains without regionally bounded resources. Research in informatics and medicine are not unique to Alberta and, thus, AHFMR and iCORE's performances have an element of global context. AOSTRA was designed to meet the demands of sub-national industry, whereas AHFMR and iCORE were not designed to directly address industry demands. With a mandate to improve the economic potential of Alberta's energy industry, AOSTRA's outcomes were exclusively directed at projects that would create economic impact. With a focus on developing highly skilled informatics researchers and students, iCORE's outcomes were hypothesized to have eventual transformative economic impact. Finally, with a focus on medical research, AHFMR's desired impact leant toward the 'socio' side of socioeconomics. This scale can be described as a simple framework with two socioeconomic extremes; exclusive social impact and exclusive economic impact. In this framework, the 'socio' end of spectrum equals direct impact on individual Albertans and their households and the 'economic' end of the scale reflects direct impact on Alberta industry. With this scale in mind, the Trio organizations can be placed to highlight their differing impacts, as conceptualized in Figure 16.

Figure 16: Primary impact of Trio organizations



It is confirmed that the environment facing each Trio organization was different in terms of its actors, institutions, knowledge, and expected impact.

Did the Trio have a discernable impact on the Alberta sub-national system of innovation? The findings suggest that all the innovation agencies examined in this study managed instruments that were successful in creating additional research outputs (e.g. de-risked technological processes, recruitment of HQP, etc.). However, the findings also suggest that the characteristics of the target sector (e.g. energy, health, etc.), technology systems, and domain (e.g. industry, university, etc.) are critical in the assessment of the activities and impacts of innovation agencies. AOSTRA's impact on the sub-national innovation system was primarily a story of a clear success in serving industrial needs through de-risking the key elements of in-situ oil sands technology systems. This success came alongside dozens of smaller scale successes with technologies for other energy systems (e.g. enhanced oil recovery) and a failure resulting from inadequate investment in technological systems for reduced environmental impact. AHFMR's impact on the sub-national system of innovation was primarily the development of biomedical research infrastructure at Alberta universities to reach elite levels. The range of biomedical breakthroughs and the ability of Alberta's biomedical research system to attract funding from other agencies suggest that AHMFR's investments were successful.

AHFMR had less observable success in its biomedical technology commercialization efforts. None of the data from this period suggests that AHFMR had demonstrable success through its technology commercialization efforts. The comments from AHFMR's International Board of Review suggesting that AHFMR divest itself from the distraction of its technology commercialization programs are telling. While AHFMR's direct technology commercialization programs may have had uncertain direct impact, it is likely that any biomedical technology venture that emerges in Alberta is not far removed from a part of the innovation system that AHFMR impacted.

What can be said about the additionality that has been created by the Trio? All of the Trio were able to create significant input additionality with various programs. AOSTRA's partnership model drew in industry funding at a level roughly equal to its investment. iCORE and AHFMR programs that attracted or developed elite research talent usually resulted in significant additional funding from other research funding sources. Trio programs created output additionality in terms of patents, technologies and techniques, and trained individuals who carried knowledge into use. However important the input and output additionality, the most important type of additionality attributed to the Trio would be its behavior additionality. AOSTRA's investments led to behavioral changes such as industrial collaboration, use of new technological systems and the emergence of specialized SAGD service companies. AHFMR investments led to the development of an extremely capable biomedical research community which increased the profile of Alberta's research community. AHFMR's success led other jurisdictions to adjust their innovation policies to remain competitive in the pursuit of research talent. The behavioral impact of iCORE could be felt in the departments when a leading researcher would bring a new research theme into the department (e.g. quantum computing) which would attract qualitatively different students into the universities. Like AHFMR, iCORE programs were replicated by other jurisdictions who wished to remain competitive. Overall, while the input and output additionality of the Trio was significant the real impact of the Trio was in their ability to get other organizations to change their behavior.

6.4 Summary

The Trio emerged in Alberta partly because of the sub-national government being able to control the development of natural resources. Furthermore, the oil sands were both technologically challenging and valuable, which created an impetus for the sub-national system of innovation to evolve and address this deficiency. It is unlikely that the Trio would have evolved without the actions of the institutional entrepreneur Peter Lougheed; especially considering how involved he was in the design of the AOSTRA and AHFMR as well as developing supporting institutions (e.g. the Alberta Heritage Fund). When an innovation agency is created, it will be endowed with a trait of 'arms-lengthiness' which can impact the agencies strategic choice. Peter Lougheed played a major role in the founding of AOSTRA and AHFMR. Both organizations were deliberately designed by Lougheed to be at significant arm's length from the government; purportedly to avoid 'small p' political distractions and enable strategic focus on challenging scientific outcomes. A new innovation agency may incorporate design elements from other innovation agencies. When iCORE was designed, its supporters could use lessons from AHFMR to achieve similar outcomes while avoiding problems arising from the funding model.

