

C-CORE AS A NETWORKED INDUSTRIAL POLICY INITIATIVE

PETER WARRIAN & DAVID WOLFE
INNOVATION POLICY LAB, MUNK SCHOOL
UNIVERSITY OF TORONTO

July 18, 2016

C-CORE as a Networked Industrial Policy Initiative

By

Peter Warrian & David Wolfe¹
Innovation Policy Lab, Munk School
University Of Toronto

July 18, 2016

1. The authors wish to acknowledge the invaluable contribution of Mr. Wade Kearley who conducted the field interviews in the study.

EXECUTIVE SUMMARY

The objective of this Report is to analyze C-CORE and more broadly Memorial University's contribution to the innovation ecosystem in Newfoundland and Labrador within the emergent new policy framework of Network Based Industrial Policy. Understanding the unique features of the NL economy, its institutions and the dense network of local relationships that make up the NL innovation ecosystem is critical to understanding the social nature of the innovation process. It is also critical to understanding the context and contribution of academic institutions and the research infrastructure of the Province in its relationship to the knowledge-based economy and the resilience of its traditional resource-based economy.

Multi-National Corporations (MNCs) are major and sophisticated industry partners for MUN and NL. They are involved with very specific technical issues e.g. ice conditions and drilling. They may present opportunities for individuals to gain a presence in the international market. However, from the perspective of economic development, they do not expand export opportunities for NL. Further, the large international companies do not appear to have IP issues with MUN. MNCs are also much affected by the cycles of the resource economy so there are major discontinuities in their contribution to intellectual and organizational capacities in the NL research infrastructure.

NL SMEs do offer the greatest opportunities for export development and leading edge technology in specific niches such as signals processing in support of resource development and the fishery. Maker SMEs (established manufacturing and producer companies) are constrained by internal resource limits both financial and human capital and by a culture of incrementalism. They also see innovative investments solely as a cost. They tend towards the "can't pay, won't pay" end of the spectrum. The Techie SMEs (start-ups and software companies) are the greatest difference makers for future NL regional economic development but are both the least engaged and least dependent on MUN for sources of new ideas. They are also the most antagonistic towards the university administration and its past IP regime.

The negativity with some of the SMEs is returned in kind, not without some grounding in fact. Most interviewees on the business side view the MUN faculty as having a traditional ivory tower attitude to research that would remain in the lab forever. For the more 'with it' faculty they simply maneuver around the formal IP regime and engage in personal relationships that may be successful but may be the exception that proves the rule. As a whole, because in most ways MUN is the system, it can act as if it owns the system and therefore underperforms long term.

The Report also applies TRL levels to the analysis of C-CORE. Technology Readiness Levels (TRLs) have become part of the lingua franca of research policy, funding criteria and evaluation of research and technology development projects (Mankins 1995; ISO 2013). The TRL framework emphasizes step-like progress from product or process conception to commercialization. Officials and entrepreneurs who use the framework have identified the transition to the use of prototypes in a simulated environment (Level 6) to the verification of prototypes in an operational environment (Level 7) as the key challenge in upgrading firm innovation capabilities. The TRLs help identify the specific steps in technology adoption that most enterprises need assistance with: proof of concept through the application of prototypes in their operational environment (Levels 4-7).

C-CORE occupies a unique space in the innovation ecosystem. It is a university owned entity that act more like a Business Led Research Network.

It is a vital asset in the NL economy and research infrastructure. Most importantly, but least recognized, is that it is the one anchor of continuity in the face of decades of cycles of resource development and sways of government policy priorities. It has continuity of key personnel, institutional memory and key datasets from past projects. However, it is faced with managing multiple business units with different TRL trajectories. The Marine Institute, on the other hand, is probably the closest fit with the academic studies for a functioning networked industrial policy agent.

To understand the contribution an institution like C-CORE makes to an emergent networked industrial policy, it is critical to de-construct the economics of universities and the knowledge economy and to be able to be specific about the actual channels of knowledge transfer. In the case of Memorial University and C-CORE, three factors stand out.

While preserving its traditional anchor roles of teaching and research, MUN has modified and extended its role in technology transfer with the establishment of C-CORE as a standalone entity outside of the university's mainstream operating entities.

Second, as C-CORE has evolved and learned from past experience and experiments such as royalties, equity shares, etc., it has evolved to the stage where it now seeks to function as far as possible outside of the university's IP regime.

Third, C-CORE as a hybrid institution is functioning in effect as a University owned Business Led Research Network. This is confirmed by the application in this Report of TRL scales to C-CORE projects and the comparing of these results with other Business-Led Centres of Excellence (BLRC) networks across the country. C-CORE is clearly differentiated from the traditional University profile.

Fourth, if it is desirable to have C-CORE function as a true equivalent of a business led research network, then it should be benchmarked against BLRCs in its governance, developmental goals for commercialization, funding mechanisms and technical coordination. For example, a business-led organization like ReMAP in Toronto has a Board with government and academic representatives but is chaired and has a majority membership from the private sector. It 'crowd sources' its research project funding from its government and industry partners for five year cycles. It manages projects with defined TRL entry and exit points. And, it accelerates the pace of innovation by leveraging the whole value chain from SMEs to MNCs and customers.

The innovation story embedded in C-CORE is rich and complex. Its total contribution to the NL innovation ecosystem would be more fully understood by further examination of the specific forms of knowledge creation and technology transfer taking place within the individual projects at each of the TRL stages.

This Report is not a cluster study. However, previous research on the NL Ocean Technology cluster has emphasized that it's outward orientation coupled with the dominance of only a few firms within the cluster in terms of buyer/supplier relationships and collaborations suggests the cluster is vulnerable to external economic shocks. This has now happened with the collapse of oil prices. The Ocean cluster and the NL research infrastructure are about to be subjected to a severe stress test.

TABLE OF CONTENTS

Introduction	6
Universities and the Knowledge Economy	11
TRLs and Metrics for Policy.....	17
Networked Industrial Policy.....	21
Newfoundland’s Ocean Technology Cluster	26
Implications of Research Findings for Policy.....	30
Conclusions	33

INTRODUCTION

Background and Purpose of the Study

The objective of this Report is to analyze C-CORE and more broadly Memorial University's contribution to the innovation ecosystem in Newfoundland and Labrador within the emergent new policy framework of Network Based Industrial Policy. Understanding the unique features of the NL economy, its institutions and the dense network of local relationships that make up the NL innovation ecosystem is critical to understanding the social nature of the innovation process. It is also critical to understanding the context and contribution of academic institutions and the research infrastructure of the Province in its relationship to the knowledge-based economy and the resilience of its traditional resource-based economy.

The challenges that the NL economy faces, particularly with the downturn in energy prices, is not unlike that currently faced by Ontario with its mature automotive sector. For both provinces, lessons and directions can be drawn by looking at examples from the UK, Germany and the USA. However, at the end of the day, it is the unique features and capacities of the Province¹ that will frame the options and prospects for the future.

This Report builds upon original field research. It seeks to elaborate on the data points and views which arose in individual interviews, drawing out the analytical and policy issues in the findings.²

Section 1 provides a brief overview of the origins and role of C-Core to date, its role within the postsecondary educational system and the place that it occupies within the broader regional innovation system in Newfoundland and Labrador.

Section 2 discusses the role of the university in the knowledge economy based on the latest thinking in the academic literature. It describes in a rigorous way the kinds of knowledge produced in universities and the specific channels of knowledge transfer that take place in interaction with external entities. This is not limited to conventional issues of Intellectual Property (IP) regimes.

Technology Readiness Levels (TRLs) have become a pervasive methodology for policy formation, funding criteria and evaluation of public and private research endeavours. **Section 3** extends the discussion by looking at the TRL practices of C-CORE research projects. It then compares them to data from other Canadian research organizations in terms of the stages of intervention and technology transfer that are taking place.

Section 4 discusses the recent emergence of Networked Industrial Policy as the latest form of policy discussion and implementation among various jurisdictions following upon the Financial Crisis of 2008-09. Particular importance is placed on the building up of regionally-specific Industrial Commons of shared public goods such as laboratories, shared equipment, expertise, etc. Of particular concern for policy makers is the interaction between academic institutions and SME firms.

Section 5 references some of the major findings of the field research done for this Study that bear upon the policy issues discussed in previous sections. It also identifies several policy challenges that arose in the sometimes contradictory views given by the interviewees.

Section 6 presents some conclusions about where C-CORE and MUN more generally, are placed within the innovation eco-system of Newfoundland and Labrador. Suggestions are made about how the research may contribute to future strategy and policy dialogue that may take place within the university and with its partners. Lessons learned will hopefully assist efforts to enhance the University's contribution to the Region's innovation eco-system in the future.

¹ In this Report, the term "region" as used in the academic literature on innovation can be equated with the Province of Newfoundland and Labrador.

² The issues of methodology, research instruments and interview metadata are addressed in the Preliminary Report.

C-CORE Profile

C-CORE is a not-for-profit Canadian northern and Arctic research and development (R&D) corporation headquartered on the campus of Memorial University in St John's, NL, with additional facilities in Ottawa ON, and Halifax, NS. This Canadian ISO 9001-registered R&D organization has a mandate to create value in the private and public sectors by undertaking new, applied research and development, generating knowledge, developing technology solutions and driving innovation while continuously growing capacity and capability.

