Social capital as an outcome of government's transformational role in the Triple Helix Model: A Case of a Large-scale S&T project

Puja Sharma*, Peter W.B. Phillips, and Camille D. Ryan
University of Saskatchewan

*Corresponding author: JSGS of Public Policy, University of Saskatchewan, Saskatoon, Canada, S7N 5B8 <puja.sharma@usask.ca>

Abstract: Governments, across national boundaries, are progressively involved in the triple helix interactions with the industry and academia. In this post war role the state is financially and policy wise encouraging interdisciplinary research and innovation projects as a public venture capitalist. There is an enhanced and continual backing from the government for research projects that fit into the 'big science' schema. Despite growing interest in this area, documentary evidence is deficient in its justification for government's motivation to fund and promote large-scale S&T projects. This paper will address these gaps with reference to the concepts of triple helix, networks and social capital.

Key words: Innovation, National Systems of Innovation, Social Capital, Entrepreneurial, Public Venture Capitalist

1. Introduction

At the global level, a dynamic and encouraging change is witnessed in the approach towards research and innovation. Research efforts are increasingly undertaken on a wider scale with pronounced elements of linkages and collaborations across national and academic boundaries. Intra-disciplinary and localized research projects are evolving into partnership oriented research programs that are mutually beneficial to all the involved stakeholders. The geographical and disciplinary limits in research are being dispelled to make way for a more unified and interactive research culture. It is a gradual recognition that national progress and growth objectives cannot be met by 'operational isolation.' The private and public domains are rampantly interrelating and involved in a dialogue on the potency and significance of collaborative partnerships.

The social organization of contemporary society is divided into three distinct entities: the state, academia, and industry. New challenges and mounting pressures to form research-oriented functional linkages that align well with the notion of 'big science' and economies of scale are forcing the three pillars of modern society to engage increasingly in cross-functional interactions.

Now, the exchange, association, and cooperation amongst the 'three pillars' of research society, the university, industry, and the government, can effectively be deciphered in terms of the "triple helix model" (Etzkowitz, 1998). This model of triple helix captures the stand alone status and intricacies of multiple reciprocal relationships among public, private, and academic institutional settings and postulates institutional orders and restructuring of organizational fields (Benner Mats, 2000). The three functionally and schematically distinct entities, when introduced into a triple helix world, develop in utility and expand outcomes. It is assumed that the restructuring of different helices and the enhancement of organization arrangements/incentives in triple helix arrangement foster innovation and improve research results. The triple helix model with rearrangements, mobility, and integration, evident

in 'macro-circulation and microcirculations,' stimulates hybridization, innovation, and research, ultimately evolving into dynamic networks of communication and interaction (Etzkowitz, 2008; Leydesdorff L., 2000).

The triple helix theory was the result of analysis that essentially was meant to explain the university's relationship with the government and the industry, in a dynamic social and innovation setting (Benner Mats, 2000; Etzkowitz, 2008, 7). The triple helix model is distinct from the traditional linear model of innovation—it is spiral in organization and captures multiple reciprocal relationships among public, private, and academic institutional settings. These spiral patterns of linkages operate in diverse stages of innovation process.

Unlike the *laissez-faire* model, where societal organization of entities is based on boundary preservation, restricted interactions, and clear role distinction (where industry is in charge of production, government works in regulation, and university deals with basic research), the triple helix model retains each sphere's independence while facilitating interaction. The interaction amongst institutional spheres of industry, university, and the government entails execution of each actor's own fundamental responsibility, while assuming some functions of other elements in the triple helix world. This alternating, duality in role, in varying combinations, facilitates active exchanges, stimulates innovation and creativity, and improves individual performance in the process (Etzkowitz 2008, 12-18).

System stability has been one of the core issues of integrative systems which affects the triple helix model. It is argued that gradual transformation and negotiations amongst actors can generate new organizational manifestations that have a coherent and stable institutional order. However, a contrasting view is that while the triple helix model depicts research arrangements in the contemporary world, it still lacks in a specified explanation of the interplay between transitional actors, organizations, and the institutions (Benner Mats, 2000, p. 299).

2. State-of-the-Art

Under the 'revolving door' interface of triple helix model, government, industry, and the university have significantly adjusted and been internally transformed to "take the role of the other", while still performing the traditionally assigned tasks and maintaining distinct identities (Etzkowitz, 2008, p. 9). For example, in a contemporary knowledge based economy, each institutional sphere in the triple helix is more likely to adopt characteristics of a creative source to support the emergence of creativity arising in other spirals.

In a modern societal setup, under the auspices of the triple helix, three subsequent role-transitions are evident: (i) the government(s), with its fundamental role as a regulator, is functionally mimicking industry in incentivizing innovation; (ii) industry continues its primary role in productive activities but also does research and training in a role similar to the universities; and (iii) the university conducts its principle business of disseminating knowledge while adopting some business and governance functions (Etzkowitz, 2008; Etzkowitz Henry, 2007).

These trilateral interactions within the triple helix model are exceedingly crucial and significant in a number of ways. However, this paper targets to only examine the transformational aspect of one of the three helices: 'the government.' The transition from the industrial to post-industrial knowledge economy and the dynamism required to achieve social growth has triggered a transformation in the role of the government at an instrumental level. This newly acquired function of the government is often described as 'public venture capitalist.'

In traditional times, top down centralized models, with government at the helm of affairs—as the prime regulator of firm and academic activities—was highly successful in the military-industrial complex in both socialist and capitalist economies. With the end of the cold war, the government role

as top-down coordinator was diluted and public finance has contracted sharply. The decentralization transition in capitalist societies was most notable in the research and innovation system, where governments supported a shift from "disciplinary to inter-disciplinary research" (Etzkowitz, 2008, pp. 60-61).

In the contemporary age this new role of government as 'venture capitalist' can, in some settings, be a form of 'entrepreneurship,' an expression that is often restrictively applied to commercialization of new products or technologies. This term has a more elaborate connotation as a process that identifies progressive opportunities, allocates resources in new prospects, and consequently creates value through realizing a vision—a role that government is now increasingly executing as a key stakeholder of the innovation process (Etzkowitz, 1983).

The triple helix fundamentals operationalize to aggregate resources, reduce friction, and to facilitate collaboration across national, regional, and local boundaries. Government in its non-centralized and peripheral form contributes to productive triple helix relationships whereas state centralization limits ideas and initiatives. In a decentralized economic setup the state emerges as an entity more open to the idea of equality and allocates resources to new prospects and opportunities in anticipation of improving local and regional prospects.

