Public-Private Partnerships and Public Policy: A Comparative Social Network and Public Policy Analysis on Competing National Systems of Innovation

Camille D. Ryan*, Peter W.B. Phillips and William P. Boland
University of Saskatchewan

*Corresponding (and presenting) Author

Abstract: Innovation is increasingly viewed as a key determinant of economic growth. There are a number of competing theories on innovation. Recent literature indicates innovation occurs at the global level. One such perspective suggests the key to economic growth is dependent on developing an institutional framework that links local non-codified knowledge with global flows of codified knowledge such as intellectual property rights and proprietary technologies. This article builds upon previous research and uses social network analysis, case study and vulnerability analysis to examine pulse crop R&D networks, in particular those in Canada and Australia. This article demonstrates that the public-private partnership is the institutional framework and organizational structure that links local assets to global knowledge flows.

Key Words: public private partnerships; global innovation systems; institutions; networks; social network analysis

1. Introduction

Innovation is increasingly viewed as a key determinant of economic growth. There are a number of divergent perspectives on innovation. One posits that the private sector, at the firm level, is the primary source of innovation (Solow, 1956 and Arrow, 1962). Another firm-centric view suggests innovation is the result of endogenously developed knowledge occurring at the firm level but impacting at the macroeconomic level (Krugman, 1998 and Romer, 1990). The institutional approach examines the effect of economies of scale and scope on developing systems of innovation at the local, regional or national levels (Porter, 1990, Lundvall, 1992 and Nelson, 1988). A more recent institutional perspective suggests that innovation is the result of interactions between university, industry and government actors or organizations at either the micro or macro level. This view asserts that universities are at the centre of knowledge generation and diffusion networks and that they develop collaborative links between the three sectors and with the market (Etzkowitz and Ranga, 2010). A universal perspective suggests that innovation occurs at the global level and the key to economic growth is developing an institutional framework that connects local capabilities to global knowledge flows, such as patents and intellectual property rights (IPRs), to create a value-added process (Bathelt, 2004, Phillips, 2002). One common theme that underscores the recent collaborative-oriented institutional and global perspectives is the need for the utilization of public-private partnership[1] (P3) organizations to forge the links, either globally or institutionally, between various organizations and networks to facilitate the knowledge generation and diffusion process (Bathelt, 2004; Etzkowitz and Ranga, 2010).

This empirical study expands upon previous research (Boland et al 2010) and further explores the theory, analysis and policy review of the P3 as an institution to manage collaborative research and development (R&D) networks and innovation systems in a globalized environment. In particular, this study looks at pulse crop R&D networks in Australia and Canada. Section two contextualizes the origins and theory of the P3 organizational format and its applicability to R&D network management. Section three examines the science and technology (S&T) and R&D dependent pulse breeding sector. Section four contains the theory of knowledge and the methodology used in this paper. Section five reviews the findings of this analysis, including qualitative observations from in-depth interviews with individuals affiliated with key organizations/firms in Australia. Section six provides a summary of P3s within the context of this study and the concluding section, section seven, discusses the strategic implications of this work.

2. State of the Art

2.1 P3s defined and contextualized

From a definitional approach, a P3 refers to any collaborative engagement between public, private, and/or voluntary actors or organizations. No one standard model exists for P3s; rather, they should be viewed as a process that allocates risk and reward on an equitable basis among key stakeholders. A true public-private partnership (P3) must involve the sharing of authority, risk, responsibility, accountability and benefit. P3s are not a contracting out of government services, nor are they a privatization of government services as the public sector retains an active role in the management of P3s. There are few true legal joint-liability partnerships as this contradicts the requirement for government accountability regarding the use of public funds (Allan, 2000). Therefore, the majority of P3s involve some form of collaboration between the public and/or private and/or voluntary sectors with varying levels of the sharing of risks and benefits.