C-CORE wholly owned by and maintains a close collaborative relationship with Memorial University. It has a Fiduciary Board appointed by the President of MUN and it includes a variety of corporate and administrative links. They have access to Memorial's extensive facilities, diverse academic expertise and a \$100 million research portfolio. C-CORE supports faculty positions at Memorial and continually interacts with Memorial students. They have supported more than 1100 undergraduate, graduate and post-doctoral students and incubated eighteen new technology companies. In addition, senior members of Memorial faculty and administration serve on the board of C-CORE.

The impetus to create C-CORE began in the early 1970s with the work of then-president of Memorial University, Dr. Moses Morgan and the dean of the university's Faculty of Engineering at the time, Dr. Angus Bruneau. They identified the need for such a research entity in a proposal to the Science Council of Canada writing that: "...the frontiers of this country are being rolled back revealing the vastness and wealth of ... our great lands, their mass covered by the surrounding oceans.... To realize the potential benefits these territories and seas may bring..., massive efforts will have to be made... to explore and grapple with our ocean environment on a scale and in ways we have not yet imagined."

The solution they proposed required that, "The gathering of scientific data must be continued of course, but must be supplemented with development of engineering systems for the economic utilization of our ocean-based resources in environments different from any in which activity has ever before been attempted. For this basic reason, a Centre for Cold Ocean Resources Engineering in this country is essential." With initial funding from the Devonian Foundation of Calgary, C-CORE was founded.

When C-CORE was established in 1975 it was charged with a mandate to provide solutions to the challenges of offshore oil and gas development on the Grand Banks off Newfoundland and Labrador where ice and icebergs provided unique challenges.

According to its website, C-CORE provides research-based advisory services and technology services to help clients seeking ways to mitigate the risks of operating in harsh environments and to address security, sustainability and safety issues regardless of where in the world they operate. During its first decade, that meant that C-CORE focused applied research on understanding the behavior and prevalence of sea ice and icebergs in regions of potential development, and on developing techniques to mitigate risk in those locations through physical management. During the second decade of C-CORE's operations it faced an evolution of the oil and gas sector that encouraged leaner operations, strong emphasis on the bottom line and a more rapid commercialization of R&D investments.

In its evolution since that time, C-CORE has approached increasing globalization as an opportunity to diversify its technical capabilities and its market portfolio. Their services expanded in areas where they consider themselves world leaders including ice engineering, remote sensing and geotechnical engineering. And they have been successful in marketing these services internationally. Over the past few years C-CORE has worked on every continent and in most oceans. They have built systems used in space. And, building on their core expertise in offshore oil and gas, they have entered new market sectors such as pipelines, mining and hydro-power. Fifty percent of its annual revenues of 2015 are derived from ocean technology research.

From the staff of approximately 100 scientists, engineers and other professionals, project teams are assembled based on client need, drawing on internal expertise across disciplines, as well as national/international academic, institutional and corporate partnerships, in order to support increasingly safe and sustainable operations in challenging environments around the globe.

C-CORE, with its expertise concentrated in the early stages of the value chain for innovative and commercialization, has faced the need to adapt and evolve by seeking to provide more relevance in the conversion of early research into commercial application. In the pursuit of its mission, C-CORE continues to strive to include in its services, not only engineering research and development, but also the practical application of new technologies.

And while their contribution to the early stages of the innovation chain is undisputed, their success and their role in commercialization of technologies is a topic of debate among the private and public leaders of the province's innovation ecosystem. At issue are not only competence in commercialization but also the question of its role and whether or not C-CORE is or ought to be partnering with and /or in competition with the private sector.

President and CEO of C-CORE, Dr. Charles Randell began with his first assignment at C-CORE, as a technician investigating ways to blow up icebergs. Since he became President and CEO of C-CORE in 2006, the corporation has increased its personnel by half and doubled its annual revenue while expanding to open the Ontario and Nova Scotia offices and launch LOOKNorth, a Canadian Centre of Excellence for remote sensing innovation to support remote resource development and operations, and also the Centre for Arctic Resource Development (CARD) – a long-term R&D initiative in partnership with the oil and gas industry.

Because of its longevity and the level of involvement with the oil and gas sector, C-CORE is also a vital repository for data collected during the initial and early phases of offshore exploration with the capability of making that data available for application in today's more advanced production, development and exploration phase of the O&G sector in offshore Newfoundland and Labrador. That means the private sector today has access to data that might otherwise have been lost as the other players in the early research either moved on to other regions of the globe or ceased to exist altogether.

C-CORE SERVICES

C-CORE provides research-based advisory services and technology solutions to national and international clients in the natural resource, energy, security and transportation sectors. Public sector clients can also access services to address security, sustainability and safety issues for regulatory and operating needs.

C-CORE describes its primary mission as one to develop and apply advanced engineering principles to solve operational challenges in the natural resources and public service sectors. They also pursue two secondary missions, first to further the understanding of the physical world in ways that lead to informed decisions and designs and safe development; and second to develop highly qualified personnel, particularly in advanced engineering.

Over the four decades in operation, C-CORE has focused on assembling the world's preeminent team in ice engineering, remote sensing and geotechnical engineering. Among the tools it has provided to its researchers is one of the largest geotechnical centrifuges in the world. The centrifuge can simulate twenty years of freezing and thawing in just eight hours and demonstrate its impact on model-size ocean equipment such as offshore rigs and pipelines. And as a result of their research C-CORE has developed simulation tools to enable its clients to forecast iceberg movement and prepare mitigation strategies to protect built structures and facilities in the offshore. The simulations can take into consideration a range of factors from potential impact on manmade structures, location, size and direction of drift, number of icebergs on a threatening course, and available mitigation or size and availability of tow vessels. C-CORE was a partner in the

development of the iceberg net which, because of its designed capability to reduce the likelihood of iceberg roll during towing, is now in common use across the industry.

CENTRES OF EXCELLENCE

Guided by its vision and its mission, C-CORE has established two centres of excellence: LOOKNorth, a national Centre of Excellence for Commercialization and Research dedicated to remote sensing innovation; and the Centre for Arctic Resource Development (CARD), dedicated to medium- and long-term Arctic research and development with an emphasis on “responsible, cost-effective development of hydrocarbons in high latitudes.”

THE BOARD OF C-CORE

In Addition to Dr. Charles Randell, Ph.D., P.Eng., FCAE, President and CEO, C-CORE, the current Board of Directors includes David Oake, (Chair), President, Invenio Consulting Inc.; Mark MacLeod, (Vice-Chair), Vice-President, Atlantic Canada, Chevron Canada Ltd.; David Alcock, President, Dispute Resolutions; Tom Bursey, Vice-President, Corporate Services and CFO, Council of Canadian Academies; John Eidsnes, Technology Director, North Sea & Canada, Subsea 7; Ray Gosine, Associate Vice-President (Research), Collaborations and Partnerships, Memorial University of Newfoundland; Brent Janke, P.Eng. PMP, Vice President, East Coast, Suncor Energy Inc.; Jim Keating, Vice-President, Oil & Gas, Nalcor Energy; Paula McDonald, B.Comm., FCPA, FCA, CMA, President, Altair Holdings, Inc.; Greg Naterer, Dean, Faculty of Engineering and Applied Science and Professor of Mechanical Engineering, Memorial University of Newfoundland; and Sadie Sellars, P.Eng., Technical Manager – Hebron Project, ExxonMobil.

UNIVERSITIES AND THE KNOWLEDGE ECONOMY

It is widely accepted that Universities, and their generation of scientific knowledge, have a critical role to play in the knowledge economy³. Among the key contributions that research universities make to economic growth are the performance of research and the training of highly qualified personnel, both of which are sustained by networks and social interaction. Universities act as a primary source of 'knowledge workers', as well as a primary source of the key factor of production – knowledge itself.

It is interesting to know how new this view is in the 900-year history of universities. Their role in scientific knowledge production has a relatively short history of about 150 years since von Humboldt's reforms at the University of Berlin in 1810 and the founding of MIT in 1861. Before that, the role of universities was to preserve and transmit the established and largely unchanging body of classical learning.

For economists of science, the system of "open science" comprises a set of shared rules and incentives including: giving credit for a new scientific finding to whomever first discovered it; assessing the validity of the scientific knowledge through a process of peer reviews; and diffusing knowledge through publicly accessible tools such as scientific journals and conferences.

More recent attention is paid to the direct transfer of knowledge in the form of new technologies and new intellectual property to counterparts in the economic world: companies, public bodies, non-profit organizations and other stakeholders.

The crucial role of universities in these models is in the accumulation of knowledge that underpins economic growth. The knowledge created by universities is pipelined into the economic system through the graduates who enter the workforce, increasing the stock of human capital; and, more directly in the form of academic research achievements which firms convert into innovations that can be exploited commercially.

However, the models do not explain precisely through what exact channels this is achieved. The university is a complex institution and it has a multifaceted relationship to the economy.

From multiple studies of economic return on basic research and government funded research, the following benefits have been identified:

1. Producing new scientific information.
2. Training skilled graduates.
3. Supporting scientific networks and stimulating interaction with firms.
4. Expanding the capacity for problem solving.
5. Producing new instrumentation, methodologies and techniques.
6. Creating new firms.
7. Providing knowledge on the social impact of innovation.
8. Access to specialized facilities, such as unique tools and equipment.