Table 1: OECD member's National S&T Policy Frameworks

Country	S&T policy frameworks	Common network encouraging strategic elements across national science policy frameworks
Australia	Powering Ideas, 2009	Strengthen integrated approach to innovation and improve Australia's linkages with global innovation systems
Canada	Mobilizing Science and Technology to Canada's Advantage, 2007	One of the core strategic principles is "fostering partnership"
Denmark	Globalisation Strategy 2012	Focus on efforts that contribute to networking and collaboration with worldwide research initiatives
Finland	Innovation Strategy, 2008	Encourage key stakeholder involvement in the innovation process and in the development of collaborative alliances amongst domestic firms involved in innovation activities
France	National Research and Innovation Strategy, 2008	Prioritize synergised innovation efforts amongst stakeholders present in competing innovation clusters
Germany	High-Tech Strategy 2020	Encourage innovation based linkages
Netherlands	R&D Promotion Act (WBSO)	Add funds to strengthen domestic and foreign innovation linkages
Sweden	Research and Innovation Bill, 2008	Renew funding to promote sustained research relationships
UK	Science and Innovation Investment Framework (SIIF)	Focus research and innovation activities on large innovative firms and strong internal/foreign linkages
USA	American Recovery and Reinvestment Act, 2009	Allocate financial backing to large-scale partnership oriented innovation models

Source: (Australia-OECD, 2010; Denmark-OECD, 2010; Finland-OECD, 2010; France-OECD, 2010; Industry, 2010; Netherland-OECD, 2010; PDSC, 2007; Sweden-OECD, 2010; UK-OECD, 2010; USA-OECD, 2010)

The role of the government as public venture capitalist is evident in various programs both at the provincial and federal levels, where the government attempts to fill the financial gap in those areas that are excluded from the university support for firm formation and from investments by private venture capitalist. This counterintuitive assessment of the government role has functioned most often in areas such as health and biotechnology research.

Over the last decade governments around the world have financially sponsored programs and projects that foster partnerships and encourage collaborations across disciplines and national boundaries (Table 1). Public financial support is rendered to private and university owned projects or ventures that contribute to the nation's vision and priorities. A large number of developed and transitional economies are increasingly implementing projects with a wider scale and scope in order to

extend their reach. The state in its public venture capital role facilitates 'big science' initiatives and is looking at ways to overcome the shortage of private investments for startups and early stage projects due to their uncertain profit margins. The state is beginning to filling this shortage, emerging as a major financial source for large-scale ventures, especially the ones that support national strategic objectives. The financial support for new initiatives is usually accompanied and directed by customized S&T policy frameworks and agendas.

2.1 Government in Canada: passive regulator or active facilitator of S&T research? In accordance with Table 1, the governments from a range of Organization for Economic Cooperation and Development (OECD) countries, including the federal government in Canada, are increasingly inclined to support research-based joint initiatives that support national growth and global competitiveness. In the last decade, the Canadian federal and provincial government have experimented and tested different coordinated models which promise enhanced downstream innovative outcomes. Strong progressive policy directives have been implemented that closely reflect the government's inclination towards augmenting partnership and cooperation mechanisms, international S&T relations, and enhancement of cross-sectoral coordination that facilitates innovation in Canadian S&T research. These principles of 'big science' are strongly reflected in the contemporary Canadian S&T policy framework—Mobilizing Science and Technology to Canada's Advantage in 2007 (Brassard, April 1996; Fast, December 2007; PDSC, 2007). The traditional opposition to government supporting research evident before 1940 has been reversed as the university and industry sought public funds. The position of the Canadian government now is to increase public R&D spending to address market failures and to support entrepreneurs with excellent but high risk ideas that could normally not find private capital to support their research.

As shown in Figure 1, the contemporary Canadian government is disproportionately supporting basic research (as reflected in above average HRST occupations as a percent of total employment, scientific articles and the percent of firms with new-to-market product innovations). One way Canada supports this is through large-scale research projects which employ large multidisciplinary teams of researchers.

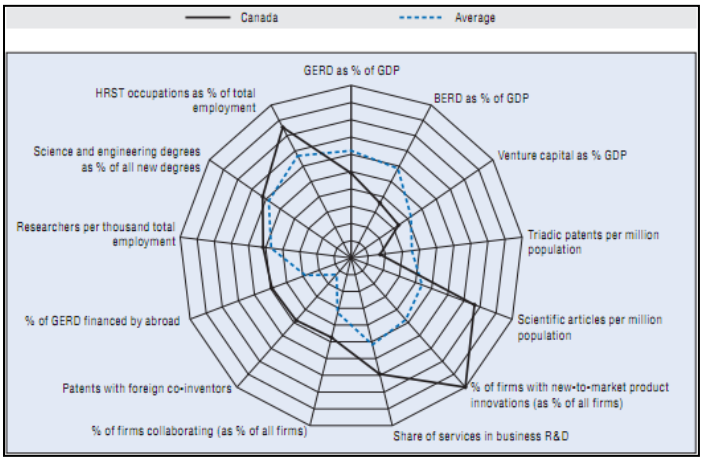


Figure 1: Science and Innovation Profile of Canada
(Source: http://dx.doi.org/10.1787/888932333291)

Research can be termed 'large-scale' if it utilize large-scale infrastructure and/or address problems that are large and complex but focused (Nass J.Sharyl, 2003, pp. 17-18). Under the big science theme, large-scale projects are emerging as key manifestations of the government's vision to support inter-disciplinary, cross-collaborative, team-based research projects which develop and use elements of partnership and networking. The government provides 'seed money' to universities and

private research facilities to conduct national goal-oriented research. The large-scale projects are known to benefit from economies of scope and scale and to offer the potential to make significant contributions to multiple disciplinary fields.[1]

There are a number of core questions related to the novel public venture capitalist role of government. Why is the government increasingly supporting large-scale research and innovation projects? What is the foundation of the government's decision to sustain large-scale research? Do large-scale projects display a potential to assist government in achieving the innovation agenda? There is a need to examine the collaboration- and networking-related concept of 'social capital' which is theoretically regarded as necessary for realizing enhanced innovation outcomes from large-scale investments.

2.2 Social Capital: an examination of diverse disciplinary and individual perspectives: Since the 1990s the concept of 'social capital' has assumed a central place in social scientific literature and has been well received by "a diverse host of individuals and organizations such as academics, governments, non-governmental organizations (NGOs), as well as transnational entities like the World Bank and UNDP" (Kazemipur, April 2004). However, despite this extensive interest in the topic, social capital does not have a clear and undisputed definition. This is at least partly due to its substantive and ideological complexities. While there are some commonalities in the various meanings assigned to social capital in the literature, there are still substantial and perplexing differences. One of the reasons cited for the lack of a universal definition for social capital is that "the definition of social capital is not limited to answering the question—what is social capital?" Instead most of the precedent definitions are structured to answer questions such as: "where does social capital reside? How can social capital be used? how can social capital be changed?" (Lindon J. Robison, 2002, p. 2). The ensuing review of literature attempts to reveal common and frequent patterns in current definitions or conceptualisations of social capital in order to extract answers for three main queries: what is social capital, where does it reside, and what are its outcomes?

A review of common definitions on social capital (Table 2) suggests they can be classified into four main typologies based on whether they focus on: (i) actions; (ii) structural placement in the network; (iii) psychological placement in the network; and (iv) resources.

Under the '**action-based classification,'** social capital is termed as a factor that facilitates collaborative, cooperative or common actions, or frames expectations of action in a group or a network. A number of sociologists have made substantial contributions to expand this categorization of social capital. According to Coleman (1990), social capital is an entity that has some attribute of social structure and facilitates certain actions of individuals who are within that structure. The definition specifies *what is social capital* (an entity with social structure), *where it resides* (social structure), and *what are its end outcomes* (facilitating actions from structure stakeholders) (Coleman, 1990). In a corresponding perspective, Portes and Sensenbrenner (1993) described social capital as "those expectations for action within a collectivity that affect the economic goals and goal-seeking behaviour of its members." This definition combines responses to *what is social capital* (the expectations for action within a collectivity), *where it resides* (collectivity), and *what is the function of social capital* (to effect the economic goals and goal-seeking behaviour of its members) (Portes Alejandro, May 1993, p. 1323). Putnam (1993) has defined social capital as "features of social organizations such as trust, norms, and networks that can improve the efficiency of society by facilitating coordinated actions." This definition clarifies *where* social capital r*esides* (in networks) and what *social capital*

[1] Prima-facie large-scale projects are conducted by multiple institutions, are multidisciplinary, cross-collaborative, and require management of diverse & complementary components. They are often considered an 'artefact' of big science and economies of scale. Large-scale projects provide abundant opportunities for interacting, sharing, networking, synergising efforts and therefore could be the probable source of latent capacity for innovation.