The Trio created impact by influencing others to create the desired impact. For the most part the Trio used economic incentives to get firms or university departments to deliver the innovation function (e.g. R&D, training). An important exception was AOSTRA leading the Underground Test Facility initiative, which was instrumental to the development of in-situ oil sand technological systems. When new technology systems need to be widely adopted within a sector innovation agency programs can be designed to facilitate incremental knowledge transfer between stakeholders within a sub-national region. For example, AOSTRA's intellectual property policy was instrumental in the transfer of the oil sands technical knowledge. Without that element, the flow of knowledge from projects would have been much more limited. Many of the Trio programs created impact after the investment of other organizations, which is an efficient operational design but has an impact upon the range of strategies an innovation agency can pursue. Occasionally an innovation agency is willing to lead investment (e.g. the UTF or iCORE CPE Chairs) in pursuit of strategic goals. Some Trio programs led to unanticipated consequences. There were examples of Trio programs having unforeseen challenges resulting from the methods utilized to create impact. AOSTRA did not prioritize environmental technologies and AHFMR developed a funding model for researchers which was difficult to sustain.

Finally, the nature of the discernable impact of an innovation agencies will vary based upon what part of the sub-national system it is mandated to affect. An innovation agency mandated to work with industry on projects with clear utility will have qualitatively different impact than one working with universities exploring the boundaries of knowledge. AOSTRA had significant economic impact, primarily through the development of in-situ oil sands techniques. AHMFR had discernable impact upon the quality of the biomedical research conducted at Alberta universities. AHFMR's impact upon the economy through technology commercialization or clinical outcomes was indirect and difficult to assess. iCORE was also able to impact the research capabilities of Alberta universities, although its impact was constrained by a more modest budget and shorter period of operation compared to AOSTRA and AHFMR. The Trio created meaningful input and output additionality, but the behavioral additionality they created is the most important to appreciate. Taken together these finding suggest that the Trio were instrumental in Alberta's sub-national system of innovation.

7 Conclusion

7.1 Review

Innovation policy can be critical to the economic development of a region with abundant natural resources. This thesis examined how the government of Alberta created three innovation agencies to affect the sub-national system of innovation and whether said agencies were instrumental in the affecting the capabilities of the sub-national system of innovation.

This research is needed because often studies of sub-nation systems of innovation do not incorporate the historical elements that give the region a distinct character. Also, innovation agencies are an important option for governments to implement their innovation policy and studies of sub-national systems of innovation may not incorporate these organizations into their frameworks. The actions of institutional entrepreneurs are another dynamic that may be underappreciated as a source of change in a sub-national system of innovation. Finally, this research addresses a gap in the literature specific to understanding Alberta sub-national system of innovation and three significant innovation agencies.

7.2 Key points and recommendations

It makes sense that the natural resources can affect the character of a local economy; and the resultant economic structure will impact the role of the sub-national region in the national and global context. The economic development of a region like Alberta was shaped by the needs of the political and economic institutions in Ottawa and London. Yet the resources that were so desirable did not simply appear under the institutional control of the Crown. The access to the natural resources from which Alberta's system of innovation emerged began with the treaties with First Nations peoples. The challenging dynamic between Ottawa and Edmonton relating to control of natural resources is also noteworthy. The recognition of the headwaters of natural resource abundance is often overlooked, although it is expected that First Nations institutions will play an increasing role in natural resource development and may even provide incremental demands (e.g. environmental mitigation, economic development) that will drive incremental technical change. It is recommended that when analyzing the history of a resource-focused sub-national system of innovation that the historical institutional context be examined for significant clues to the region's character.

Sub-national regions may have valuable and technically challenging natural resources, which can lead to the government to consider investing in their development. The example of AOSTRA shows that innovation agencies can be extraordinarily effective agents in transforming the behavior of firms and qualitatively changing a sector of the economy (through expansion of knowledge, development of supply chains, etc.). It is important to recognize that AOSTRA acted as a signal maker and assumed some risk by establishing the Underground Test Facility. AOSTRA also implemented an important intellectual property and knowledge management regime that allowed knowledge to be more effectively shared across firm boundaries. The situation that led to AOSTRA is extremely context specific; nevertheless, regions that have valuable and technically challenging natural resources that are being underdeveloped by industry may want to closely examine what made AOSTRA effective and determine if a similar approach might suit their context.

In this thesis, innovation agencies have been shown to play an important role in the delivery of a government's innovation policy. Providing an ability to focus on a specialized innovation function and to provide an arm's length relationship between policymaking and program delivery. There is room in the systems of innovation literature to recognize that these organizations can play a role in qualitatively changing the sub-national system of innovation. The nature and scope of the potential impact of an innovation agency will vary dramatically depending upon the target group for programs as well as the agency's organizational effectiveness and program design. However, given the impact of the Trio, it is not unreasonable to speculate that innovation agencies are organizations that are uniquely positioned in a sub-national system of innovation to enable qualitative change in the system. If the conditions are favorable, the potential impact can be epic, leading to qualitative change on a large scale. Future research should be directed towards better understanding the role and the functioning of innovation agencies within the systems of innovation framework. This would also include the idea that innovation agencies should be able to learn from each other in terms of what are effective techniques to achieve desired outcomes.

It is important to recognize that institutional entrepreneurs can drive institutional change which could include innovation policy such as the formation of innovation agencies. In Alberta, there was the alpha institutional entrepreneur Peter Lougheed; and there were other individuals who were important in identifying functional gaps and working with the government to create policy to address these gaps. The effort of these individuals are discernable vectors in the narrative of a sub-national system of innovation. This makes perfect sense as these individuals are, by definition, positioned to adjust the institutions of the region; their impact will be greatest if they are savvy and positioned to understand signals that lead to perceived gaps in the innovation system. In

Alberta's case Lougheed was able to lead the effort to qualitatively change the energy and health innovation systems. Since institutional entrepreneurs adjust elements at the institutional level their potential impact can be significant in a sub-national region. It is recommended that research into the functioning of systems of innovation consider whether the role of innovation policy (including innovation agencies) was at least partially contingent upon the actions of an individual institutional entrepreneur.