The latest research on the University and economic growth (Geuna & Rossi, 2015) looks to three channels of knowledge in the complex system of educational institutions: teaching, research and knowledge transfer. The institution's contribution is different but measurable in each of these channels. The engagement policy may also be an additional source of collaborative knowledge generation.

Synergies between research and knowledge transfer channels also occur. While the traditional "open science" model of the production of scientific knowledge provides the simple diffusion of scientific results through publicly accessible channels such as conferences and scientific journals, in practice scientific

³ Geuna, A. and Rossi, F. (2015) *The University and the Economy: Pathways to Growth and Economic Development*, 2015: Elgar: Cheltenham, UK.

knowledge often requires re-elaboration and further development before it can be successfully applied by economic actors. The researchers who develop this knowledge are generally the best agents to support potential users in the process, which often requires direct interaction for the best transmitting of tacit knowledge, the complementary tool required for implementation of codified knowledge. This highlights the importance of channels such as consultancy and contract research. Legislation such as the US Bayh-Dole Act of 1980 was a major turning point in assigning property rights of research results from government funded research to universities to give them incentives to do more commercially promising research and through sale and licensing of these rights particularly for the benefit of SME firms who did not have sufficient internal resources and access to universities.

Also critical is the university's role in production of human capital. This takes place through three main mechanisms. First, education increases the stock of human capital which increases labour productivity and therefore economic growth. Second, the presence of educated workers facilitates and accelerates the adoption of existing technologies not yet fully implemented. Third, a workforce with a higher level of education has more chance of introducing product and process innovation and therefore economically exploiting radically new technology.

For returns on investment in education, much of the impact on earnings particularly in the early years is because education reduces the probability of unemployment. The fundamental question is whether choices in education stem from individual characteristics that are difficult to observe, or whether they are plausibly also included among the characteristics that influence labour market outcomes.

The macroeconomic evidence is less clear about the impact on economic growth. The years of university education have important external effects due to their impact on the adoption of new technologies, but the results are not very robust.

THREE MODELS OF KNOWLEDGE PRODUCTION & KNOWLEDGE TRANSFER

Model	Assumption	Main Theoretical reference	Reference Period	Instrument to promote knowledge production	Instrument to promote knowledge transfer
Public knowledge	Knowledge as information	Information economics; Linear model of innovation; Epidemic model of diffusion of innovation.	Since the 1950s	Public funding of knowledge production through government agencies and universities.	Public diffusion of research results
Appropriable Knowledge	Knowledge as information	Information economics; New institutional economics.	Since the 1970s	Application and enforcement of well-defined intellectual property rights.	System of intellectual property rights fosters efficient markets for technology transfer.
Interactive knowledge	Knowledge as tacit, sticky, localized, specialized, cumulative,	Knowledge economics; Resource theory of the firm, other approaches to the firm; Institutional	Since the 1980s	Implementation of mechanisms promoting interaction between agents to produce new	Implementation of mechanisms promoting interaction between agents to transfer existing

	recombined	economics; Non-linear innovation models.		knowledge.	knowledge.
--	------------	--	--	------------	------------

Source: Geuna & Rossi (2015)

While the main research role of universities has traditionally been seen as the conduct of basic research, they have come under increasing pressure in recent years to expand this role. A more comparative and historical perspective suggests that the role of the universities has never been limited to the performance of basic research. This view is very much the result of the postwar 'social contract' for science which Ben Martin suggests was forged in the aftermath of World War II. Based on the success of the wartime research efforts in mobilizing national scientific research capabilities in aid of the war effort (Audretsch, Bozeman, et al. 2002, 162–64), the social contract saw society willing to fund massive investments in basic research in the expectation of long-term economic benefits, while leaving the principal research institutions, the universities, autonomous in the conduct of that research. The social contract for science implied a high degree of autonomy for the realm of science, vigorously reinforced by the 'boundary work' of the scientific community itself; it afforded 'expert' status to the role of scientists in the exercise of judgment about most matters relating to the conduct of scientific investigations and the application of the resulting knowledge; and it privileged the role of the universities and other public research organizations as the principal site for the conduct of scientific research (although these arrangements exhibited considerable national variation) (Martin 2003; Brooks 1996).

However, if one adopts a longer-term historical perspective, this shift appears less like a new phenomenon than a return to the conditions that prevailed prior to World War II. As Stokes suggests (1997), and Martin acknowledges, the university has been the locus of both basic and applied research over most of its history, and even at the height of the postwar period, much government funding was also directed at applied research. In the late 19th century the expectation that universities would contribute to broader social and economic goals was widespread among some of the European universities, particularly those in Germany which were based on the Humboldt model, as well as in Japan. Even in the U.S., the land grant universities established by the Morrill Act in 1862 were allocated many of these functions (Martin 2003).

Although the postwar social contract, with its strong affinity to the linear model of innovation, set out the guiding principles for federal funding of university research, the research system in the U.S. was characterized by a high degree of decentralization in terms of the multiple sources of institutional control and sources of funding, both for ongoing operations, as well as the conduct of scientific research. Closely related to this was the highly competitive nature of the university system, especially in terms of research funding. Competition for research funding placed continuing pressure on the universities to adjust their research priorities, policies, and cost structures to the prevailing demand in the market for academic research. The highly regional nature of the university system in the U.S. ensured that the research activities of the universities were linked to the economic base of their regions (a legacy of the land grant tradition), but also provided an important source of new knowledge and ideas for the stimulus of local industry. Finally, the linking of research activities and graduate teaching contributed to the process of knowledge transfer from the universities to industry embedded in the tacit know-how of their graduates (Rosenberg and Nelson 1996; Feller 1999; Pavitt 2001).

The changes that have impacted on the university system in recent decades are part of the broader trends in the shifting locations for the performance of basic and applied R&D. At issue is the changing nature of the relationship between the universities and the broader innovation system in which they are embedded, as well as the process of scientific investigation and discovery that underlies the knowledge production function (Gibbons, Limoges, et al. 1994). Since the early 1980s, private firms have expanded their research linkages with universities, partly in response to the rising cost of conducting R&D. This trend has been marked by the proliferation of a new range of university–industry technology transfer mechanisms, including: industry liaison offices (ILOs) in universities, research parks affiliated with universities, university–industry consortia, research institutes and centres of excellence, regional development organizations and spinoff firms. These mechanisms

perform a wide range of functions, including the negotiation of industrial research contracts, the identification of opportunities for university research in the marketplace and the facilitation of licensing or patenting of research results or the spinoff of new firms. However, the mere proliferation of these activities should not be equated with an increase in their effectiveness or efficiency (Doutriaux and Barker, 1995, Etzkowitz, 1999).

Expectations about the new role for universities were affected by three intersecting trends: 1) the linking of government funding for academic research and economic policy; 2) the development of more long term relationships between firms and academic researchers; and 3) the increasing direct participation of universities in commercializing research (Etzkowitz and Webster 1998; Geiger 2004). The resulting pressure on universities to collaborate with private firms created an internal tension between their role in the development and transmission of knowledge (research and teaching) and that of transferring knowledge to other actors in the innovation system (OECD 1999, 7–8). Universities are now expected to generate more applied knowledge of greater relevance to industry, to diffuse knowledge, and provide technical support to industry. In part, this shift reflects the change in the nature of business R&D described above, but it is also the result of a parallel expectation on the part of government that their investments in basic research will produce an increased economic return.

Many studies have tried to quantify to what extent knowledge produced by universities is shared with firms. The hypothesis is that companies benefit from spillovers of knowledge from academic research, especially when these enjoy geographic and/or technological proximity with universities. Public research makes an important contribution to activities of industrial innovation. Public research often enables innovations that would not have been possible otherwise or would have been achieved only with great delay. This is an important contributor in the growth of total factor productivity with a generally higher impact on productivity than private research investment.

The benefits are not however equally spread. Research from the USA and EU highlight how a minority, but important number of firms, view university knowledge as an important source of innovation. But this source is generally regarded as less important than other sources closer to the firms, such as clients, suppliers, partner companies and internal sources. The knowledge transfer channels that firms regard as more important comprises the diffusion of scientific knowledge through open science and employment relationships e.g. hiring graduates, etc.

Direct collaboration with university departments and research laboratories is increasing, while channels based on transfer of intellectual property are declining. Many universities generate more revenue from contract or collaborative research activities than through formal IP agreements. The “products” of traditional activities such as university teaching and research also have important repercussions for the transfer of knowledge.

There is no simple, single policy answer, but there is a clear move away from the model of “pure” public funding of research and a shift toward more complex forms of intervention in support of collaborative research between universities, firms and other organizations in the transfer of knowledge in many forms. The rise of Interactive Knowledge as described in the Table above and the local example of the Marine Institute are useful guide posts for the way forward.

Universities and Channels of Knowledge Transfer

The core modern university functions of teaching, research and knowledge transfer have all been the subject of extensive analysis for economic performance metrics, often accompanied by linkages to funding formulae. For the purposes of this study, we are interested primarily in the specific channels of knowledge transfer between the university and the regional innovation system.