There are a number of factors influencing the advent of P3. From an ideological perspective, for the proponents of New Public Management (NPM) the P3 represents both a policy option and an organizational structure to reduce the size and scope of government by transferring delivery of a good or service to the most efficient sector. In this viewpoint the state becomes a network manager and procurer of goods and services at the expense of being a supplier of goods and services. In place of a direct relationship with the citizen, government uses financial incentives and collaboration with the private and voluntary sectors to provide goods and services to consumers (Milward and Provan, 2000). From a fiscal perspective, the development of government austerity programs beginning in 1979 in Great Britain with the election of Margaret Thatcher, in 1981 in the US with the election of Ronald Reagan, and with the subsequent elections of the Mulroney and Howard governments in Canada and Australia, all signalled the end of an era of direct government intervention in the economy. And, from a social-economic perspective, the combined effects of globalization and technological development, especially in telecommunications and computers, have facilitated a "compression of time and

[1] These partnerships may also be referred to as hybrid organizations.

space”, which has rendered the bureaucratic and hierarchical-structured state as an ineffective and inefficient method of program management and service delivery (Gilpin, 2001).

2.2 The network society and the challenge of governance

We are in an era characterized by a transformation away from government, a hierarchal structured bureaucracy with a centralized decision making process, to governance, a distributed decision making process that operates in a network environment defined by collaboration and is horizontally configured (Rhodes, 1995). Governance can be framed by the theory of “fiscal equivalence” (Olson, 1969), where the fiscal boundaries of the funder of a public good should correspond to the physical boundaries of the consumer of a public good. Governance can be further framed by the “principle of subsidiarity”, where the lowest level of government in contact with a particular public process should be the level of government that governs that process (Rhodes, 1995 and OECD, 2000).

The new governance paradigm is challenging the structure and process of government in four ways. First, individually, new actors, and collectively, new interest groups are demanding to be a part of the governing process. This desire for participation is most evident in the area of science and technology, particularly in genetically engineered food products. The desire by citizens to be a part of the decision-making process accelerates the transfer of regulatory power away from government and to the voluntary/civil sector and the citizen (Pal and Maxwell, 2003). Second, the policy issues generated by science and technology exceed the technical capability of government to manage, giving rise to the need to procure expertise from non-governmental organizations (NGOs). Third, the rise of independent research organizations, foundations and think tanks, further the transfer of regulatory governance to the civil sector while simultaneously providing the knowledge to both government and citizen alike required by the advent of the governance paradigm (Lindquist, 2006 and Hird, 2005). Fourth, the diminution of government has led to the development of spatial oriented policy making conducted through shareholder networks (Hajer, 2003).

The state is being transformed into a developer of human capital and social capital, with an emphasis of using this capital to develop links between individuals and organizations to facilitate the formation of networks. The objective of governments in this environment is the transfer of state responsibilities to individuals and NGOS through the innovative use of P3s as learning organizations (OECD, 2000). Governance in the new institutional environment is focused on problem solving through the exchange of knowledge and resources between the public, private and volunteer sectors (Ibid).

2.3 Collaboration, the new production of knowledge and the P3

P3s merge the expertise of the public, private and voluntary sectors to help solve intractable social or economic problems. In doing so, collaboration between the divergent sectors facilitates innovative and synergistic responses to policy problems that would not otherwise occur. Collaboration through P3s empowers actors who lack an institutional or political voice, enabling the marginalized to deal with pressing policy problems. Cooperation creates interdependencies between actors and organizations laying the foundation for collaborative governance (Salamon, 2002).

One area in which the advent of collaborative governance is evident is in the production of knowledge. Innovation is dependent on turning the recombining of different types of knowledge into new ideas, markets, products or services that meet with market or societal acceptance. The theory and typology of knowledge is expanded in section 4.1. Two unique and separate processes of knowledge production have been identified (Gibbons, et al, 1994). Mode I knowledge production is described as a linear and institutional process that is dependent on the individual scientist for impetus in a discipline specific environment. Mode I production is characterized by the autonomy of the both research institution and the researcher and by the experimental and theoretical purpose of the intellectual endeavour. Mode II knowledge production occurs within "heterogeneously organized" networks that are problem and solution organized—transient in nature and horizontal in configuration. Mode II can be characterized by the reflexive nature of the investigation; knowledge production is a dialogic process based upon a high level of interaction between researcher and the research topic. The feedback loops generated by the reflexive process lead to the self-governing nature of Mode II knowledge production (Nowotny, et al, 2003).