When one examines a 'secondary'[47] innovation agency (like any of the Trio) and asks whether it has been successful in the creation of impact, the answer must be mindful that these innovation agencies were never designed to be the primary providers of an innovation function to the system. The Trio did not conduct research or develop technologies themselves. It is the portfolio of firms or academics that the Trio supported that are the primary providers of the desired innovation function. Most of the instruments that the Trio used were designed to co-invest with stakeholders on desired initiatives, which supports this perspective. Also 'successful' instrumentality for an innovation agency will vary significantly depending upon the sector and stakeholders it is mandated to affect. An innovation agency working with the oil sands industry on optimization of monetarily quantifiable technical processes will succeed very differently compared to an innovation agency looking to attract or develop research talent at the leading edge of science. The thesis argues that the innovation agencies were all instrumental in their own way, relative to sector, stakeholder and scale. It is suggested that any approach to examining the instrumentality of a secondary innovation agency needs to incorporate an examination of the recipient organization as well.

[47] In Section 2.2.2.2 secondary organizations are defined as organizations that affect the behavior of organizations (e.g. firms, universities) that provide innovation functions directly (e.g. research).

7.3 Future research

7.3.1 The role of the individuals

In the case studies individuals from across government, university, and industry domains were behind the early identification of gaps in the sub-national system of innovation and the creation of the conditions necessary for institutional entrepreneurs to incubate innovation agencies. Further research into these individuals, the importance of their social networks, and how they utilized their capabilities to begin to establish innovation agencies could add to the emerging literature on institutional entrepreneurship. These individuals exert significant influence on both the creation of and evolution of institutions related to innovation agencies (e.g. policy instruments, assessment of innovation agency performance, etc.).

A sub-theme of this research may explore the idea of deliberately developing a institutional entrepreneur support system. Perhaps allowing innovation policy ideas to be discussed and incubated in an open evolutionary format may lead to better policy. Perhaps encouraging increased institutional entrepreneurship training (and systems of innovation training) within government and universities would increase the pool of available knowledgeable institutional entrepreneurs. Finally, perhaps agents from the 'start up' ecosystem could be better leveraged to create more modern innovation agencies.

7.3.2 The role of boards and committees

Innovation agencies often have boards and committees that bring individuals from industry, university, and government together to provide governance to the innovation agency. Perhaps the board, and specifically the chair, plays a critical role in moderating innovation agency and government interactions. Perhaps the boards of innovation agencies vary in the extent to which they integrate direct investment adjudication and scientific assessment into their mandates. Also, perhaps the boards of innovation agencies may be in conflicts of interest, given that they may have roles in the organizations that the innovation agencies are directed to support. For the purposes of improving the operations of innovation agencies, a deeper examination of the role of boards and committees is an area of interest for future study.

7.3.3 The Heritage Fund

The funding model for Alberta's Heritage Fund was modified in 1987 and received no natural resource revenue or investment yields. Further research into this policy evolution and a counterfactual discussion of what difference more effective use a larger sovereign wealth fund could have made for a sub-national region like Alberta would be an interesting endeavor.

7.3.4 Additional Alberta innovation agency case analysis

Future research could utilize a similar mixed method approach to examine other innovation agency cases. Research could conduct a historical analysis of a region and then conduct case study analysis. Future research may also broaden from innovation agencies that remained public organizations to include investigations of innovation agencies that began as publically funded and evolved to become public-private partnerships (e.g. Spatial Data Warehouse) or moved completely to maintaining a market focus (e.g. Computer Modeling Group). A list of Alberta-based innovation agencies that could be interesting cases for future research is presented in Table 25.

Table 25: Potential innovation agencies for future research

Innovation agency	Brief description
Alberta Heritage Fund for Science and Engineering Research (known as 'Alberta Ingenuity')	Innovation agency with a mandate to improve science and engineering research capabilities. Some functional overlap with iCORE. Funded by the Alberta Heritage Fund. Sunset with Bill 27.
Spatial Data Warehouse	Innovation agency that focused upon reservoir modeling software. Began as a not for profit, converted to for profit.
Computer Modeling Group	Innovation agency that focused upon reservoir modeling software. Began as a not for profit, converted to a for profit.
Alberta Science and Research Authority (ASRA)	Innovation agency that acted as the operating arm of the Alberta's Ministry of Innovation and Science and oversaw organizations (e.g. Alberta Research Council, iCORE, etc.). In 2005, ASRA's function of overseeing other organizations was removed and ASRA then focused on its advisory role to the government. Sunset with Bill 27.
AMERA	Innovation agency that provided environmental monitoring capabilities for government, industry, academia, and the public. Was dissolved in 2016, upon review by the government. The NDP government (which had replaced the incumbent Conservative government) assessed AMERA and determined that its function was better provided by the government itself.
Alberta Research Council	Innovation agency and primary organization (i.e. directly provided R&D functionality) with a mandate to provide applied research capabilities to Alberta's economy. Worked closely with AOSTRA. Sunset with Bill 27.