Table 2: Conceptual summary of social capital				
Typology*	**Authors**	**What is social capital?**	**Where social capital resides?**	**What are benefits/outcomes of Social capital**
Action based view on social capital	Coleman (1990)	an entity with social structure	In social structure	facilitates actions from structure stakeholders
	Portes and Sensenbrenner (1993)	the expectations for action within a collectivity	in collectivity	affect the economic goals and goal-seeking behaviour of its members
	Putnam (1993)		in networks	improves the efficiency of society by facilitating coordinated actions
	Fukuyama (1995,1997)	ability of people to work in groups, with shared informal values or norms	among members of group	permits cooperation amongst group members
	Narayan and Pritchett (1997)			increase community cooperative action; strengthen communal harmony to speed diffusion of innovations; improve quantity/ quality of information flows and reduce transactions costs; split risk and facilitate riskier activities
	Kwon (2002)	fabric of social relations	in social relations	it can be activated to facilitate action
Social Capital resulting from positional placement of individual in a network/ structure	Baker (1990)	resources driven by actors from social structures	in social structures	used to pursue actors individual interests
	Schiff (1992)	set of elements of the social structure	in social structure	is its purpose (affects relations among people, inputs of production/utility function)
	Burt (1992, 2000)		in network structures	give opportunity to network individuals to use other forms of capital
	Portes (1995)	capacity of individuals to command resources	in networks or social structures	
	Kwon (2002)	resource available to actors as a function of their location	in structure of social relations	
Social Capital from placement of individual in a network/ structure	Bourdieu (1985, 2006)	social obligations or connections		convertible into economic capital under certain conditions
	Robinson (2002)	is sympathy	in exchange relationship	generates potential benefit, advantage and preferential treatment for network members
Resource based view on social Capital	Boxman (1991)	property of a network; network-as-resources	personal networks	where people benefit in a social network through exchange of social resources
	Bourdieu (1985, 2006)	aggregate of actual or potential resources		network of institutionalized relationships
	Nahapiet & Ghoshal (1998)	sum of actual and potential resources in a network	network of relationships	
	Knoke (1999)	social actors create and mobilize their network connections	network connections	gain access to other social actors' resources

does (improves the efficiency of society by facilitating coordinated actions) (Lindon J. Robison, 2002, p. 4; R. D. Putnam, January, 1995, p. 67). Fukuyama (1995, 1997) classified social capital in the form of community action directed by norms and values. Social capital is the ability of people to work together for common purposes in groups and organizations and is the existence of a certain set of informal values or norms shared among members of a group that permit cooperation among them. His definition *describes social capital* (ability of people to work together in groups, certain informal values or norms shared by members in a group), identifies *where it resides* (amongst members of group), and notes *its functions* (permits cooperation amongst group members) (Fukuyama, 1995, p. 10; 1997). Narayan and Pritchett (1997) perceived social capital as a central factor that can *produce a number of outcomes*, including increased community cooperative action, strengthened communal harmony that speeds diffusion of innovations, improved quantity and quality of information flows that reduces transactions costs and split risk that allows for more risky and high return activities (Lindon J. Robison, 2002, p. 3). Finally, Kwon (2002) stated that social capital is "produced by the fabric of social relations and mobilized to facilitate action." This definition describes *what is social capital* (fabric of social relations), *where it resides* (in social relations), and what are the *consequential outcomes of social capital* (it can be activated to facilitate action) (Kwon, January 2002, pp. 17-18).

The classification based on '**positional placement of an individual in a network/structure'** is based on the premise that well connected individuals in a group or a network can be an asset, allow access to resources, facilitate pursuit of interests; and positively affect relationships. A range of sociologists have contributed to this line of argument. According to Baker (1990), social capital is "a resource that actors derive from specific social structures and then use to pursue their interests; it is created by changes in the relationship among actors." This definition elucidates *what is social capital* (resource driven by actors from social structures), *where it resides* (social structures), and *what is its function* (used to pursue actors individual interests) (Baker, November 1990, p. 619). Schiff (1992) acknowledged social capital as a "set of elements of the social structure that affects relations among people and are inputs or arguments of the production and/or utility function." This definition identifies *what is social capital* (a set of elements of the social structure), *where it resides* (the social structure), and *what is its purpose* (affects relations among people, inputs of production/utility function) (Schiff, April 1992, p. 160). In the view of Burt (1992, 2000), the certain positional placement of an individual in the network structure can be an asset and create opportunities to use other forms of capital. This definition of social capital illustrates *where social capital resides* (in network structures) and *what can be accomplished through it* (receive opportunities to use other forms of capital) (G. Burt, 1992 p. 9; R. S. Burt, 2000, p. 3). Similarly Portes (1995) views social capital as an individual's capacity to access scarce resources due to membership in networks or broader social structures. This definition gives a perspective on *what is social capital* (the capacity of individuals to command scarce resources) and *where it is located* (networks or broader social structures) (Portes, 1995 p. 12). In a structural construct, Kwon (2002) states that the social structure has an impact on the amount of social capital produced. Social capital is created from the very social structure in which the actor resides. Here *social capital is* the resource available to actors, is a function of their location and *resides in* the structure of their social relations (Kwon, January 2002, p. 18).

Alternatively, the classification of social capital based on '**psychological placement of individual in a network/structure'** suggests that the influence and authority of an individual in a network can provide preferential treatment, give access to resources and be converted to economic or monetary outcomes. A number of authors have augmented this view with well-placed arguments. According to sociologist Bourdieu (1985) (and his capitalist perspective) social capital is "social obligations ('connections'), which is convertible, in certain conditions, into economic capital." The resulting economic capital is ready convertible into money. This simplifies *what is social capital* (a social obligation or connections) and *what are its benefits* (convertible into economic capital)

(Bourdieu, 1985, p. 243). Robison (2002) states that social capital "is a person's or group's sympathy toward another person or group that may produce a potential benefit, advantage, and preferential treatment for another person or group of persons beyond that expected in an exchange relationship." This definition gives a distinct idea of *what is social capital* (sympathy), *where it resides* (in exchange relationship), and *what is its function* (produce potential benefit, advantage and preferential treatment) (Robison, 2002, 6).