One method for managing collaborative research is the use of the research and development partnership (R&D P3). There is a large body of empirical research on R&D partnerships, for example, pertaining to this research: in agricultural economics and agricultural innovation systems (Hall, 2006; Hartwich, et al, 2007 and Binenbaum et al, 2001). Despite this body of work, the theory of the R&D P3 remains underdeveloped. Hagedoorn, et al, in 2000, suggest that, at the minimum, three complimentary but unique theories are needed to explain why public and private actors and institutions collaborate on R&D. The first, transaction cost economics postulates, that over time, firms seek the lowest cost of contract enforcement. In an environment defined by uncertainty over intangible assets such as knowledge and by uncertainty over cost of monitoring the performance of the partners, R&D partnerships are defined as a "hybrid form of organization between the market and the hierarchy to facilitate carrying out an activity specifically related to the production and dissemination of technical knowledge" (Ibid, 571). The second, strategic management suggests that firms use partnerships and networks as a means of achieving economies of scale and scope, which are unobtainable in the absence of collaboration. Third, industrial organization theory posits that knowledge development is a public good, as the returns on investment are insufficient to warrant basic research and development. However, for cost sharing and commercialization reasons public and private collaboration is required for the development of basic knowledge.

3.0 Research Focus: Global Pulse Breeding System

3.1 What are pulses?

Pulses are the edible seeds of legumes. Pulse crops include field pea, dry bean, lentil, chickpea and faba bean. They comprise a small but very important part of the 1800 species in the legume family. The use of pulses dates back more than 20,000 years and now spans the globe. Lentils originated from the wild lentils that still grow in Turkey and other Middle Eastern countries while field pea, faba bean and chickpea originated in western Asia. Dry beans originated in South and Central America. Pulses are now grown on all continents of the world and are an important source of protein, providing about 10% of the total dietary protein in the world (Sask. Pulse Growers' Website). Pulses have twice the protein content of most cereal grains. Bean, field pea and chickpea are the three most important pulse crops in terms area and production. Pea is produced mainly in developed countries such as France, Canada and Australia, and chickpea is produced and consumed mainly in India. Lentil is produced mainly in India, Turkey and Canada. Beans of various types are produced in many countries around the world. In

2002-6, Australia, Canada and the US accounted for 12% global pulse production and 41% of global exports (Boland, Phillips and Ryan 2010). Pulse production has risen significantly in the above three countries in recent years but India is generally the largest producer of pulses in the world, producing 14 million tonnes a year (Grain Nutrition 2011). However, production in India has stagnated in recent years. Thus, India has developed into a major market for Australian pulses (AgriCommodity 2010).

3.2 Pulse breeding R&D

Plant breeding is, essentially, the art and science of adjusting plant genetics to develop desirable characteristics. Practiced for hundreds of years, plant breeding has an interesting and extensive history and successful practice can involve various techniques ranging from simply selecting plants with desirable characteristics for propagation to the use of more modern and complex molecular techniques.