7.3.5 Optimizing the creation and management of innovation agencies

Perhaps there is a need for a new approach to the early stages of innovation agency formation. The government could create a system where the ideas for innovation agencies are incubated. Incubation could consist of taking embryonic innovation agencies and subsidizing the establishment of their legal routines, strategic routines, instrument design, financial routines, socioeconomic performance assessment, user feedback, etc. There could be improved quality of operations in these innovation agencies that result from their not having to create routines from scratch. It may also allow for the improved standardization of additionality assessment.

7.4 Summary

If the role of innovation agencies and how they emerge and evolve in Alberta remains under-examined there is a risk that future investments in innovation agencies will be unnecessarily inefficient. Furthermore, without considering innovation agencies as a distinct class of organization the systems of innovation research community risk overlooking a potentially significant source of dynamism. With AOSTRA's impact on in-situ oil sand technology systems, AHFMR's impact on biomedical research and iCORE's impact on university informatics research capabilities there is no doubt the Trio made a discernable and significant impact.

Examination of the origins and evolutions of innovation agencies has just begun both in the Alberta context and in the systems of innovation literature. Innovation agencies are an important tool for governments to alter the trajectories of sub-national systems of innovation and positively impact the socioeconomic prospects of the regions. Innovation agencies are important and underappreciated examples of entrepreneurial government behavior that can lead to qualitative technical change at a sub-national level.

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Appendix A: Interviewees

Name	Date of Interview	Role in Innovation System
Brian Unger	October 4, 2013	First CEO of iCORE
Bob Church	October 8, 2013	Political Entrepreneur
Richard Taylor	November 8, 2013	Scientific Committee Advisor iCORE
Randy Goebel	November 21, 2013	Second CEO of iCORE
Fred Stewart	December 4, 2013	Government of Alberta
Lynn Sutherland	December 20, 2013	iCORE Management
Bob Fessenden	December 12, 2013	Government of Alberta
Ron Dyck	December 13, 2013	Government of Alberta
Gord Sustrick	January 30, 2014	Lawyer
Eddy Isaacs	March 3, 2014	AOSTRA
Kevin Keough	March 6, 2014	CEO AHFMR
Matt Spence	May 2, 2014	CEO AHFMR
Jacques Magnon	July 4, 2014	CEO AHFMR
Mel Wong	August 11, 2014	Government of Alberta
Stephen Lougheed	September 19, 2014	CEO Alberta Innovates
David Morhardt	October 9, 2014	Government of Alberta
Gavin Wright	December 18, 2014	Stanford university Economist
Khalid Aziz	December 18, 2014	Founder of Computer Modeling Group
Tom Corr	January 30, 2015	CEO of Ontario Centres of Excellence

Appendix B: NIH Extramural Funding to Canadian Provinces 1992 – 2006

	1992	1993	1994	1995	1996	1997	1998	1999	2000
BC	140,239	530,287	913,867	481,755	1,004,595	2,287,567	3,668,832	3,789,047	3,847,784
Alberta			41,278	119,578		221,083	374,926	734,678	1,889,578
SK						75,812	76,643	78,312	
MB	844,630		434,079		122,613	302,630	365,118	162,872	777,532
ON	736,979	1,949,328	1,755,582	1,862,008	7,445,742	10,643,322	7,849,033	9,322,055	10,727,589
QC	751,750	1,036,513	1,115,016	371,343	1,748,391	4,916,576	5,135,619	6,883,993	4,162,672
NS						106,091	144,082	135,647	133,810
Total	2,473,598	3,516,128	4,259,822	2,834,684	10,321,341	18,553,081	17,614,253	21,106,604	21,538,965

	2001	2002	2003	2004	2005	2006
BC	3,722,007	3,918,959	5,322,392	9,999,052	8,491,844	8,398,734
Alberta	1,648,231	3,183,740	3,381,906	6,081,020	6,000,201	9,261,802
SK						
MB	1,270,339	1,057,274	629,854	1,232,709	765,826	1,303,693
ON	12,399,182	15,247,806	31,073,808	33,912,814	29,558,940	35,758,874
QC	5,034,947	4,675,502	7,593,626	13,743,297	11,709,258	7,442,442
NS	132,175	200,000	200,000	200,000	200,000	268,000
Total	24,206,881	28,283,281	48,201,586	65,168,892	56,726,069	62,433,545

http://report.nih.gov/reportmap.aspx

Note: Provinces with no NIH funding are excluded from the table

Appendix C: Bill 27

Province of Alberta

ALBERTA RESEARCH AND INNOVATION ACT

Statutes of Alberta, 2009
Chapter A-31.7

Current as of January 1, 2010

Office Consolidation

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Note

All persons making use of this consolidation are reminded that it has no legislative sanction, that amendments have been embodied for convenience of reference only. The official Statutes and Regulations should be consulted for all purposes of interpreting and applying the law.

Amendments Not in Force

This consolidation incorporates only those amendments in force on the consolidation date shown on the cover. It does not include the following amendments:

Regulations

The following is a list of the regulations made under the *Alberta Research and Innovation Act* that are filed as Alberta Regulations under the Regulations Act

	Alta. Reg.	*Amendments*
Alberta Research and Innovation Act		
Alberta Research and Innovation	203/2009	*288/2009*

NOTE: AR 203/2009 comes into force on the coming into force of section 7 of the Act. Section 7 of the Act comes into force January 1, 2010.