Yet the task of transferring knowledge from universities to industries has proven to be more complex and the role of universities in economic development is much more varied than the linear conception of the

innovation process allows. As noted above, conventional approaches to the issue of knowledge flows between universities and industry frequently treat knowledge itself as a universally available commodity, virtually as a free public good, and knowledge transfer as a commercial and legal transaction between clearly defined agents. This view simplifies the complex nature of scientific knowledge and the linkages and processes that facilitate knowledge flows across institutional boundaries and enable a firm to absorb and employ that knowledge. Successful knowledge transfer depends on the type of knowledge involved, and how it is employed. A careful examination of the existing research on university–industry knowledge transfer is essential for a more balanced perspective on this relationship. As Mowery et al. have recently argued, “Any assessment of the economic role of universities must recognize the numerous, diverse channels through which university research influences industrial innovation and vice versa” (2004, 179).

Universities are not just providers of commercializable knowledge or even highly qualified research scientists; they perform a variety of additional roles that are crucial for the development of the local economy. In addition to generating new knowledge through the conduct of basic research, universities provide both formal and informal technical support, as well as specialized expertise and facilities for on-going, firm-based R&D activities. A recent examination by the National Academy of Engineering documents the multiple ways in which universities contribute to the development and expansion of local industry: through the provision of skilled graduates who become key players in local industry; through the conduct of long-term fundamental research that contributes to the science base and understanding available to private firms; through the promotion of an atmosphere of intellectual diversity that tolerates different approaches to the solution of technical problems; through direct collaboration with industry both on specific projects and in longer term relationships; by serving as test beds for new technologies and research instrumentation that are ultimately transferred to industry; and finally as the nuclei for start-up companies that spin-off from universities to become the seeds of new business (National Academy of Engineering 2003, 46–48; Grossman, Reid, et al. 2001; Mowery, Nelson, et al. 2004). As national science systems become more interconnected and as the knowledge base required to support the production of ‘complex technologies’, university research becomes increasingly important to local firms not just for the transfer of knowledge generated through its own research activities, but also as a conduit enabling firms to access knowledge from the ‘global pipelines’ of international academic research networks (Bathelt, Malmberg, et al. 2004; OECD 1999).

A firm’s ability to access significant scientific knowledge through partnerships with external sources, including universities, is increasingly seen as a source of competitive advantage. From a regional economics perspective, the expectation is that firms and universities located in the same region can share knowledge and each adds this to their respective innovation activities, which stimulates the collective processes of learning and enhances the development of “regional capabilities”. Of particular importance is the ability of firms to efficiently and rapidly identify the knowledge needed to integrate into their own specific research, development and production activities. Interactive learning processes supported by local institutions are critical for regional actors.

The governance of such relations is important. The exchange of knowledge between universities and firms can be managed through personal interaction i.e. contracts between university employees and firm employees, typically engineers and researchers. These often arise out of shared social networks and are typically rooted in mutual trust. Or, the relationship can be managed through institutional collaboration between universities and firms managed by units such as departments, offices of technology transfer, research centres, etc. The argument is made that the institutional model is more effective and efficient than the pre-existing personal contractual model.

There is also evidence that very often knowledge transfer from universities to firms occurs not through formal collaboration targeting R&D, but actually through the supply of services such as safety and quality control of products and the provision of various kinds of business consultancy.

The reasons why firms collaborate with universities has been little studied in detail. Compared to firms with no formal linkages to universities, those that do collaborate tend to be larger, have more absorptive capacity

and to use knowledge and information from other locations. Firms that interact directly with university researchers are often smaller and implement strategies of “open innovation”, based on the use of external knowledge.

Personal collaborations seem to facilitate the absorption of knowledge acquired externally and to integrate knowledge and expertise developed in collaboration with other partners. This implies an important role for knowledge transfer processes at a regional level. However, these do not tend to appear in standard statistics for knowledge transfer between universities and industries.

Many small firms seem capable of taking part in knowledge transfer activities without involving institutional structures. This runs against the assumptions of policy since the Bayh-Dole Act and the institutionalization of technology transfer processes made involving small firms indispensable. At the same time, reliance on personal contractual processes requires universities to review regulations governing consultancy and the legal implications of their collaborations.

What the latest innovation literature suggests is that firms are more inclined to work together with universities when located in the same region where the issues are more business-consultancy related, such as management, marketing, logistics and legal matters where geographic proximity aides the transfer of very specific knowledge to the firm and the context of its operations is critical. Large firms, because there is less need for proximity, are less likely to be involved with universities in the same location when partnerships cover research and testing activities that may involve transfer of more abstract or generic knowledge.

Universities wanting to collaborate with firms in the same region should aim at development of scientific skills in fields similar to the sectors of activity of regional firms and in the skills targeting their organization and management. They should also reach out to smaller firms which often lack the resources needed to collaborate with universities further afield and that could benefit from collaboration within the region, such as in the MUN/C-CORE case.

TRLS AND METRICS FOR POLICY

There have been significant changes made to the configuration and priorities of research infrastructure to better support the renewal of Canadian industry. There are a more limited number of industry specific initiatives. The research institutions include universities, government laboratories and business-led research networks. The data cited below draws from field research in Ontario and Newfoundland and Labrador, including a major university with a recognized capacity in deep engineering expertise; a government laboratory; and a business-led research network.

Innovation and Technology Readiness Levels (TRLs)

Analysis of innovation policies and their efficacy can be assisted by the use of Technology Readiness Level (TRL) scales. Within the general theme and policy objective of supporting innovation, these scales can reveal more explicitly in what ways local and regional industries are being assisted, including the nature of the intervention or technical developments, who is taking what risks and the explicit outcomes. There is also increased use of the Technology Readiness Levels scales as a planning tool for innovation management across a range of jurisdictions. It has become an important metric for decision making about actions of Research and Technology Organizations (RTOs) in the research and innovation ecosystem in Europe, for instance. The range of institutions usually included in RTO definitions includes universities and research centres such as MUN and C-CORE.

TECHNOLOGY READINESS LEVELS IN THE EUROPEAN COMMISSION⁴

Technology Readiness Level (TRL)	Description
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

The successful development of an innovation system highly depends on the successful management and alignment of these individual technology pathways. Assessment of the readiness of the individual technologies can also enable risk reduction in budgeting and planning. This observation was the starting point

⁴ EARTO (European Association of Research and Technology Organizations), 2014. "The TRL Scale as a Research & Innovation Policy Tool, EARTO Recommendations". April 30, 2014.

for the development of the TRL scale and is one of the drivers for its continued use in technology commercialization and R&D planning.

The original TRL scale was about product oriented technologies. However they have also become critical in assessing appropriate levels of public support. For instance, a first approximation of the TRL scale and appropriate government funding is as follows: TRL 1-3 Fundamental Research (100% funding), TRL 4-7 Industrial Research (50% funding), and TRL 8 & 9 Experimental Development (25% funding).

The OECD distinguishes 4 research levels: Basic research (TRL1-3), Development (TRL3-5), Demonstration (TRL 6-7), and Early Deployment (TRL8-9). Also the European Investment Bank (EIB), distinguishes only between Research (TRL1-3), Development (TRL 3-6), Innovation (TRL6-8) and Production support (TRL9). The conclusion can be drawn that the distinction between 9 scales is often considered too granular and consolidation to broader classifications is found to be a more practical application of the tool.

From TRL 1 to TRL 3, the close connection of RTOs to industry partners gives them first-hand information on the needs of operating companies and thus the ability to create innovative concepts of economic relevance. Further, the close connection of RTOs to academia gives them access to state-of-the-art scientific development and the expertise to make the translation from academic results towards applications. RTOs' research and development infrastructure plays a key role in the formulation of the technology scale as well as in the experimental proof of concept for existing industries, start-ups, spin-offs, SMEs, and large enterprises seeking growth and/or renewal.

From TRL 4 to TRL 7, this is believed to be the most prominent area of RTO activity. They typically do not work alone but in collaboration with industrial partners including SMEs, academia and other RTOs. They support the crossing of the valley of death in R&D by providing different physical research infrastructure, expertise, and unique multidisciplinary approach. Further, RTOs support this crossing by their knowledge of industrial environments, practicalities, and limitations allowing them to be the ideal project lead in certain situations. In this area they typically support existing companies in developing their ideas towards real-world application. They also develop ideas perhaps originating from basic research or their preceding research towards spin-offs and solutions to meet industry needs. The view is that creation of new industries cannot happen without experience of the entire TRL chain. Technology assessment supports the further shaping of innovations that are more accepted by society.