Lastly, the '**resource based classification'** asserts social capital connotes 'resource availability and access.' Boxman (1991) offers the perspective that social capital is "someone's personal network and all the resources a person has access to through this network." This standpoint *explains social capital* (as property of a network), *where it resides* (personal networks), and *what it can achieve* (a "network-as-resources" where people benefit through exchange of social resources) (Boxman Ed A.W., 1991, p. 52). In another remark Bourdieu (1992, 2006) notes social capital is "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition." The definition explains *what is social capital* (sum of actual or potential resources), and *where it resides* (network of institutionalized relationships) (Bourdieu, 2006; Pierre Bourdieu, 1992, p. 119). Nahapiet & Ghoshal (1998) frame social capital as a sum of actual or potential resources embedded within, available through, and derived from the network of relationships. The above definition explains *what is social capital* (sum of the actual and potential resources in a network), and *where it resides* (network of relationships) (Nahapiet Janine, April 1998, p. 243). Similarly, Knoke (1999) indicates that "social capital is a process by which social actors create and mobilize their network connections within and between organizations to gain access to other social actors' resources." He thereby delimits the *social capital essentials* (social actors create and mobilize their network connections), *its location* (in network connections), and *its outcome* (gain access to other social actors' resources) (Knoke, 1999, p. 18).

The reviewed perspectives on social capital indicate disagreements and even contradictions in the definitions of social capital which vary based on either source, actor-relations, effects of social interaction, or type of linkages (Kwon, January 2002; Lindon J. Robison, 2002; R.D. Putnam, 2000). As mentioned earlier, four common typologies have emerged. All four typologies consistently indicate that social capital resides in one element of a network (i.e. network structure, social structure, exchange relationships or personal network)—thus the presence of a network environment emerges as a necessary condition for production and survival of social capital.

It is not viable to justly examine all four typologies at once in detail. However, extracting the common patterns from all four typologies that concern the presence or absence of a network structure in projects of scale is feasible and is selected for further examination in this paper. Social capital will be assessed based on the presence of network structure (by implication, the absence of network organization will be assumed to denote weak or absent social capital). We then examine government's role as public venture capitalist in facilitating large-scale S&T projects and their efforts to develop networks.

3. Research Hypothesis

The research tests one main null hypothesis and four sub-hypothesis relate to the effect of social capital (mentioned in section 5). The main null hypothesis (H_0) is that the Canadian government's new role as public venture does not create any functional ties or links amongst actors in large-scale projects. Thus, the *density (d) of networks produced as an outcome of governments public venture capitalist role is d=<0.*

4. Methodology

The research methodology is divided into sections 4.1,4.2, and 4.3, which respectively lay out the nature of the project of interest, the data collected and the Social Network Analysis methods we will use for the analysis..

4.1 Large-scale project of interest: The current research assesses the impact of 10 years of federal government's funding to Genome Canada (GC) large-scale S&T projects spanning 2000-2009.[2] Genome Canada is a special operating agency that has adopted the federal government's vision of implementing contemporary science and research management practices and an innovative business model in Canada. The federal funding received by Genome Canada is used to develop an overarching 'umbrella model' to draw industry, government departments and agencies, universities, and the public together for effective operationalization of large-scale genomic- and proteomics-oriented research projects (Genome, 2008, 2010; PDSC, 2007). However, it unclear if federal investments in Genome Canada's large-scale projects create network structures or not?

4.2 Data Collection: The data has been collected for 139 individual researchers from GC who signed large-scale projects in the Applied Genomics for Bioproducts and Crops (ABC) competition in 2009. These 139 actors, in 12 projects, were awarded $112 million to spend on large-scale science. The engagement and performance of these 139 individuals was traced back into previous large-scale competitions—Competition I (2001), Competition II (2001), Competition III (2004) and the ABC competition (2009) sponsored by Genome Canada, the Advanced Food and Materials Network (AFMNET, 2001-11) funded by the National Centres of Excellence Program and the Agricultural Bioproducts Innovation Program (2008-11) funded by Agriculture and Agri-Food Canada. Four types of ties and linkages were investigated and recorded—area of expertise, co-publications, research grants, and institutional connections. Four binary matrices were generated showing the social network and interrelationships among these 139 researchers, one for each of the four types of ties or linkages.

4.3 Social Network Analysis: The paper uses social network analysis (SNA) tools and techniques to illustrate the presence or absence of links or connections amongst actors—the base condition for a network environment. The SNA descriptive statistics are recognized to describe, predict, and test for the presence or absence of relationships in a networked environment. The SNA statistics provide information about the individual distributions of actors in the network, their relationships and attributes, and joint distributions of statistical association. As affirmed by Hanneman (2010), SNA produces descriptive and analytical statistics that permits one to draw inferences on network-related concepts with confidence (Hanneman A. Robert, 2010b, 1). The collected data is analyzed using SNA tools available through the Analytical Technologies-UCINET software. Also, the Netdraw application is employed to create 'socio-grams,' visual depictions of the relationships between various network actors (Borgatti, 2002). The SNA network density measure and related statistical tools are used. Network density measure is not ego-centric and pertains to whole network. Density creates a quantitative base to affirm the presence or absence of linkages amongst project actors and assess the intensity of linkages between these actors based on directed or undirected collaborative activity.

The network density measure: (i) gives insights into the level of an actor's social capital and their social constraint; (ii) demonstrates the overall volume of interactions among a team's members in

[2] GC raised $1.6 billion from 2000-2010: 56% of the funds are channelled from the federal government, 24% of the funds are directed from the provincial governments and the remaining 20% of the funds are raised from the industry, universities and foreign contributions (Genome, 2011).

a network (based on average number of ties per team member); and (iii) measures the ratio of interconnections within a given network (S. P. Borgatti, Everett, M. G., & Freeman, L. C., 2002; Hanneman A. Robert, 2010a; Knoke D., 1982, p. 45; Sparrowe., April 2001). The density measure of a binary network (non-valued, with 0 and 1) is calculated as the total number of ties in a matrix divided by the total number of possible ties. The value of density ranges from 0 to 1 where 0 means no connection and 1 means all actors are connected. Density is classically expressed by the formula 1:

Formula 1:

$$Density_{Local} = \frac{2L}{N(N-1)}$$

where all possible ties in a matrix are denoted by N, the total number of actual ties amongst the actors in the network is denoted by *L*, and the denominator equation that accounts for all possible permutations and combinations is *N(N-1).*

However, there is a problem with classical network density formula. It assumes that all observations or relations are independent. This is an unreasonable supposition as the ties are really generated by the same actors in the network. It is therefore more useful to use the 'bootstrap density measure' devised by Efron in 1979. This method uses the actual data on the actual actors, with the observed differences in actor means and variances. This is a much more realistic approximation to get actual sampling variability, create descriptive density, and extract standard error statistics for the network of interest. This bootstrap method is based on re-sampling that constructs many artificial data sets out of the observed data set and uses the variability between these artificial data sets. The collected data is considered as a population and artificial samples of say size *N* are drawn by replacement from the collected data. For this purpose current research uses 'bootstrap density' measures. This method is simple and straightforward in deriving estimates of standard errors and confidence intervals for complex estimators of complex parameters of the distribution, such as correlation coefficients (Snijders Tom A.B., 1999; Wikipiedia, May 2011).