ALBERTA RESEARCH AND INNOVATION ACT

Chapter A-31.7

Table of Contents

HER MAJESTY, by and with the advice and consent of the Legislative Assembly of Alberta, enacts as follows:

Definitions

1 In this Act,

(a) "Authority" means the Alberta Research and Innovation Authority established by section 3;
(b) "endowment Fund" means a Fund continued by section 11;
(c) "Minister" means the Minister of Advanced Education and Technology;
(d) "personal information" means personal information as defined in the Freedom of Information and Protection of Privacy Act;
(e) "research and innovation corporation" means a corporation established under section 7(1).

Purpose

2 The purpose of this Act is to promote and provide for the strategic and effective use of funding and other resources to meet the research and innovation priorities of the Government, including fostering the development and growth of new and existing industries and supporting a balanced long-term program of research and innovation directed to the discovery of new knowledge and the application of that knowledge to improve the quality of life of Albertans.

Alberta Research and Innovation Authority

3(1) The Alberta Research and Innovation Authority is established.

(2) The purposes of the Authority are

(a) to provide strategic advice and recommendations to the Minister on research and innovation matters relating to the purposes of this Act, and

(b) to carry out other duties determined by the Minister.

(3) The Authority reports to the Minister through the Chair of the Authority and is responsible for submitting to the Minister, at the times and in the form determined by the Minister, reports and plans as requested by the Minister.

(4) The Authority may make bylaws governing the calling of its meetings and the conduct of its business at meetings.

(5) The Authority may establish committees, which may consist of persons who are not members of the Authority, to assist the Authority with carrying out its purposes.

Membership

4(1) The Authority shall consist of not more than 12 members appointed by the Lieutenant Governor in Council.

(2) A member holds office for a term not exceeding 5 years but may be reappointed for further terms not exceeding 5 years so long as the reappointment would not result in the person serving as a member for more than 10 consecutive years.

(3) A break in service of less than 2 years shall be disregarded in determining the number of consecutive years under subsection (2).

(4) The Lieutenant Governor in Council shall designate one of the members as Chair and one of the members as Vice-chair.

(5) A member ceases to hold office when

(a) the member resigns,

(b) the member expires,

(c) the member is terminated by the Lieutenant Governor in Council, or

(d) the member is disqualified under the regulations.

(6) A members resignation become s effective when it is received by the Chair in writing or at the time specified in the resignation, whichever is later.

(7) The Chair shall send a copy of a resignation to the Minister forthwith.

(8) Notwithstanding subsections (2) and (5)(b), where a members appointment expires, the member continues to hold office until

(a) the member is reappointed,

(b) a successor is appointed, or

(c) 3 months has elapsed since the expiry, whichever occurs

first.

(9) The Lieutenant Governor in Council may determine the remuneration and travelling, living and other expenses payable to members of the Authority and to members of committees established by the Authority.

Alberta Research and Innovation Committee

5(1) The Alberta Research and Innovation Committee is established consisting of the chairs of the research and innovation corporations and any other persons appointed by the Minister.

(2) The purpose of the Alberta Research and Innovation Committee is to provide advice and recommendations to the Minister respecting

(a) the roles and responsibilities of research and innovation corporations,

(b) the co-ordination and prioritization of activities and initiatives of the research and innovation corporations, and

(c) other issues that may arise in relation to research and innovation matters, as required by the Minister.

(3) The Minister is the chair of the Alberta Research and Innovation Committee.

Cross-Government Portfolio Advisory Committee

6(1) The Cross-Government Portfolio Advisory Committee is established consisting of those members of the Executive Council whom the Lieutenant Governor in Council designates as having responsibilities for matters related to research and innovation.

(2) The purpose of the Cross-Government Portfolio Advisory Committee is to provide advice and recommendations to the Minister

(a) on payments from the endowment Funds, and

(b) on other funding matters determined by the Minister relating to the funding of research and innovation.

(3) The Minister is the chair of the Cross-Government Portfolio Advisory Committee.

Establishment of research and innovation corporations

7(1) The Lieutenant Governor in Council may, in accordance with the regulations under subsection (2), establish up to 4 research and innovation corporations to do either or both of the following:

(a) to meet the research and innovation priorities of the Government in the following areas or in a combination of the areas:

(i) agriculture;

(ii) forestry;

(iii) energy;

(iv) the environment;

(v) health;

(vi) any other area determined under the regulations;

(b) to foster the development and growth of new and existing industries through research and innovation.

(2) The Lieutenant Governor in Council may make regulations

(a) respecting the establishment of a research and innovation corporation including, without limitation, regulations respecting the following:

(i) the name of the corporation;

(ii) the objects of the corporation;

(iii) the capacity and powers of the corporation, including the power to borrow, invest, purchase shares and give indemnities;

(iv) the size and composition of the board of directors;

(v) eligibility for appointment to the board of directors;

(vi) the method of appointment and terms of office of members of the board of directors and the designation of a chair and vice-chair or election of officers;

(vii) the remuneration and expenses payable to members of the board of directors, including members of any committees established by the corporation or the board;

(viii) the roles and responsibilities of the board of directors;

(ix) the hiring and the remuneration of employees;

(x) the calling of meetings and rules of procedure for meetings;

(xi) a code of ethical conduct, including conflict of interest guidelines and any other guidelines and policies in respect of directors, officers and employees of the corporation;

(xii) the disqualification of members of the board of directors;

(xiii) the making of bylaws and the subject-matters that may be dealt with by bylaw;

(b) respecting the entering into of joint venture or partnership arrangements by the corporation;

(c) respecting the establishment of subsidiaries by the corporation;

(d) respecting the preparation of records and accounts under section 9(1);

(e) respecting the preparation and submitting of reports, plans and budgets;

(f) determining other areas for the purpose of section 7(1)(a)(vi);

(g) respecting any terms and conditions regarding the acceptance and use by the corporation of funds from sources other than an endowment Fund or the Government;

(h) respecting the dissolution or liquidation and dissolution of the corporation, the manner in which the dissolution and any liquidation are to be carried out, and the winding-up of the activities of the corporation.