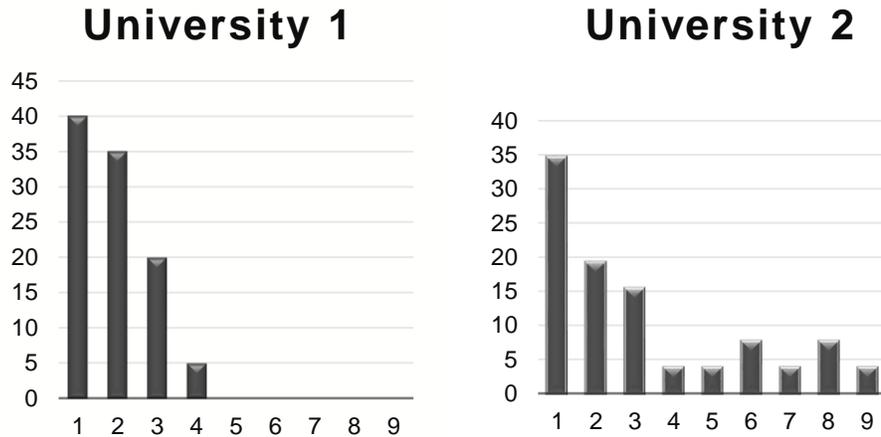
From TRL 8 to 9, RTOs often perform foresight activities that are needed, for example, when introducing new technologies to market. These studies are part of analyzing the operational environment and the implications of introducing emerging technology to it. Activities here are mainly performed by industrial partners with a support of research infrastructure. But for non-commercial application (space for instance), RTOs have the research facilities to allow the development of specific products or systems proven in an operational environment. Also various user experience studies and analyses are performed to support the deployment of technology in its actual operational environment. Demonstration in operational environments may, especially in the case of new technologies and new manufacturing, require fine-tuning on-site. Here research infrastructure has a supporting role and research is used to find the final settings.

TRL Applications in Canada

Field research has found a significant divergence of TRL scales being used in various research institutions in Canada. The leading ReMAP business-led network for electronics manufacturing uses TRL 4-7. The Ontario Centres of Excellence uses 4-6. The aerospace consortium also uses 4-6. Industry Canada uses 5-7. These are small differences that make for large variation in policy objectives. The data in the graphics is derived from recent field research studies at the Innovation Policy Lab.

UNIVERSITY RESEARCH INFRASTRUCTURE

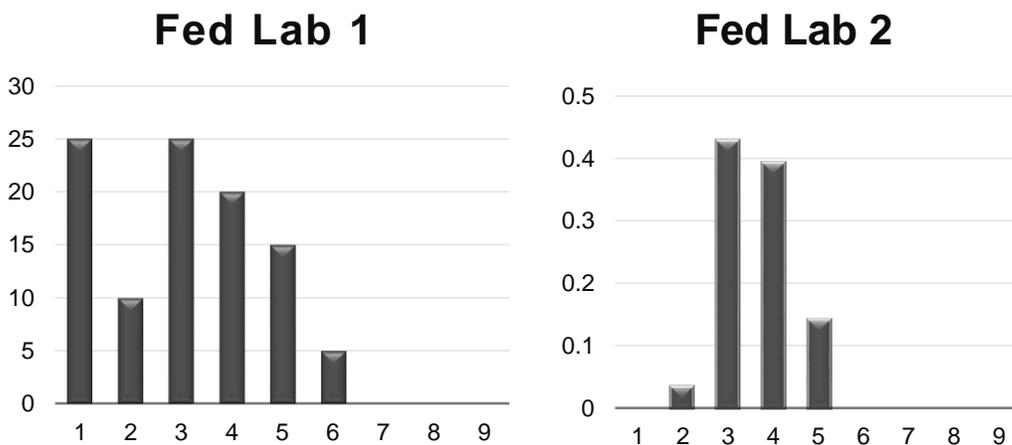
The following are the percentage distribution of university-based research projects by TRL stage.



University research has traditionally been overwhelmingly concentrated in the TRL 1-4 end of the spectrum. The culture of the university emphasizing discovery science and the incentive structure of the professoriate reinforce this practice. However, the cumulative weighting of over 25% of the projects at the TRL 5-9 level is reflective of a significant shift in priorities in recent years. In addition, the not insignificant presence of projects at the TRL 8 & 9 stages reflects the fact that it is not unusual for manufacturing processing issues arising as products move out towards the marketplace require additional basic metallurgical issues to be re-examined within the university context.

GOVERNMENT LABORATORY

The following are the percentage distribution of government laboratory research projects by TRL stage.

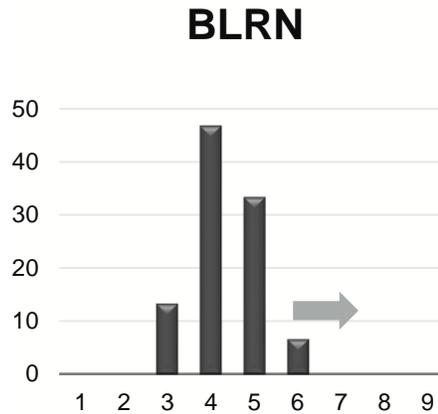


These federal labs, following a major policy shift under the Harper government, now concentrate resources and activity in the TRL 4-7 levels. Interviews reveal that this is a qualitative change from 10 years ago when 80% of laboratory projects would have been at the TRL 1-4 level. The implication is that government laboratories now function less like universities than in the past. Lab managers also say that the technical

technology and engineering levels they operate at mean that the potential universe of industry SME partners is limited to 10% of the firms or less.

BUSINESS LED RESEARCH NETWORKS

The following are the percentage distribution of business led research network projects by TRL stage.



Business-led Networks of Centres of Excellence are a relatively recent addition to the Canadian research landscape and our field research indicates that BLRNs are still very much a work in progress. Their objective is to have all of their projects entering at TRL 4 and progress through to TRL 7 over a five year period. Secondly, BLRN managers expect that they can migrate through these stages at a much quicker pace than other institutions even where their portfolio of projects may closely parallel those of a government laboratory or academic institution. Their argument is two-fold: First, they organize their partnerships intentionally around a coalition including OEMs, universities or colleges, plus select SME firms that have unique engineering or technology expertise. Second, the BLRN always includes an active manufacturing partner. In essence, it is the value chain of the BLRN partnerships that provides the leverage for an accelerated rate of innovation.

NETWORKED INDUSTRIAL POLICY

Efforts to facilitate the more effective transfer of knowledge from university-based research institutions to commercial firms can also benefit from a better understanding of recent trends in thinking about the most effective policy supports for industrial innovation in Europe and the U.S. Much of this thinking is currently being synthesized in the growing literature on the importance of Networked Industrial Policy (NIP). The focus on Networked Industrial Policy originates primarily in the manufacturing sector of the economy, however the attention paid in this literature to the impact of global supply chains and the dynamics of innovation can apply equally to changes occurring in resource-based industries as well.

Firms today are faced with shorter product life cycles, hard-to-manufacture product designs and increasing technological parity, which require an exceedingly diverse range of capabilities. This leads a growing number of firms to focus on “core competences” and rely on foreign and domestic manufacturing and non-manufacturing firms for everything else in order to save time and resources and enhance flexibility (Herrigel 2010). However, the aggressive offloading of low value added manufacturing operations to developing countries has begun to hollow out supply chains in industrial economies. Outsourcing has expanded to include higher value-added production operations and services, bringing into question the dichotomous view of economic activities in terms of the production of goods and services (Andreoni and Gomez 2012). At the core of these developments has been the inability to completely separate R&D/design and manufacturing processes because of complementary relationships between product and process innovation (Breznitz and Cowhey 2012; Pisano and Shih 2009). Another factor has been the gradual development of national innovation systems (the organized collection of public and private assets that create and utilize technologies) in developing economies, which can provide the environment where companies can transfer both low and high value-added operations (Tassey 2010). These developments compromise the ability of developed economies to capture economic value and generate employment, since product evolution often occurs elsewhere. Even advanced economies with substantial support for manufacturers, such as Germany, are facing rising competition from emerging economies.

Simultaneously, developments in key enabling technologies are rapidly changing the competitive basis for manufacturing industries. A case in point is the transformation of the automobile from a “modestly complex set of hardware components into today’s modern automobile, which contains 17 subsystems for which electronics is a central element” (Tassey 2014, 29-30). Furthermore, the dwindling of natural resources has increased demand for product and manufacturing energy and resource efficiency. In line with these developments, there has been a renewed interest in industrial policy across leading jurisdictions in Europe, North America and Asia that aims to strengthen manufacturing competitiveness with explicit benefits directed towards a range of traditional industries. In spite of the well documented differences in institutional settings between Europe and North America, a growing body of research suggests that there is convergence between policy approaches being adopted in Germany and the US. Some of these initiatives share a long-term focus on the continued development and diffusion of general purpose technologies, such as new materials, IT and batteries, which drive the transformation and greening of the automotive industry, but they apply more generally to a wider range of industries (Tassey 2014; Mazzucatto 2013; Perez 2013). In fact, Bryson et al. argue that these technological developments – including developments in additive and digital manufacturing – will be a critical driver of the new manufacturing revolution (2013).

Furthermore, policy makers at all levels of governance across a wide range of jurisdictions are adopting a place-based, smart-specialization approach to local and regional economic development. The approach underlines the need for regions to specialize in knowledge-intensive industries tailored to the prevailing reality of their specific regional contexts and to leverage the advantages that can be gained from multi-level governance mechanisms (Wolfe 2013). These initiatives not only support the generation of new forms of basic knowledge relevant to the industry and advanced production processing techniques, but also promote the

subsequent adoption and diffusion of more advanced technology production. The focus is on “linking the various elements of the regional and local research infrastructure with the productive capabilities of local firms by promoting processes of clustering” (Wolfe and Hepburn 2013). As such, new industrial policy instruments being adopted by governments aim to address both traditional markets, as well as more innovative system failure in supporting the upgrading and improvement of industrial capabilities (Crafts and Hughes 2013).