The process of plant breeding in general, and pulse breeding in particular, has been permanently altered by three ongoing and interrelated revolutions. First, plant breeding has evolved from a hands–on and observational supply push process, generally conducted by public agencies, to a globalized and technologically driven demand pull and scientific process taking place in local, national and regional networks. This process is similar to the contrasts between Mode I and Mode II knowledge production. Second, the introduction of national and international IPR regimes governing plant breeding has privatized of most aspects related to plant breeding in the developed world and has facilitated access and benefit conflicts regarding the acquisition and use of technology in the developing world where IPRs are not in use. Third, due to fiscal concerns, the funding of plant breeding has also been privatized, forcing research centres, industry groups and producer organizations into new funding and R&D relationships (Brennan and Mullen, 2002; Huffman and Just, 1998; Alston and Pardey, 1998). The ongoing series of revolutions within plant breeding has created the “orphan” crop--neglected by both public and private sectors due to acreage or profitability issues. Orphan crops exist in an institutional vacuum, where neither the public nor private sectors are capable of supplying goods. Despite this, pulse crops are a vibrant and expanding export industry for Canada, the US and Australia, representing a highly competitive multi-billion dollar global sector. The global pulse breeding R&D system provides the scientific foundation for a US$200 billion commodity production system.

3.3 Composition of the global pulse R&D system

The global pulse breeding system of 247 actors, explored and evaluated by Boland (2010), is comprised of 45 P3s, 106 government research centers, 83 universities and 13 private sector actors. The global system is constructed on three autonomous regional systems (ibid). The European Union (EU) System has 27 P3s, 40 government agencies, 55 universities and 12 private firms involved in pulse breeding R&D. The EU System is a producer, consumer and minor exporter of pulses. The Developing World System is constructed of 10 P3s, 41 government research centers, 17 universities and one private firm. The Developing World System is a producer, primary global consumer and an importer/exporter of pulse crops. The Export System, which consists of Canada, the US and Australia, consists of 17 P3s, 26 government agencies and 22 universities for a total of 65 actors. The Export System is devoted to the production of exportable pulse crops with little internal consumption of pulse crops. Table 1, below, provides an overview of the three systems.

Table 1: Production and exports of pulses, 2003-07, million tonnes				
	Production		**Exports**	
	Volume	**% total**	**Volume**	**% total**
Export System	***7,604***	***12%***	***4,292***	***45%***
EU System	7,241	12%	1,640	17%
Developing World System	45,046	76%	3,570	38%
World Total	59,892	100%	9,503	100%

Source: FAOStat.org and Authors' Calculations

Australia, Canada and the US, identified as the export system, accounts for the highest volume of exports in pulses (45%). Given its distinguishable performance relative to other systems, the Export system is of key interest in this study.

4.0 Theory and Methodology

4.1 Theory

Innovation is defined not only through mere 'invention' but, rather, through a broader, more significant process of turning new information into knowledge that can produce new goods, services or organizations that posses long-term staying power within society or the economy (Phillips, 2007). The process of innovation begins when new information is transformed into one of six types of knowledge. There are two types of codified knowledge, know-why and know-what, two types of non-codified knowledge, know-how and know-who and two types of relational-spatial knowledge, know-where and know-when.

4.1.1 Codified knowledge: Each type of knowledge can be further delineated by their unique characteristics. Know-why knowledge is the product of a formal and collective process which is primarily concerned with articulating the scientific laws of nature. Much of this work takes place in universities and other publicly funded research institutions. From a plant genetic resource (PGR) perspective, each type of knowledge also possesses specific features (Phillips 2001, 2002). The disciplines of applied and theoretical genetics, molecular biology, biochemistry, plant physiology and genomics are in the domain of know-why knowledge. Know-what knowledge concerns facts and systematic details and procedures of both genetic crossing and the selection of desirable plant traits during the breeding process. Know-what knowledge is created in both public and private institutions and with the advent of PBRs and IPRs has become commoditized and integrated into increasingly sophisticated technology transfer processes.