(3) A research and innovation corporation shall not make loans or give guarantees.

(4) The share capital of a research and innovation corporation consists of one share owned by the Crown.

(5) The fiscal year of a research and innovation corporation is April 1 to the following March 31.

(6) A research and innovation corporation is not an agent of the Crown.

Duty of care

8(1) Every director, officer and employee of a research and innovation corporation shall comply with this Act, the regulations and the bylaws of the corporation.

(2) No provision in any contract, resolution or bylaw relieves any director, officer or employee of a research and innovation corporation from the duty to act in accordance with this Act, the regulations and the bylaws, or from liability for a breach of that duty.

(3) Every director and officer of a research and innovation corporation, in exercising powers and performing duties,

(a) shall act honestly and in good faith and with a view to the best interests of the corporation, and

(b) shall exercise the care, diligence and skill that a reasonably prudent person would exercise in comparable circumstances.

(4) In considering whether the exercise of a power or the performance of a duty is in the best interests of the research and innovation corporation, a director or officer, as the case may be, may have due regard to the interests of the Crown.

Records and accounts

9(1) Subject to the regulations, a research and innovation corporation shall prepare records and accounts.

(2) The Minister may request from a research and innovation corporation any information, including personal information, the Minister considers necessary, and the corporation shall disclose the information in the form and manner determined by the Minister.

(3) A research and innovation corporation shall allow the Minister or the Ministers representative to inspect and make copies of all records, accounts, reports and other documents of the corporation and, in the case of an electronic document, print the electronic document, and otherwise review the operations of the corporation.

(4) If the information disclosed under subsection (2) or contained in records, accounts, reports and other documents of the research and innovation corporation referred to in subsection (3) is personal information, the Minister may collect, use and disclose that personal information

(a) for the purposes of reviewing and monitoring the operations of the corporation,

(b) for the purposes of administering this Act and the regulations,

(c) for the purposes of ensuring the corporation is carrying out the objects of the corporation, and

(d) for any other purpose authorized by regulation.

(5) If the information disclosed under subsection (2) or contained in records, accounts, reports and other documents of the research and innovation corporation inspected, copied or printed under subsection (3) relates to labour relations, is a trade secret or is of a commercial, financial, scientific or technical nature, the information is to be treated as having been provided in confidence.

Directives

10 The Minister may issue directives that must be followed by a research and innovation corporation, the board of directors of the corporation, or both, in carrying out their powers, duties and functions under this Act.

Endowment Funds

11(1) The Alberta Heritage Foundation for Medical Research Endowment Fund and the Alberta Heritage Science and Engineering Research Endowment Fund are continued.

(2) The endowment Funds are to be used for the purposes of this Act, including,

(a) in the case of the Alberta Heritage Foundation for Medical Research Endowment Fund, to support a balanced long-term program of research and innovation related to health and directed to the discovery of new knowledge and the application of that knowledge to improve health and the quality of health services in Alberta, and

(b) in the case of the Alberta Heritage Science and Engineering Research Endowment Fund, to support a balanced long-term program of research and innovation directed to the discovery of new knowledge and the application of that knowledge to the commercialization of technology.

(3) The Minister of Finance and Enterprise shall hold and administer the endowment Funds and has the same powers of investment with respect to the endowment Funds that the Minister of Finance and Enterprise has with respect to the General Revenue Fund under the *Financial Administration Act*.

(4) The income of an endowment Fund derived from investments made under subsection (3) accrues to and forms part of the Fund.

(5) In addition to the money currently in the endowment Funds, the Funds may include money voted by the Legislature for the purposes of the Funds.

(6) The Minister of Finance and Enterprise shall, as soon as practicable after the end of each fiscal year of the Crown, prepare a report summarizing the transactions and affairs of the endowment Funds during the preceding fiscal year and shall lay a copy of it before the Legislative Assembly if it is then sitting, and if it is not then sitting, within 15 days after the commencement of the next sitting.

Payments from an endowment Fund

12(1) The Minister of Finance and Enterprise must, at the request of the Minister of Advanced Education and Technology made on reasonable notice, pay from the specified endowment Fund money that, in the opinion of the Minister of Advanced Education and Technology, is required to carry out the purposes of the Fund, which include the funding of the research and innovation corporations.

(2) Subject to subsection (4) and the regulations, the aggregate of amounts paid under subsection (1) from an endowment Fund in a fiscal year may not exceed 4.5% of the market value of the Fund.

(3) The market value for the purpose of subsection (2) is the average of the market values determined on March 31 of the preceding 3 fiscal years.