Among the key policy tools being adopted by governments are cluster initiatives and alternative forms of public-private partnerships that bring together cross-sectoral knowledge and expertise to “help build systems, create networks, develop institutions and align strategic priorities” (Warwick 2013, 4). A core concern of recent policy efforts has been to provide more effective support for small and medium-sized enterprises (SMEs), which design and produce the majority of components for OEMs in both the US and Germany. These policy approaches recognize that the ability of SMEs to innovate is essential in light of deepening trends for specialization, especially in the US, but many SMEs lack the capability to do so. Clark argues that firms in the supply chain “bear the brunt of the shifts of risks and costs that come with vertical disintegration” (2013, 6). One way to overcome these deficiencies is through “engaging in inter-organizational networks, which reinforce SMEs’ innovative ability by providing them with a window on technological and market change, and sources of technical assistance and potentially available resource flows” (Dodourova & Bevis 2012, 3).

Consequently, recent industrial innovation policies focus on improving firm access to regional assets – including skilled labor, new associational forms of organization, and necessary inputs to the production process, including funding and land. For multifaceted industrial innovation programs to succeed, officials have to work to improve policy coordination across multiple levels of governance and strategically important areas, such as basic and applied research, standardization measures as well as deployment and market access (EC 2013, KET report).

An emerging body of literature, suggests that the objectives and basic strategies of industrial policy are beginning to merge across countries, despite continued heterogeneity in the range of particular policy measures employed (O’Sullivan et al., 2013). European and U.S. policies have played an increasingly important role in “underwriting and encouraging the advance of new technologies in the business economy” (Block 2008, 2). In addition to aiding in the development of novel technologies, there are concurrent attempts to promote the diffusion of existing and emerging research and technical skills to the production economy. Both the development of key enabling technologies and their diffusion to the industrial sector are being facilitated through the adoption of networked industrial policies. Policy makers seek to employ public-private partnerships that can serve as intermediaries and strengthen linkages between and within firm networks, multiple levels of government and research institutions. The growing relevance of the regional level of policy making has led to the adoption of a smart specialization in Europe and a cluster-focused approach in the US targeted at building local capabilities.

With the globalization of production, each country has also faced unique competitiveness challenges stemming from the dynamics of its productive and institutional setting. This accounts for the continued heterogeneity of initiatives despite their convergence in several aspects. Regional industrial ecosystems often fail to provide small and medium sized enterprises with the resources they need to link innovation and production and hence hinders disruptive innovation in legacy sectors (Clark 2013; Tassej 2010; Berger 2013). This has resulted in supplier network structures where only a minority of firms pursue innovation as part and parcel of their business.

Different aspects of the new industrial policy designed to respond to these emerging challenges have developed through stages. Focusing on commonalities across countries, some scholars represent the current approach to economic intervention as an integration of previously disparate measures, including innovation, education, regional development as well as a range of other policies in an attempt to tackle a range of societal challenges. In a similar vein, Warwick (2013) as well as Negoita (2014) note industrial policy has moved from a traditional approach based on product market intervention (subsidies, state ownership, tariff

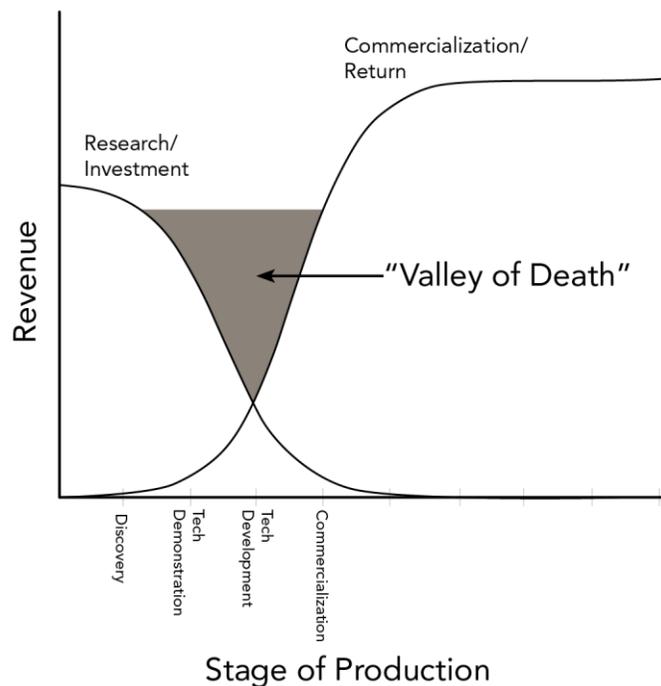
protection), through a set of measures to combat market failures, or non-sector specific funding for activities such as research and development, environment restoration and labor market programs, to a third stage of helping to build up systems, create networks, develop institutions and align strategic priorities. Even though their focus is solely on manufacturing-related industrial policies in advanced economies, O'Sullivan et al. (2013) have similar findings. They argue that recent initiatives are characterized by: 1) public-private collaboration in designing industrial support systems, 2) long-term investment and planning in the context of program design, as well as by 3) the coordination and alignment of industry-related policy measures. As such, these government policies could have the potential to develop resources to create customized institutional frameworks required for the development and commercialization of cutting edge research.

Connecting the Dots Between Theory and Policy

The centrepiece of the new Networked Industrial Policy frame is the interactions between SME firms and their local Industrial Commons, particularly their educational institutions and research infrastructure. This is the big policy bet that enhancing the innovative performance of SME firms is absolutely key to economic growth in the long term. That is why close attention has been paid in this Study to the interaction and attitudes of SME firms towards C-CORE and MUN more generally.

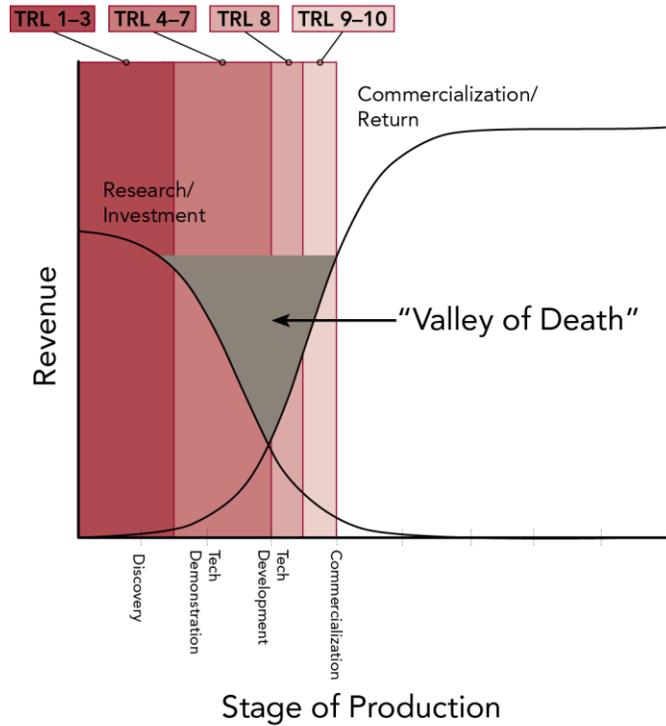
Analytically, this means trying to connect the dots between the challenges of innovative investments for the firms and the specific channels of knowledge interaction and technology transfer with the university. SME firms and their industry associations across Canada and elsewhere put the Valley of Death issue at the forefront of their challenges. The issue is the gap in resources and in time between initial investments in R&D for new technologies and the payback period in the marketplace. The challenge is summarized in the graphic below.

Innovation Ecosystem



The opportunities for government policy intervention, using the TRL scales can be mapped against the SME challenge.

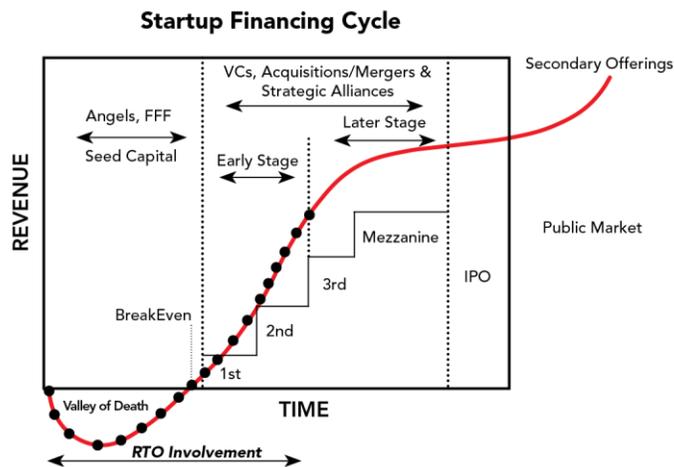
Innovation Ecosystem



The combination of the two graphics gives an insightful picture of how and when governments can put meat on the bones of the general policy objective of assisting innovation for SMEs as well as some more fine grained industrial policy definition of what do to and when as well as how the risks are to be shared.

Some have even gone further in suggesting how TRL scales can be used to understand the funding cycle for innovative SMEs.

TRLs & The Funding Space



Research on this issue is on-going at the Innovation Policy Lab at the University of Toronto.⁵

⁵ Samford, Warrian & Goracinova (2016) "Public and Private Goods in the Development of Additive Manufacturing Capacity", IPL: University of Toronto.