One can start by assuming the data for the network has *N* nodes represented as *i = 1* to *N*, and the link between the nodes is *i* and *j* denoted as Y_{ij}. A large number *M* (say 5000) of bootstrap samples are drawn from observed data by the following procedure: a random replacement sample is drawn from the nodes and denoted by *i(1), ..., i(N).* The value *i(k)* shows that independent sample is drawn from *1* to *N*. Whenever the replacement artificial network *Y** is induced by nodes *i(1)* to *i(N)*, which are same as the nodes of the original collected data, then nodes *k* and *h* in the replacement artificial network will corresponds to different original vertices *i(k)* and *i(h)* as such:

Formula 2:

$$Y^{*}_{k\,h} = Y_{i(k)\,i(h)}, \quad for\ i(k) \neq i(h)$$

Formula 2 shows that in artificial network the tie between node *k* and *h* is the same as the tie between vertices *i*(*k*) and *i*(*h*) in the observed network. This process of re-sampling vertices leaves the basic network structure intact. The re-sampling is followed by calculation of the bootstrap standard error. The above given process of re-sampling and generation of artificial networks is repeated *M* times (5000 times). For each artificial network statistics $Z^{*(1)}$ to $Z^{*(M)}$ are calculated. For example: $Z^{*(m)}$ is based on the *m*'th artificially generated network Y^{*}. The standard error is generated where $Z^{*(\cdot)}$ is the mean of $Z^{*(m)}$ so that:

Formula 3:

$$SE(Z) = \sqrt{\frac{1}{M\text{-}1}\sum_{m=1}^{M}(Z^{*(m)} - Z^{*(\cdot)})^{2}}$$

The main assumption of the bootstrap standard error is that it is rational to regard the vertices as interchangeable, as the observed vertices are indeed treated interchangeably in the sampling process.

The efficiency of the density of the network can be determined by comparing original network statistics Z with a theoretical value μ.

Formula 4: $$t = \frac{Z-\mu}{\sigma}$$

A threshold number of t=1.65 is the critical value associated with a maximum Type 1 error of 0.05 in a 1-tailed test. For example, in a knowledge transmission network where *t>1.65*, the transmission of information is effective and when *t<1.65* transmission is ineffective (Snijders Tom A.B., 1999, pp. 4-6).

5. Findings and Interpretations

The bootstrap method is used to calculate the densities and related measures for all four matrices created for the Genome Canada researchers engaged in the ABC large-scale projects. The outcome of the analysis from UCINET is illustrated in Table 3.

Table 3: Bootstrap densities and standard error for four types of ties/connections in Genome Canada government funded large-scale project

Type of ties	Parameter value/ Hypothetical mean (*u*)	Average Bootstrap density (d)	Difference (*u*)-(d)	Standard Error of difference	t-statistics	p-value
Area of expertise	0	0.6490	0.6490	0.0440	14.9	p=0.001
Institutional Connections	0	0.0380	0.0380	0.007	5.84	p=0.001
Co-publications	0	0.0116	0.0116	0.003	4.64	p=0.001
Research Grants	0	0.0141	0.0141	0.005	2.87	p=0.004

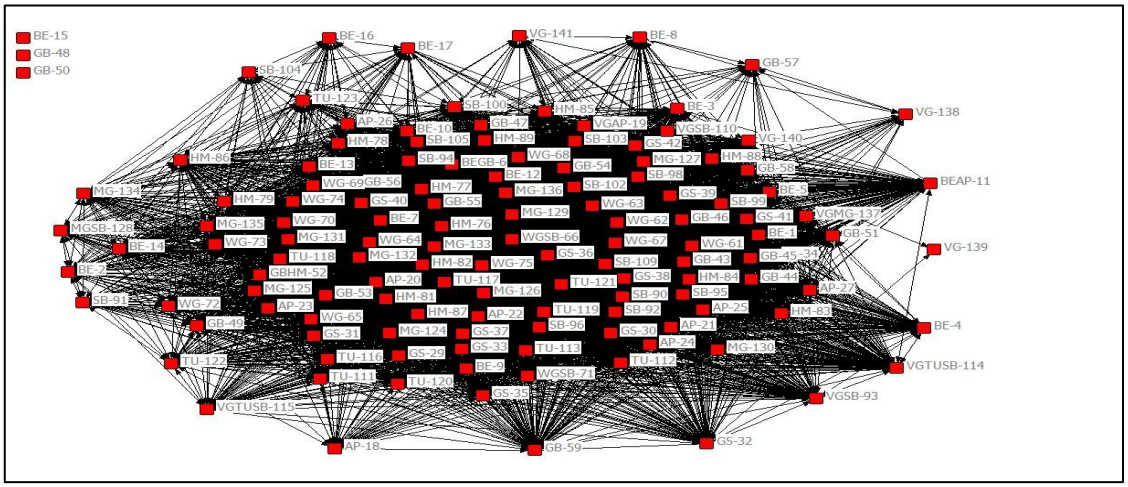
** Source: Authors calculations

*** Degree of freedom (N-1) where N=139

This data is used to affirm whether the GC ABC large-scale projects exhibit the networks and network ties that are necessary to generate social capital. The primary hypothesis was that the government's role as a public venture capitalist fails to create ties amongst large-scale project actors. The main null hypothesis (H_0) that the density of ties amongst actors in large-scale projects is *d<= 0* is tested in the four sub-sectors.

5.1 Area of expertise ties amongst GC's large-scale S&T project actors: According to Table 3, the parameter test value divided by the assumed mean for the 'area of expertise matrix' is 0. When the bootstrap method is used, the mean of this sampling distribution (observed density) is computed to be 0.6490. The difference between the null and observed values of density is 0.6490. The estimated standard error of density (standard deviation) is 0.0440. The calculated t-statistic for the matrix is 14.9, which allows us to infer the density is statistically different than zero at the 99.9% confidence level. It is highly implausible that a difference this large can happen by random sampling variation, if the null hypothesis (d = 0) was really true for the population.

Thus, it can be safely concluded that the population has a mean different than the hypothetical value entered and that this difference is statistically significant. Concurrently, it implies that the financial support of the government to large-scale S&T projects provides an environment that links actors that have similar areas of expertise. The presence of dense linkages is further affirmed in *Sociogram 1*. This environment has a propensity to network and create social capital. Hence, the null hypothesis *(H_0-1) that 'large-scale projects receiving public venture capital, are ineffective in connecting/linking actors with similarity in areas of expertise'* ***is rejected****.*

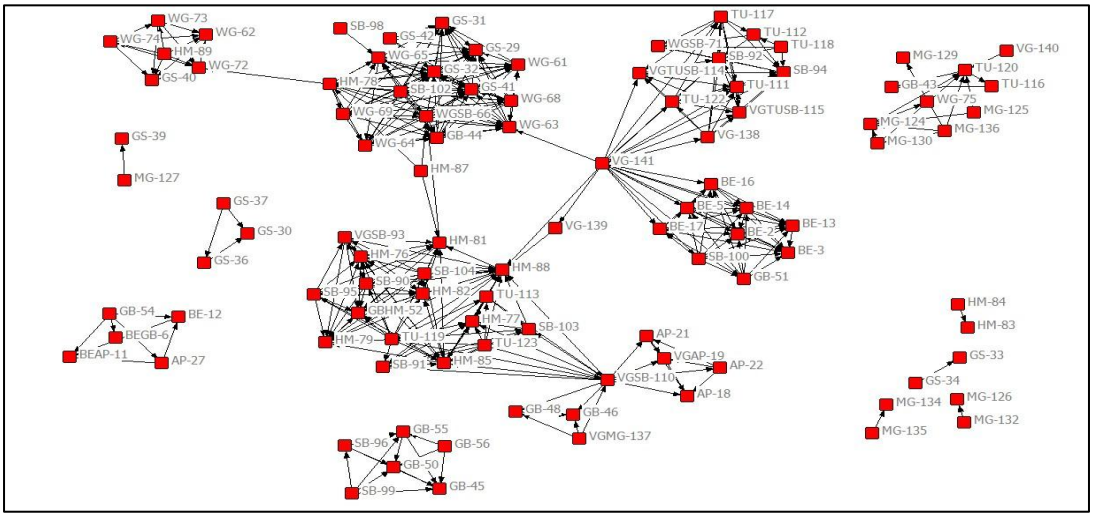


Socio-gram 1: Area of expertise network with 139 actors from Genome Canada's government funded large-scale project