*4.1.2 Non-codified knowledge: K*now-who knowledge refers to the ability to identify and locate key knowledge practitioners who posses information critical to a given transformation process. This type of knowledge is not codified and is embedded in individuals, institutions, and in networks or clusters engaged in similar research objectives. Due to the development of information and communications technology, knowledge development is no longer confined to institutions but occurs in widely dispersed networks characterized by multiple sites of knowledge development. In this environment know-who knowledge becomes an important component of the plant breeding process. These particular characteristics of knowledge development and management tend to concentrate innovative activity within local, regional, national, economic and functional clusters that facilitate that transfer of information, knowledge and people between communities and organizations of various institutional configurations (Phillips, Boland and Ryan 2009). These characteristics are evident in research and development clusters such as Silicon Valley, the Boston Route 128 Corridor, North Carolina's Research Triangle, Western Europe's BioValley and Saskatoon's biotechnology community. Know-how knowledge integrates the properties of know-what and know-why domains in plant breeding to produce new market ready varieties. This process combines the knowledge developed at universities and technical schools and incorporates it with the skills derived from "learning by doing". This unique combination of skill and knowledge is contained within private or public institutions, is difficult to codify or transfer to other organizations and may be encompassed in closed community or proprietary processes.

4.1.3 Relational-spatial knowledge: Know-where knowledge and know-when knowledge are becoming increasingly important in a time of globalization. Both terms originate in the analysis of traditional knowledge (Crookshanks and Phillips, 2010). Know-where and know-when traditional knowledge pertains to understanding where and when specific naturally occurring plants and animals would bloom or congregate to provide a harvest of food and sustenance related items to tribal cultures. Taken in a modern, globalized context, know-where and know-when refer to an intimate understanding the location and timing of governance related events that are critical to any R&D process. Know-where knowledge posits that innovation and change often are the result of entrepreneurs who are located at the intersections and borders of dissimilar social networks, differentiated institutional structures and independent research disciplines, acting as a conduit for change by facilitating the transfer of ideas between these separate arenas (Campbell, 2004). Know-when knowledge suggests innovation is dependent upon knowing when windows of opportunity for change open simultaneously in multiple arenas (state, market and volunteer sectors) presenting the prospect for change (Teisman, 2000).

4.2 Methodology

Social network analysis (SNA) is a research tool that illuminates previously invisible relations between actors and institutions in a networked and centerless environment (Mead, 2001). SNA enables a researcher to identify the relative position, function and power ranking of the individual actors, nodes and sub-networks in a quantifiable and graphical manner. SNA makes it possible to identify knowledge flows and stocks "as well as under- and over-utilized individuals and organizations within a given network" (Phillips, Boland and Ryan, 2009). As economic growth is highly dependent on linking into and manipulating the global flows of knowledge, SNA can identify the spatial coordinates of the institutions that posses the knowledge stocks and determine the direction of the flows of knowledge. Ryan (2008) suggests SNA can be utilized to deconstruct the institutional activities that are responsible for knowledge development. There are four measures of analysis that are used in this study. One is related to network density; the other three are measures of centrality applied to individual actors.

Density measures the proportion of bilateral ties between actors against the maximum amount of ties possible. The objective is to identify and measure the ratio of interconnections within a given network. Density—which ranges from zero to one—is determined by dividing the number of actual bilateral connections into the maximum number of bilateral connections possible (Knoke and Kuklinski 1982). Equation one contains the density formula.

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

Centrality measures the relative importance of an individual actor based upon their location within a social network. Total degree centrality is a ratio of the amount of actual ties divided by the maximum amount of ties, or as Ryan (2008) suggests "the degree to which one actor is connected to other network actors", as it determines the level of intra-network connectedness. An actor with a measure of zero is not connected within a network, whereas an actor with a measure of one indicates an actor is connected to every possible actor in the network (Phillips, Boland and Ryan, 2009). A higher total degree centrality implies a higher level of network activity (Mote, 2005). Equation two contains the total degree centrality formula.

$$TotalDegreeCentrality = \frac{\mathrm{td}(\mathrm{x_i})}{2 * (\mathrm{N} - 1)} \qquad \text{Equation 2}$$