NEWFOUNDLAND'S OCEAN TECHNOLOGY CLUSTER

As the preceding discussion makes clear, the promotion of more tightly networked relations between research institutions, innovation intermediaries and closely clustered groups of firms is a critical ingredient for success in the New Industrial Policy literature. The Government of Canada, through the National Research Council and other agencies, has pursued a strategy focused on the development of technology clusters since the late 1990s. In Newfoundland and Labrador the principal cluster that has been the focus of these efforts is the ocean technology industries and infrastructure.⁶

Clusters can be understood as groups of systematically co-located firms and other organizations (e.g., government, research institutes, trade associations, universities) that exhibit strong inter-organizational ties or linkages. These linkages may be comprised of, for example, buyer-supplier relationships, labour market specializations, and product or service specializations, among other possibilities. The organization and dynamics of clusters depends on the quantity and quality of such linkages as well as their orientation i.e., whether linkages are predominantly inward (toward other co-located firms/organizations within a region), outward (toward other firms/organizations outside a region), or some combination thereof.

The cluster literature highlights the relevance of networks of interrelated firms as key factors in the ability to produce innovative new products or processes in a timely fashion for global markets. Knowledge flows within and between clusters are critical to fostering and sustaining innovations. A growing body of empirical research provides solid evidence of the positive impact that clusters have on improved economic performance in local and regional economies. The key questions that arise from this literature concern the way in which local conditions influence the developmental path of individual clusters, the extent to which they are rooted in specific local factors that contribute to the growth of clusters, the relative influence of local dynamics in stimulating the competitive capabilities of the cluster, and the extent to which external supports, in the form of research infrastructure, government policy and cluster associations, are essential for the success of local clusters.

Conceptual foundations of cluster or agglomeration studies are found in a diverse group of theories: Marshallian theory, location theory, transaction cost and institutional theory, international business theory, regional studies, and strategic management. The question of how to understand localization economies is unresolved. Major groups of theories attempt to explain agglomerative behaviour in terms of transaction costs, trust and untraded interdependencies among firms, collective learning, and institutional or evolutionary economies involving economies of scale, path dependence, or network formation.

The first approach, following in the tradition of Marshall, places greater emphasis on the influence of agglomeration economies and supply side externalities. This approach views clusters as the product of traditional agglomeration economies, where firms co-located in the cluster benefit from the easier access to, and reduced costs of, certain collective resources, such as a specialized infrastructure or access to a local labour market for specialized skills. The concentration of critical factors of production in specific regions reinforces the effects of increasing returns in the region. An external economy is a spillover effect in which the activity of one agent has an intentional or unintentional effect on another. (The focus is on positive externalities, although negative ones also exist). Marshall identified the three principal sources of external economies: input sharing, labour market pooling, and knowledge spillovers. Input sharing occurs when firms share a local supplier industry that emerges to service downstream customers. Labour market pooling occurs when human capital with special skills is available in a particular location (labour markets are traditionally considered to be geographically sticky). Knowledge spillovers occur when "the secrets of industry are in the

⁶ Colborne, B. (2006), "St. John's ocean technology cluster: can government make it so?". Canadian Public Administration, 49(1): 46-59.

air" and diffusion of tacit knowledge takes place through deliberate or unanticipated pathways. Marshall uses the example of workers learning to use new technologies.

The second view emphasizes the role of knowledge and learning processes in sustaining clusters, often on the basis of local flows of spatially sticky tacit knowledge. This perspective highlights the ways in which the benefits derived from externalities in the form of knowledge spillovers are tied to ensembles of related capabilities. From this perspective, the economic advantages conferred by the institutional infrastructure of the region are a vital element in the 'supply architecture' for learning and innovation. Knowledge spillovers, in particular, are believed to be an important mechanism of learning and innovation within clusters.

However, it is also clear that many business location decisions are determined not by Marshallian external economies but by access to natural factors of production such as energy, or by access to essential infrastructure such as transportation facilities. Moreover, agglomeration economies are also driven by urbanization economies - benefits that the firm realizes from locating in economically larger or more industrially diverse environments. The diversity of theoretical perspectives on agglomeration and localization and the emergence of a large hybridized, eclectic literature has provided valuable insights into the dynamics that drive successful clusters, but also left the field open to a variety of different policy approaches as to the most effective mechanisms to support the growth of clusters.

The top of a value chain is the intellectual input - design and innovation, which leads to new products, approaches, or technology. This is fundamentally the underlying approach and end objective for the ocean technology cluster in Newfoundland and Labrador. Ocean technology in Newfoundland and Labrador has its modern roots in the establishment of the Ocean Sciences Centre at Memorial University in the mid-1960s. The university expanded its interest with the Centre for Cold Ocean Resource Engineering (C-CORE) in 1975. Early public sector attempts to generate technology-based economic activity revolved around marketing local centres of excellence, the collection of public-sector research facilities. This initiative emphasized securing international contracts for the facilities rather than promoting local industrial research and spin-off activities. By the mid-1990s, the ocean technology community had come close to collapse. The atmosphere of innovation was replaced by a scramble to get in on very competitive oil projects. However, at the same time, and almost in spite of the institutional and oil activity, a successful cohort of companies producing charting, remote sensing, data recording, and communications products for ocean applications has grown up and is currently operating in St. John's. This is the true core of the present-day cluster.

Analysis of Newfoundland and Labrador's clustering efforts was made by Colborne with respect to the Finnish experience. He concluded that:

- Public policy, aimed at the St. John's ocean technology cluster, is too focused on educational and research organizations. There is a need to move towards policies that foster an industrially-dominated ocean technology cluster and place the public infrastructure in a proper supporting role.
- The Newfoundland and Labrador ocean technology industry is diverse. It is difficult to define the cluster in terms more detailed than ocean technologies. This description is sufficiently broad to encompass many activities that are not mutually supportive. Natural selection may ultimately narrow the focus but it would not be appropriate for government policy to prescribe this selection.
- There is no core industry and no vertically integrated industry, either of which would substantially strengthen an industrial cluster. The province has not capitalized on the fishery to develop a supporting technology industry, nor is it clear that growth in the offshore oil industry will lead to locally-based technology producers. Federal and provincial governments should set an example by using their own ocean-related requirements as an industrial development tool.

The impact of research can lead to exaggerated expectations. Much research in any field is non-productive in terms of commercial output, at least in the short run. Furthermore, there is little evidence that innovation can be logically planned or organized, and a lot of evidence that true innovations arise from previously unconsidered approaches or combinations - so-called network innovation. But, accepting these qualifications, more research activity does lead to an increased probability of beneficial outcomes.

The importance of a strong research base, underpinned by a strong educational system, is identified in most of the references cited in Colborne's paper. Research is the seed of technology industries and government support is a major element of research. Generally higher levels of publicly funded research increase the propensity of technology industries to develop, which leads to more industrial research and eventually to cluster developments. Programs should be oriented to concentrate research activity and to provide incentives for researchers to disseminate their knowledge to industry. This is not as direct as subsidies but it is more likely to have a lasting effect.

Further perspective on the NL Oceans Technology Cluster was added by Lepawsky's study for the Harris Centre in 2009.⁷ He concluded that members of the NL cluster are linked much more strongly to suppliers and clients/customers outside the region than inside. This predominantly outward orientation of the cluster is consistent with Ocean Advance's own visioning process represented in the association's report, *Outward Bound 2015*. Many firms engage in cooperative relationships with other firms and organizations to develop novel goods or services. The majority of these innovation activities involved cooperation between Oceans Advance members. However a relatively small number of firms account for most of the collaborative relationships in the cluster. The cluster's outward orientation coupled with the dominance of only a few firms within the cluster in terms of buyer/supplier relationships and collaborations suggest the cluster is vulnerable to external economic shocks.

This has now happened with the collapse of oil prices. The cluster and the NL research infrastructure are about to have a severe stress test.

In terms of priorities, in recent years, ocean cluster firms predominantly engaged in R&D linked to new or significantly improved goods or services. This activity was mostly in-house R&D given that few firms purchased R&D services from other organizations. The next most important R&D activity was the acquisition of advanced machinery, equipment, or computer hardware or software to produce new or significantly improved goods or services. Perhaps unsurprisingly, the importance of R&D staff as sources of knowledge for innovation is of the highest relative importance for firms' innovation activities with the finding that 'the market' is a significant source of ideas for firms' innovation activities. The majority of respondents ranked clients/customers as having high importance as a source of knowledge for innovation activities.

The next most important external sources of knowledge for firms' innovation activities are firms' suppliers followed by firms' interactions with universities. It is worth noting that firms' perceive their interactions with universities to be of higher importance relative to those with colleges or technical institutes.

The Lepawsky study participants perceive several key gaps and barriers to innovation and the commercialization of innovation in the cluster and LIS. Firms are challenged in being able to attract the scale of required staff and appropriately qualified staff. Another key challenge to innovation for firms is insufficient funding and finance for their innovation activities. Challenges to commercialization are more mixed. One issue ranked of high importance by participants is uncertain demand for innovative products. However, most firms rank a lack of knowledge of markets as being of low importance in terms of the problems they have experienced when trying to commercialize their innovation projects. Other issues ranked of high importance by participants include the market being already dominated by established firms, that there is a lack of consumer acceptance of innovative products, and/or a lack of government standards.