Source: Authors calculations

Number of links/connections in the area of expertise network=12529

5.2 Institutional Connections amongst GC's large-scale S&T project actors: As shown in Table 3, the parameter test value divided by the assumed mean for 'research grants ties' is 0. The mean of this sampling distribution (observed density) is computed to 0.0380. While the density of this matrix is not as high as the area of expertise matrix (0.6490), it still it indicates the presence of actor ties. The difference between the null and observed values of institutional connections density is 0.0380. The estimated standard error of density is 0.007. The t-statistic of 5.84 for the matrix is significant at the 99.9 percentile. Thus it is implausible to conclude that this difference between the sample mean (0.0380) and the hypothetical mean (0) is due to a coincidence arising from random sampling. One can safely infer that the population has a mean different than the hypothetical value entered and that this difference is statistically significant. Correspondingly, it indicates that the financial support for the ABC projects has generated an environment that works to link network actors that have the same departmental or institutional affiliation. This is visually affirmed in *socio-gram 2.* One can conclude that this funding environment has a tendency to generate network structure and social capital. Hence, null hypothesis *(H_0-2) that 'large-scale projects receiving public venture capital, are ineffective in connecting actors with previous institutional kinship"* ***is rejected****.* The government funding links actors in intra/inter institutional linkages favourable for interdisciplinary research and dissemination of knowledge.

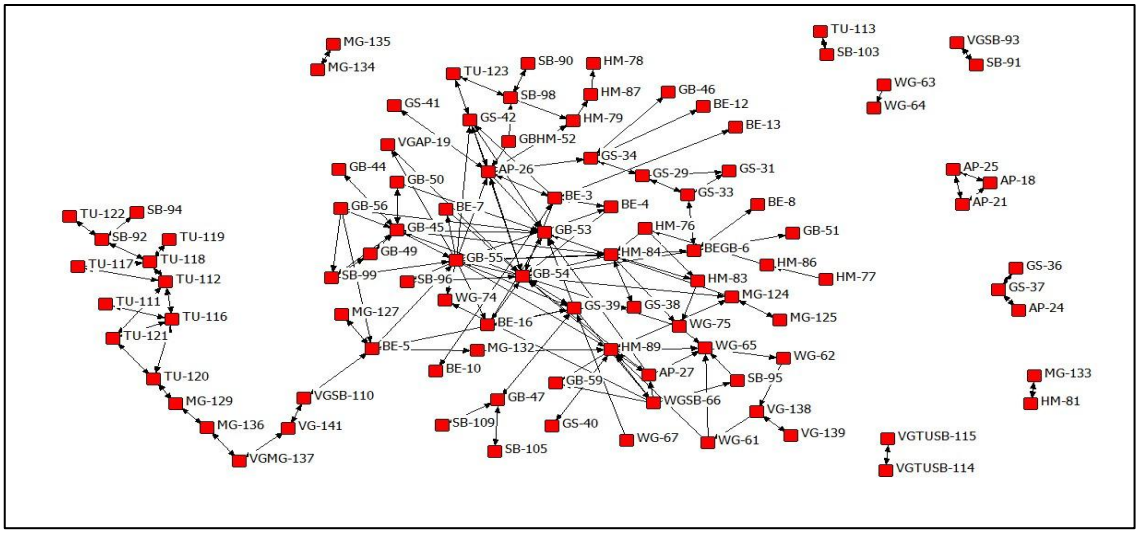


Socio-gram 2: Institutional connections network with 139 actors from Genome Canada's government funded large-scale project

Source: Authors calculations

Number of links/connections in institutional connections network=369

5.3 Co-publication ties amongst GC's large-scale S&T project actors: Table 3 presents the results of the bootstrap method for prior co-publication links among the 139 researchers in the ABC competition. The mean of this sampling distribution is computed to 0.0116; while not as high as the density of area of expertise matrix or institutional connection matrix, it still confirms presence of ties that generates a network. The difference between the null and observed values of co-publication density is 0.0116, with an estimated standard error of density (standard deviation) of 0.003. The t-statistic of co-publication matrix (4.64) is significant at the 99.9% level.



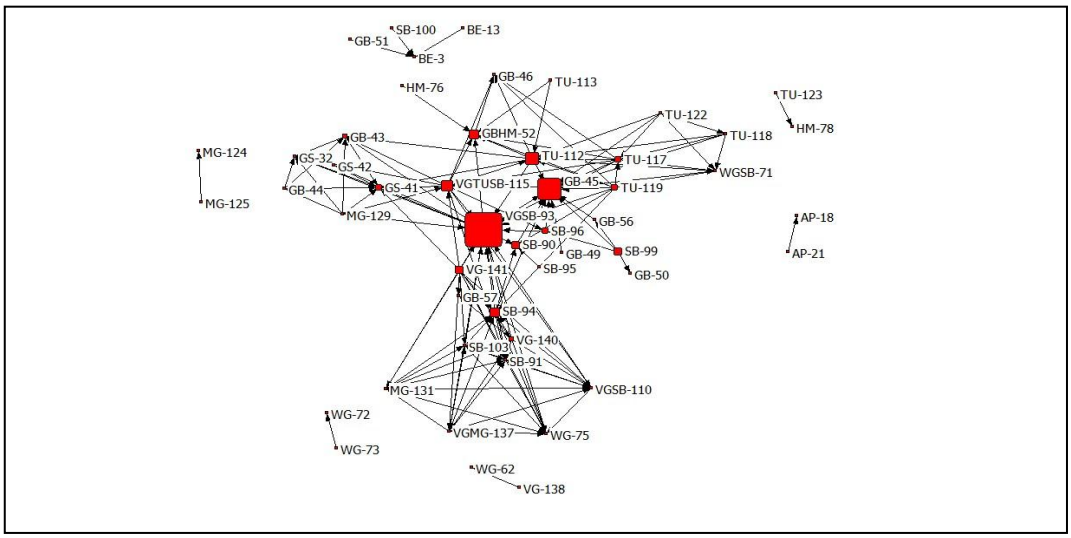
Socio-gram 3: Co-publication network for 139 actors from Genome Canada's government funded large-scale projects

*** Source: Authors calculations*

Number of links/connections in co-publications network=223

One can conclude that it is virtually impossible that the difference between the sample mean (0.0116) and the hypothetical mean (0) arises due to a coincidence of random sampling. We can safely conclude that the population has a positive mean and that this is statistically significant. It confirms that the financial support from the government to large-scale S&T projects creates an environment which links individuals networked through prior co-publication ties. The presence of ties is also visually affirmed in socio-gram 3. Thus, we can safely conclude that this environment has a tendency for generation of both significant network structure and social capital. Hence, null hypothesis (H0-3) that "large- scale projects receiving public venture capital, are ineffective in linking actors in co-publication ties" is rejected.