Betweenness centrality measures the level of connectedness to actors that are not well connected in a network. Betweenness implies a role as a "gatekeeper" and "intermediary" within a social network conferring a level of independence unavailable to other actors (ibid). Valentine (1995) posits that betweenness centrality measures how often an individual actor is located on the shortest path between other actors and sub-networks. In other words, actors with a high degree of betweenness exhibit a level of independence as they experience higher flows of information and may also receive new information sooner than other actors. A higher betweenness centrality measure implies a greater level of control over information (ibid). Equation three contains the betweeness equation, where g_{ij} represents the number of ties linking i and j and $g_{ij}(p_k)$ is the number of these ties that contain individual k.

$$Betweennes\,sCentrality = 2\sum_i \sum_j \frac{\dfrac{g_{ij}(p_k)}{g_{ij}}}{n2 - 3n + 2} \qquad \text{Equation 3}$$

The eigenvector measure is an indicator of power within a social network. Eigenvector measures the centrality of the individual actor along with the centrality of that particular actor's connections (Bonacich, 1972). A high eigenvector rating implies relative power in a network is derived from the relative importance of an actor's connections, not the quantity of connections. Actors with a high eigenvector measure are regarded as powerful and influential actors within a social network (Ryan, 2008). An actor with a higher eigenvector ranking suggests greater diversity in sources of information (ibid).

Table 2: Typology of Centrality Measures		
Measure	**Descriptor**	**Meaning**
Total degree centrality (TDC)	intra-network connectivity	An actor or principal with higher TDC is identified as a "hub" or "connector" within the network
Betweenness-centrality (BC)	Influence	An actor or principal with high BC is identified as a "broker" or "bridge" and can connect or disconnect groups within the network
Centrality Eigenvector (CE)	Power	An actor or principal with higher CE has multiple connections with others with multiple connections

Adapted from Ryan (2008)

4.3 Data and analysis

The objective of this study is to identify, locate and categorize all P3s related to pulse breeding R&D and assess how they interact in the Export System. Two methods were employed in this search. First, an internet search was conducted starting with known public pulse breeding institutions to search for pulse R&D P3s. This was augmented with emails, phone calls and in-depth interviews. The relationships identified between actors and institutions are formal, contractual, research and/or financially based. The second method was a key word search through the ISI Web of Knowledge database to identify research and financial relationships between pulse breeders, funding agencies and R&D P3s. The search was conducted using the following keywords: "pulse crops", "legumes", "dry peas", "chickpeas", "lentils", "faba beans", "dry beans" and "lupins". In ambiguous circumstances where it was not possible to determine if the R&D activities were pulse-related or not, the actor or relationship in question was not included in this study. Therefore, some relationships, primarily financial, may have been excluded from the data.