(4) If less than 4.5% of the market value of an endowment Fund is paid from a Fund in a fiscal year, the unused portion of the amount permitted to be paid in that fiscal year may be paid in any subsequent fiscal year.

General regulations

13 The Lieutenant Governor in Council may make regulations

(a) authorizing the Minister to collect, use and disclose information, including personal information, for specified purposes;

(b) respecting the collection, use and disclosure for specified purposes of information, including personal information, among the Minister, the research and innovation corporations, the Authority and the advisory committees established by sections 5 and 6;

(c) defining terms that are used but not defined in this Act;

(d) respecting circumstances in which the percentage referred to in section 12(2) may be exceeded;

(e) providing for any matter the Lieutenant Governor in Council considers advisable for carrying out the intent and purposes of this Act.

Transitional Provisions, Consequential Amendments, Repeal and Coming into Force

Dissolution and winding-up of existing entities

14(1) In this section, entity means an entity referred to in subsection (2).

(2) The Lieutenant Governor in Council may dissolve the following entities:

(a) the Alberta Agricultural Research Institute;

(b) the Alberta Energy Research Institute;

(c) the Alberta Forestry Research Institute;

(d) the Alberta Heritage Foundation for Medical Research;

(e) the Alberta Heritage Foundation for Science and Engineering

Research;

(f) the Alberta Information and Communications Technology Institute;

(g) the Alberta Life Sciences Institute;

(h) the Alberta Research Council Inc.;

(i) the Alberta Science and Research Authority;

(j) iCORE Inc.;

(k) any subsidiary of an entity referred to in clauses (a) to (j).

(3) Where an entity is dissolved under subsection (2), the appointments of the members of the board of that entity are terminated.

(4) The Minister may, by order, with respect to an entity dissolved under subsection (2)

(a) provide for the winding-up of the affairs of the entity;

(b) provide for the transition of any of the powers, duties and functions previously carried out by the entity;

(c) transfer the assets, if any, of the entity;

(d) transfer the obligations and liabilities, if any, of the entity;

(e) provide for the transfer of records of the entity, including records containing personal information, to a research and innovation corporation;

(f) determine by or against whom any civil, criminal or administrative action or proceeding pending by or against the entity is to be continued;

(g) determine in favour of or against whom any ruling, order or judgment in favour of or against the entity is to be enforced.

(5) An order under subsection (4) may contain any provisions the Minister considers necessary to protect the interests of creditors.

(6) The Minister may from time to time give any directions the Minister considers appropriate concerning the winding-up of an entity dissolved under subsection (2).

(7) An order under subsection (4) may be made retroactive to the extent set out in the order.

(8) The *Business Corporations Act* and the *Companies Act* do not apply with respect to the dissolution and winding-up of an entity referred to in subsection (2) that was established under the *Business Corporations Act* or the *Companies Act*.

(9) The *Regulations Act* does not apply to an order under this section.

Severance and termination pay

15(1) In this section and section 16,

change in governance(a) or re structuring with respect to a dissolved entity includes

(i) the dissolution of the dissolved entity, and

(ii) a transfer of the responsibility for all or part of the operations of the dissolved entity to another entity;

dissolvedmeansanentity(b) dissolved under section 14.

(2) This section applies only in respect of employees who are not represented by a bargaining agent.

(3) Notwithstanding any other enactment or the terms of an employment contract, no employee of a dissolved entity is entitled to severance pay or termination pay or other compensation if the employees position is substantially the same after the change in governance or restructuring as it was before the change in governance or restructuring.

(4) Nothing in this section precludes an employer from voluntarily giving an employee or former employee severance pay or termination pay or other compensation.

Transitional regulations

16(1) The Lieutenant Governor in Council may make regulations

(a) respecting the transition

(i) of any of the powers, duties and functions of a dissolved entity, and

(ii) of any other matters relating to the dissolution of the dissolved entities or the repeal of an Act referred to in section 18;

(b) to remedy any confusion, difficulty, inconsistency or impossibility resulting from the dissolution of a dissolved entity or the repeal of an Act referred to in section 18.

(2) A regulation made under subsection (1) may be made retroactive to the extent set out in the regulation.

(3) A regulation made under subsection (1) is repealed on the earlier of

(a) the coming into force of a regulation that repeals the regulation made under subsection (1), and

(b) 2 years after the regulation comes into force.

(4) The repeal of a regulation under subsection (3) does not affect anything done, incurred or acquired under the authority of the regulation before the repeal of the regulation.

13

Consequential amendments
17 *(This section amends other Acts; the amendments have been incorporated into those Acts.)*

Repeals
18 The following are repealed on Proclamation:

(a) the *Alberta Heritage Foundation for Medical Research Act*, RSA 2000 cA-21;

(b) the *Alberta Heritage Foundation for Science and Engineering Research Act,* RSA 2000 cA-22;

(c) the *Alberta Science and Research Authority Act*, RSA 2000 cA-33.

Coming into force
19 This Act comes into force on Proclamation.

(NOTE: Proclaimed in force January 1, 2010)

Appendix D: Consent form

Theory of Innovation Agents in a Regional Economy.
The Case of Alberta : Leadership, Energy and Innovation.

CONSENT FORM

This research, conducted by Terry Ross from the University of Calgary, investigates the dynamics that shaped the evolution of three Provincial Corporations iCORE, AOSTRA and AHFMR. The project is premised on claim the Systems of Innovation framework is a useful for exploring the determinants of innovation in a region. The System of Innovation framework suggests that system elements (organizations, laws, natural resources, norms of behavior, and especially knowledge) interactively evolve, creating a system that can not be properly understood without a longitudinal perspective.