5.4 Research grant ties between GC's large-scale S&T project actors: Table 3 offers the test results for 'research grant ties.' The bootstrap method generates a mean of this sampling distribution of 0.0141. This value is lower than for all three preceding matrices but it does indicate the presence of prior research grant ties amongst actors in the large-scale project setting. The difference between the null and observed values of co-publication density is 0.0141. The estimated standard deviation is 0.005.



Socio-grams 4: Research grants network for 139 actors from Genome Canada's government funded large-scale projects

*** Source: Authors calculations*

Number of links/connections in the research grants network=137

With a t-statistic of 2.87 and a p-value of 0.004, it is highly improbable that the difference between the sample mean (0.0116.) and the hypothetical mean (0) is due to a coincidence arising from random sampling. The population has a positive mean that is statistically significant. The public venture capitalist role of the government is generating an environment that links actors in a way that they extend prior relationships based on winning research grants for collaborative S&T projects. The presence of ties is also visually affirmed in *socio-gram 4*. Thus, it can be safely concluded that this environment has a tendency to generate a positive network structure that builds upon and extends social capital. Hence, the final null hypothesis *(H_0-4) that 'large- scale projects receiving public venture capital, are ineffective in connecting actors for raising research grants'* ***is rejected***.

6. Conclusions

All four sub-hypothesis are rejected which fails the case for acceptance of main hypothesis (H_0). Thus, H_0 is rejected as well. In short, Genome Canada's large scale research program funded through the ABC competition mobilizes, links and potentially extends the networks and social capital inherent in this research area.

There are four inferences from the review of available literature and the data analysis. First, governments are emerging as a dynamic entrepreneur and partner in research and knowledge creation. This is in sharp contrast to the state's pre-1940 traditional function as a coordination agency and a regulator. Literature suggests that this shift is particularly evident in advanced industrial democracies with triple helix interactions. In contrast, centrally planned economies tend to be too restricted to generate positive externalities. Second, government-supported large-scale S&T projects generate enhanced opportunities for intense collaboration or interchange that builds upon and may facilitate research and innovation, co-publication, inter- or intra-departmental cooperation, and joint grant submissions. Third, large projects are a platform for triple helix exchanges between the researchers, industry, and the government sponsors. Fourth, projects of scale also shape a foundation for mobilizing social capital, which in turn is the fundamental condition for generating incremental social capital.

Private venture capitalists operate and invest in favourable projects with potential of high profit and high internal rate of return (IRR). These strictures often limit their ability to engage in or sustain projects in high risk, early, seed stages of development. In contrast, government engagement as a public venture capitalist offers the opportunity to provide financial support for early stage large-scale S&T endeavours. This support does not need to be as dependent upon the potential for financial profit. These large-scale projects can offer network structures which both depend upon and engender social capital, which in turn offer new and potentially more effective exchanges that could lead to greater innovation and enhanced social welfare.

The analysis, associated statistical tests, and refutation of the null hypotheses in all of the above examined cases has statistically and empirically confirmed that the large-scale science and technology projects that are financially assisted by the Canadian federal government, are based on functional linkages and connectivity between the project actors. The linkages offered a base both for successful generation of the ABC projects and offer a base for further creation of social capital. These networks are most pronounced when actors from same area of expertise are introduced in large-scale project settings. These instances of linkages are significantly reduced when examined through the lens of institutional affiliations and even more so when assessed in the context of co-publications or collaborating in raising research grants.

7. Policy Implications

There has been a deliberate and active effort in recent years (in Canada since the 1990s) to develop policy frameworks that expand the government's role in S&T and innovation policy. These efforts have both built upon and nurtured triple helix exchanges as explicit policy instruments.

The funding priorities of the government in Canada, and elsewhere around the world, are shifting towards support for large-scale projects. Significant federal resources in Canada have been channelled to support large-scale projects. Large-scale projects in some ways are being taken as purpose-built innovation systems in themselves—they are explicitly designed to display reflexivity, trans-disciplinarity and heterogeneity. Social capital, which we have shown does exist in large-scale projects, is posited to be readily convertible to economic capital and to assist in better utilizing other forms of capital in the economy. Therefore, large-scale S&T ventures are expected to emerge as significant contributors to a prosperous and growing economy. This research reported here offers, at a

minimum, some evidence that proactive government policy can mobilize latent social capital in support of targeted research objectives. This research does not yet show that this generates incremental output (Ryan 2008 does show in the context of a somewhat differently structured analysis that those large-scale, Genome Canada funded projects with higher social capital, as measured by density, combined with effective formal and informal leadership, delivered higher outputs). Taken together, this research offers some empirical justification for governments to direct at least a portion of future budgetary allocations towards large-scale research and innovation projects. In practices, this could involve adjusting or reforming policies and programs in order to attract large amounts of funding that are normally unattainable to smaller, investigator led projects and consider amalgamation of resources to build new facilities in support of large scale projects (e.g. genomics sequencing labs, biocontainment facilities and research instruments such as the Canadian Light Source). Agglomerating and concentrating effort in the context of large-scale research offers some prospect of accelerating knowledge dissemination and innovation.

8. Directions of future research

The current research has offered an enhanced understanding of the role of social capital in the triple helix and how the government role as venture capitalist contributes to networks that can form the basis for knowledge generation and exchange. The investigation has justified, and possibly encouraged, large-scale projects in S&T. However, it would be important to test and replicate the current research methodology in other sectors to validate these early findings. Future research could assist in expanding the understanding of networks and triple helix interactions under varying conditions. In particular, longitudinal study could assist us to interpret the transformations and building blocks in the interaction complexities within the triple helix model.

Bibliography

Australia-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles: Australia (Country notes-Reports). Retrieved 1 January 2011 http://www.oecd.org/dataoecd/31/0/46663563.pdf

Baker, Wayne E. (November 1990). Market Networks and Corporate Behaviour *The American Journal of Sociology, 96(3)*, 589-625.

Benner Mats, Sandstrom Ulf. (2000). Institutionalizing the triple helix: research funding and norms in the academic system. *Research Policy, 29*(2), 291–301

Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). UCINET for Windows: Software for Social Network Analysis Retrieved August, 2010

Borgatti, S.P. (2002). *NetDraw: Network visualization*. Harvard, MA: Analytic Technologies.

Bourdieu, Pierre (Ed.). (1985). *The forms of capital* New York: Greenwood.

Bourdieu, Pierre (Ed.). (2006). *The Forms of Capital- Education, Globalization, and Social Change*. New York: Oxford University Press.

Boxman Ed A.W., Graaf Paul M. De, Flap Hendrik D. (1991). The impact of social and human capital on the income attainment of Dutch managers. *Social Networks*, *13*, 51-73.

Brassard, Daniel. (April 1996). Science and Technology: The Federal Policy. *Parliamentary Information and Research Service* Retrieved October 20, 2010, from http://dsp-psd.pwgsc.gc.ca/Collection-R/LoPBdP/BP/bp414-e.htm#(4)END

Burt, G. (1992). *Structural Holes*. Cambridge: Harvard University Press.

Burt, R.S (Ed.). (2000). *The network structure of social capital* (Vol. 22). Greenwich: CT:JAI Press.