⁷ Lepawsky, J. (2009). "The Organization and Dynamics of Clustering and Innovation in the ocean technology sector in Newfoundland and Labrador and the St. John's city-region", Harris Centre, Memorial University of Newfoundland, September 30, 2009.

These characteristics and economic dynamics are key background factors for assessing the limitations, challenges and opportunities for C-CORE functioning and contributing to the NL innovation ecosystem. We return to these issues in the Conclusions section of the Report.

IMPLICATIONS OF RESEARCH FINDINGS FOR POLICY

The following is a summary of issues and themes that emerged from field interviews in the Study. They are a selection from the broad overall results. However, they are viewed as important because of their potential to shed light on the policy issues involved with NL research infrastructure and university-industry knowledge transfer in the Province.

The Private Sector and Regional Economic Development

Multi-National Corporations (MNCs) are major and sophisticated industry partners for MUN and NL. They are involved with very specific technical issues e.g. ice conditions and drilling. They may present opportunities for individuals to gain a presence in the international market. However, from the perspective of economic development, they do not expand export opportunities for NL. Further, the large international companies do not appear to have IP issues with MUN. MNCs are also much affected by the cycles of the resource economy so there are major discontinuities in their contribution to intellectual and organizational capacities in the NL research infrastructure.

NL SMEs do offer the greatest opportunities for export development and leading edge technology in specific niches such as signals processing in support of resource development and the fishery. Maker SMEs are constrained by internal resource limits, both financial and human capital and by a culture of incrementalism. They also see innovative investments solely as a cost. They tend towards the “can’t pay, won’t pay” end of the spectrum. The Techie SMEs are the greatest difference makers for future NL regional economic development but are both the least engaged and least dependent on MUN for sources of new ideas. They are also the most antagonistic towards the university administration and its past IP regime.

Some interviewees claim that NL has the highest density of research infrastructure per capita in the country. The margin of difference may be the Atlantic Accord requirements of educational and research spending by the operating oil and gas companies in the Offshore. However, the incremental research resources are controlled by private sector not-for-profit RTOs such as Petroleum Research Newfoundland & Labrador. They have relatively little interaction with C-CORE. Interviews said the organization was more a competitor and client than a partner.

The University

Private firms said in interviews that they have encountered problems with the university in regard to development of networked industrial policy across the board from the administration, the faculty and the students. The negativity with some of the SMEs is returned in kind, not without some grounding in fact. Among many of the faculty, there is a traditional ivory tower attitude to research that would remain in the TRL 1-3 domain forever. For the more ‘with it’ faculty they simply maneuver around the formal IP regime and engage in personal relationships that may be successful but may be the exception that proves the rule.

Private firms hiring MUN students report encountering the same intellectual possessive individualism regarding IP that they react to in dealing with the administration. As a whole, because in most ways MUN is the system, it can act as if it owns the system and therefore underperforms long term.

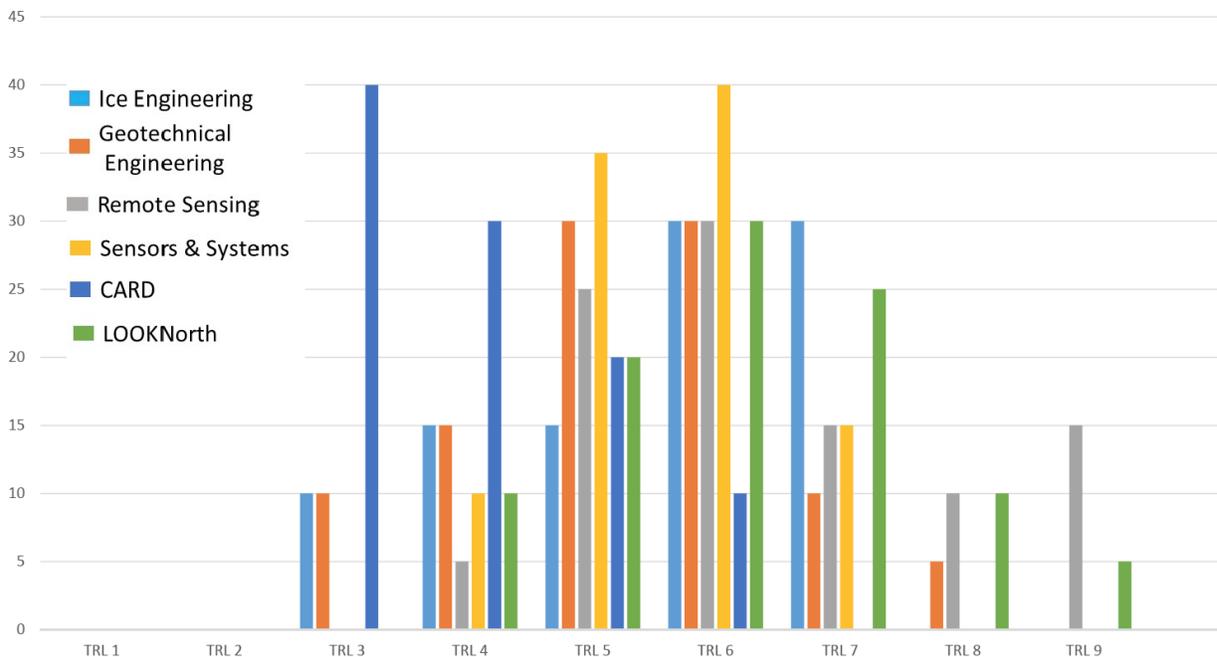
C-CORE

C-CORE occupies a unique space in the innovation ecosystem. It is a university owned entity that act more like a Business Led Research Network.

It is a vital asset in the NL economy and research infrastructure. Most importantly, but least recognized, is that it is the one anchor of continuity in the face of decades of cycles of resource development and sways of government policy priorities. It has continuity of key personnel, institutional memory and key data from previous projects done in the past. However it is faced with managing multiple business units with different TRL trajectories. The Marine Institute, on the other hand, as outlined in findings in the Preliminary Report, probably is the closest fit with the academic studies for a functioning networked industrial policy agent. It functions on an Interactive Knowledge creation practice that pragmatically avoids the major conflicts over the MUN culture and IP regime. In the Table on page 12 above, the Marine Institute fits mostly squarely into the University knowledge matrix for the contemporary best practices in Interactive Knowledge transfer. Further research on the MI model would assist in understanding and elaborating its role in the NL innovation ecosystem and lessons to be derived from it.

There are probably inherent limits on C-CORE ever being able to truly function as an entrepreneurial entity. In letter and in spirit it is still essentially a university academic institution. Interviewees say it bears the familiar bureaucratic imperatives of having to first cover overheads and manage IP issues with faculty and graduate students. Based on interviews with management it conducts the full range of TRL activities that other BLRNs in Canada do. However, for the authors, C-CORE may do these things in a self-limiting way across complex range of its business units, as confirmed in the impressive distribution of C-CORE projects across the TRL spectrum but being conducted by separate business units.

C-CORE TRLs by Business Units



There is no doubt that with 100 contracts per year, C-CORE personnel engage in many joint meetings, attempting to coordinate effect use of resources. However, if the preliminary TRL data provided are accurate

indicators, CARD and Look North for example appear to be very different sorts of businesses. They appear to be separate silos. Further, the acceleration of innovation through leveraging complete value chains, the key variable for other business led networks, appears to be missing. Further examination would be required to fully understand the TRL entry and exit points, plus the possible synergies between the business units.

CONCLUSIONS

To understand the contribution an institution like C-CORE makes to an emergent networked industrial policy, it is critical to de-construct the economics of universities and the knowledge economy and to be able to be specific about the actual channels of knowledge transfer. In the case of Memorial University and C-CORE, three factors stand out.

While preserving its traditional anchor roles of teaching and research, MUN has modified and extended its role in technology transfer with the establishment of C-CORE as a standalone entity outside of the university's established functioning entities.

Second, as C-CORE has evolved and learned from past experience and experiments such as royalties, equity shares, etc., it has evolved to the stage where it now seeks to function as far as possible outside of the university's IP regime. However, it still engages with hundreds of faculty and graduate students on individual research projects and for these the strict MUN policies have applied.

Third, C-CORE as a hybrid institution is functioning in effect as a University owned Business Led Research Network. This is confirmed by the application of TRL scales to its projects and the matching of these results with other BLRN networks across the country and clearly differentiated from the traditional University profile.

Fourth, if it is desirable to have C-CORE function as a true equivalent of a business led research network, then it should be benchmarked against BLRCs in its governance, developmental goals for commercialization, funding mechanisms and technical coordination. For example, a business-led organization like ReMAP in Toronto has a Board with government and academic representatives but is chaired and has a majority membership from the private sector. It 'crowd sources' its research project funding from its government and industry partners for five year cycles. It manages projects with defined TRL entry and exit points. And, it accelerates the pace of innovation by leveraging the whole value chain from SMEs to MNCs and customers.

The innovation story embedded in C-CORE is rich and complex. Its total contribution to the NL innovation ecosystem would be more fully understood by further examination of the specific forms of knowledge creation and technology transfer taking place within the individual projects at each of the TRL stages.