While there are numerous types of organizations within a regional system of innovation such as Universities, Government Departments, and for profit companies. Our research examines a type of organization created and beholden to the Government, an organization called the Innovation Agent.

Innovation Agents are, by definition, organizations that are created by the regional government with the purpose of catalyzing the regional system of innovation.

The research investigates the narrative of three Alberta 'Innovation Agents' as case studies for theory generation.

1. iCORE
2. AOSTRA
3. AHFMR

The three are referred to as the TRIO

Our inquiry is guided by the following questions:

- How did the (good?) idea for creation of the TRIO emerge?
- How was the TRIO given specifics in legislative form and given an implementable design?
- How did the TRIO design win approval?
- How well was the TRIO implemented?
- How well did the TRIO generate results?
- How was the TRIO re-evaluated?

You are being asked to participate because of your relevance to the TRIO and the questions listed above. While there will be no immediate benefit to you for participating in this study, the goal of this research is to gain insights that can be applied to improve the way knowledge sectors are governed in the future.

We are asking you to help by consenting to an interview or a focus group. This discussion, which has been designed to minimize the amount of time by you, typically lasts one hour. The interviews will, with your permission, be recorded.

Please note that notes and transcripts are stored in password-protected computer systems. We also assure you that your identity nor any details of your organization will be revealed in any presentation or publications that result from this research, without your expressed written permission.

Your participation in this study is strictly voluntary and you are, of course, free to choose not to answer any questions and may terminate the interview at any time with no consequences. If you have any questions regarding the study and your participation in it, please feel free to ask.

Terry Ross
University of Calgary
(403) 615-8572

Appendix E: Questionnaire

Introduction
This research focuses upon a particular phenomenon relating to a regional Government's support of knowledge-based socioeconomic development.

The phenomenon under study is: the creation and management of 'arms-length' government organizations with a primary mandate to affect change in the Innovation system in the region. This study calls these particular organizations 'Innovation Agents' and will focus on Innovation Agent case studies from Alberta as the source of data. By definition, Innovation Agents use 'programs' and 'projects' to affect change in local organizations such as Universities, Hospitals and Companies.

Our study will examine three cases of Alberta Innovation Agents and will generate theory based upon insights gained from analysing data. The following three cases are referred collectively as **'The TRIO'**:
- The Alberta Heritage Foundation for Medical Research (AHFMR)
- The Alberta Informatics Circle of Research Excellence (iCORE)
- The Alberta Oil Sands Technology and Research Authority (AOSTRA)

This interview will focus upon your insights relating to one particular CASE to allow within case insights

Our inquiry and the collection of data for the study will be guided by the following questions:
- How did the idea for creation of the TRIO emerge?
- How was the case given specifics in legislative form and given an implementable design?
- How did the case design win approval? (determined by creation of funding?)
- How well was the case implemented?
- How well did the case generate results?
- How was the case re-evaluated?

This interview will last approximately 60 min and will be recorded with your permission. You may withdraw anytime during the interview and your interview data will be deleted.

Subject Questions
Interviewee Name:

Please describe your relationship with the CASE?

What was the role that they played with the CASE? *If they weren't directly employed by the CASE organization what type of organization did they belong to?*

Case Study Questions
These questions are grouped by the 'stage' of the case.

IDEA PHASE
- How did the idea for creation of the CASE emerge?
  - *What were the events that led up to the [creation or other phase] of the* CASE*?*
  - *What was the socio-economic justification for the* CASE*?*
  - *What was assumed to be needed? What gap was the CASE meant to address in the local economy? Who assessed that gap?*

- *Were there common people behind the idea?*
- *What was the primary purposes/functions of the* CASE*?*
- *What is most important to know about how to successfully execute this phase?*

DESIGN PHASE

- How did the idea for the CASE be given legislative specifics and implementable design?
  - *What is most important to know about how to successfully execute this phase?*

APPROVAL PHASE

- How did the CASE design win approval? ('Approval' is defined as the creation of funding?)
  - *What is most important to know about how to successfully execute this phase?*

IMPLEMENTATION PHASE

- How well was the CASE implemented?
- What was the most important function that the CASE provided?
- Were there significant evolutions in the CASE? If so, what was behind them? Were any of these unexpected?
- *What is most important to know about how to successfully execute this phase?*

RESULTS PHASE

- How well did the CASE generate results (i.e. fulfilling its primary purposes/functions?)?
  - How could you tell if the CASE was having the desired impacts with its clients?
  - What was the primary system for accounting for results? What form was it in? What did it measure?
  - What really mattered that was not measured?
- *What is most important to know about how to successfully execute this phase?*

REEVALUATION PHASE

- How was the CASE re-evaluated?
  - What was the most important source of feedback between clients and IA AND government and CASE?
  - What is important to know about success at this phase?
- What were challenges to success to the CASE?
- *What is most important to know about how to successfully execute this phase?*

Overall, is there anything that was crucial to the success of the CASE that we have not discussed yet that you would like to highlight?

CONCLUSION

- Are there any other people related to CASE that we should talk to?
- Why are they important to talk to?
- What was their role (determine if they are conceptually relevant)?