Coleman, J. S. (1990). *Foundations of Social Theory*. Cambridge: Harvard University Press: MA.

Denmark-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles: Denmark (Country notes-Report). Retrieved 1 January 2011 http://www.oecd.org/dataoecd/42/13/46664002.pdf

Etzkowitz H., Leydesdorff L. (1998). The triple helix as a model for innovation studies. *Science and Public Policy, 25*(3), 195-203.

Etzkowitz, Henry. (1983). Entrepreneurial scientists and entrepreneurial universities in American academic science. *Minerva, 21*(2), 198-233. doi: 10.1007/bf01097964

Etzkowitz, Henry. (2008). *The Triple Helix: University Industry Government Innovation in Action* (First ed.). New York: Routledge.

Etzkowitz Henry, Zhou Chunyan. (2007). *Regional Innovation Initiator: The Entrepreneurial University in Various Triple Helix Models*

Singapore Triple Helix VI Conference Theme Paper Singapore. Retrieved from http://www.nus.edu.sg/nec/TripleHelix6/SingaporeConferenceThemePaper050107.pdf

Fast, Eleanor. (December 2007). *Mobilizing Science and Technology: The new federal strategy*. (PRB 07-32E). Parliamentary Information and Research Service Retrieved from http://www2.parl.gc.ca/Content/LOP/ResearchPublications/prb0732-e.pdf.

Finland-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles: Finland (Country notes-Report). Retrieved 1 January 2011 http://www.oecd.org/dataoecd/42/11/46664029.pdf

France-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles: France. Retrieved 7 January 2011, from OECD http://www.oecd.org/dataoecd/42/10/46664196.pdf

Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity*. New York: Free Press.

Fukuyama, F. (1997, 25 November, 2010). Social capital and the modern capitalist economy: Creating a high trust workplace. , 4(1). *Stern Business Magazine*.

Genome, Canada. (2008). Guidelines and Evaluation: Criteria Competition in Applied GenomicsResearch in Bioproducts or Crops, from http://www.genomecanada.ca/medias/PDF/en/Guideline_Evaluation_Criteria.pdf

Genome, Canada. (2010). About Genome Canada Retrieved 4 November 2010, from http://www.genomecanada.ca/en/about/

Genome, Canada. (2011). Co-funding Retrieved 20 Feburary, 2011, from http://www.genomecanada.ca/en/portfolio/co-funding.aspx

Hanneman A. Robert, Riddle Mark. (2010a). Chapter 7. Connection and Distance Retrieved from http://www.faculty.ucr.edu/~hanneman/nettext/C7_Connection.html#density

Hanneman A. Robert, Riddle Mark. (2010b). Chapter 18. Some Statistical Tools Retrieved from http://www.faculty.ucr.edu/~hanneman/nettext/C18_Statistics.html

Industry, Canada. (2010). Mobilizing Science and Technology to Canada's Advantage (2007)-Chapter 3: Entrepreneurial Advantage Retrieved 5 November, 2010, from http://www.ic.gc.ca/eic/site/ic1.nsf/eng/00864.html#box57

Kazemipur, Abdolmohammad. (April 2004). *Social Capital of Immigrants in Canada*. PCERII Working Paper Series. Prairie Centre of Excellence for Research on Immigration and Integration (PCERII). Edmonton. Retrieved from http://pcerii.metropolis.net/WorkingPapers/WP04.04.pdf

Knoke, D. (Ed.). (1999). *Organizational networks and corporate social capital*. Boston: Kluwer.

Knoke D., Kuklinski J.H. (1982). *Network Analysis. Series: Quantitative Applications in the Social Sciences*. CA: Thousand Oaks: Sage.

Kwon, Paul S. Adler and Seok-Woo. (January 2002). Social Capital: Prospects for a New Concept *The Academy of Management Review, 27(1),* 17-40.

Leydesdorff L., Etzkowitz H. (2000). The dynamics of innovation: from National Systems and ‘‘Mode 2’’ to a Triple Helix of university–industry–government relations. [Journal]. *29*, 109–123.

Lindon J. Robison, A. Allan Schmid and Marcelo E. Siles. (2002). Is social capital really capital? *Review of Social Economy, 60(1)*, 1-21.

Nahapiet Janine, Ghoshal Sumantra. (April 1998). Social Capital, Intellectual Capital, and the Organizational Advantage. *The Academy of Management Review, 23(2)*, 242-266.

Nass J.Sharyl, Stillman W.Bruce. (2003). Large Scale Biomedical Science- Exploring Strategies for Future research Stillman W.Bruce Nass J.Sharyl (Ed.) Retrieved from http://www.nap.edu/openbook.php?record_id=10718&page=R2

Netherland-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles:Netherland (Country notes-Report). Retrieved 1 February 2011 http://www.oecd.org/dataoecd/40/58/46665447.pdf

PDSC. (2007). *Mobilizing Science and Technology to Canada's Advantage-2007*. Ottawa: Retrieved from http://www.ic.gc.ca/eic/site/ic1.nsf/vwapj/SandTstrategy.pdf/$file/SandTstrategy.pdf.

Pierre Bourdieu, J. D. Loïc Wacquant. (1992). *An Invitation to Reflexive Sociology*. Chicago and London: University of Chicago Press.

Portes, Alejandro (Ed.). (1995). *Economic Sociology and the Sociology of Immigration: A Conceptual Overview*. New York: Russell Sage Foundation.

Portes Alejandro, Sensenbrenner Julia. (May 1993). Embeddedness and Immigration: Notes on the Social Determinants of Economic Action. *The American Journal of Sociology, 98(6)*, 1320-1350.

Putnam, R. D. (January, 1995). Bowling alone: America's declining social capital *Journal of Democracy, 6(1)*, 65-78.

Putnam, R.D. (2000). *Bowling Alone: The Collapse and Revival of American Communities*. New York: Simon &Schuster.

Ryan, Camille D. (2008) Evaluating Performance of Research Networks: a socioeconomic framework for assessing funded research projects. VDM Verlag: Germany.

Schiff, Maurice. (April 1992). Social capital, labor mobility, and welfare: The impact of uniting states. *Rationality and Society, 4*, 157-175. doi: 10.1177/1043463192004002003

Snijders Tom A.B., Borgatti Stephen P. (1999). Non-Parametric Standard Errors and Tests for Network Statistics. [Journal Article]. *Connections*, *22*(2), 61-70.

Sparrowe R. T., Liden R. C., Wayne S. J., Kraimer M.L. (April 2001). Social Networks and the Performance of Individuals and Groups. *The Academy of Management Journal*, *44*(2), 316-325.

Sweden-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles:Sweden (Country notes-Report). Retrieved 7 February 2011 http://www.oecd.org/dataoecd/41/6/46665928.pdf

UK-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles:United Kingdom (OECD Country notes-Report). Retrieved 7 February 2011 http://www.oecd.org/dataoecd/40/28/46666019.pdf

USA-OECD. (2010). OECD Science, Technology and Industry Outlook: Country Profiles: United States (Country notes-Report). Retrieved 8 February 2011 http://www.oecd.org/dataoecd/40/27/46666029.pdf

Wikipiedia. (May 2011). Bootstrapping (statistics) Retrieved 6 May, 2011, from http://en.wikipedia.org/wiki/Bootstrapping_(statistics)