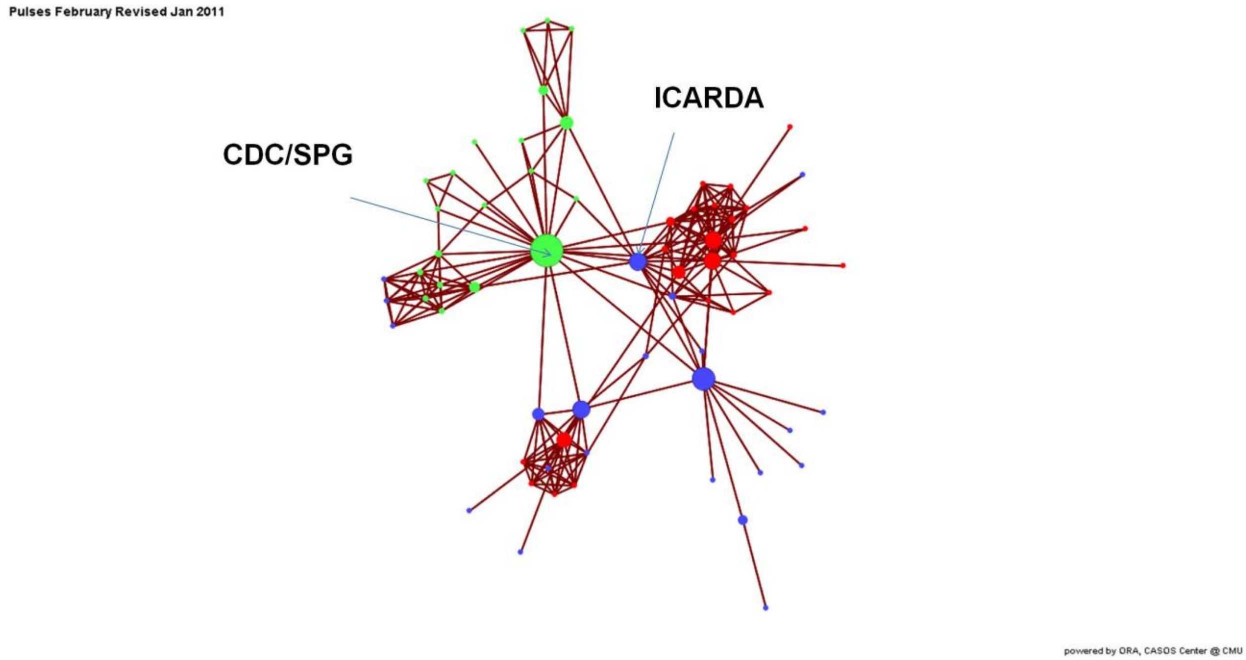
Individual actors are mapped and ranked in the analysis according to how many standard deviations their centrality measures are above the overall population mean in each of the sub-systems and the global network. Therefore, only institutions with a centrality measure of one standard deviation or more above mean are considered central actors. These actors are ranked by the number of stars in the context column, with each one representing one standard deviation.

5. Findings and interpretation

5.1 System structure and the critical role of the P3

As previously outlined, the Export System consists of the major export countries of Canada, the USA and Australia along with key globally based organizations included the International Center for Agriculture Research in the Dry Areas (ICARDA) and some individual research centers in France, India and South Africa. The following analysis offers insights into the network composition and institutional configuration of the interconnected but unique operational R&D network(s) affiliated with the System. It is distinguished by the prevalence of producer funded and governed P3s that anchor the national systems of Canada and Australia and link these systems together to create a regional innovation system (see Figure 1).

Figure 1 The Export System



In figure 1, the nodes are sized according to the betweenness measure and the two critical P3s highlighted. The Canadian System is in green, the Australian red and the balance blue.

Comprised of a total of 65 actors, the Export System has a calculated network density calculated of .108[2]. Eight of these actors have been identified as 'hubs' or 'connectors' (high Total Degree Centrality measures); 6 are identified as 'brokers' or 'bridges' within the System (characterized by high Betweeness Centralization measures) and; 5 are identified as 'power' actors (with high Eigenvector Centrality measures).

Institutionally speaking, the Export System is composed of 17 identifiable P3s (26%), 22 universities (33%) and 26 government research centers (41%). There is a discernable absence of private firms. As indicated in Table 3, the primary actors – according to the calculations – are the Crop Development Center/Saskatchewan Pulse Growers (CDC/SPG) partnership, the GRDC-Grains Research and Development Center, the Center for Legumes in a Mediterranean Area (CLIMA) and ICARDA. All four are P3s.

P3s play a key role in the Export System. Of the 19 centrally ranked actors in this network, 13 are P3s. The CDC/SPG, however, is a unique case. It is the top ranked actor according to the total degree and betweenness centrality rankings, suggesting this particular P3 is a highly connected gatekeeper controlling the flow of new information into the network and between sub-networks and isolates. Both measures suggest the CDC/SPG P3 possesses a unique status with regards to independence and influence from and over the entire network. See table 3 below for the three centrality rankings. The GRDC and CLIMA have noteworthy total degree centrality measures indicating a higher than average level of intra-network activity. Five of the six top ranked eigenvector actors are Australian, implying the Australian pulse R&D network is uniquely positioned as a power broker within the Export System.

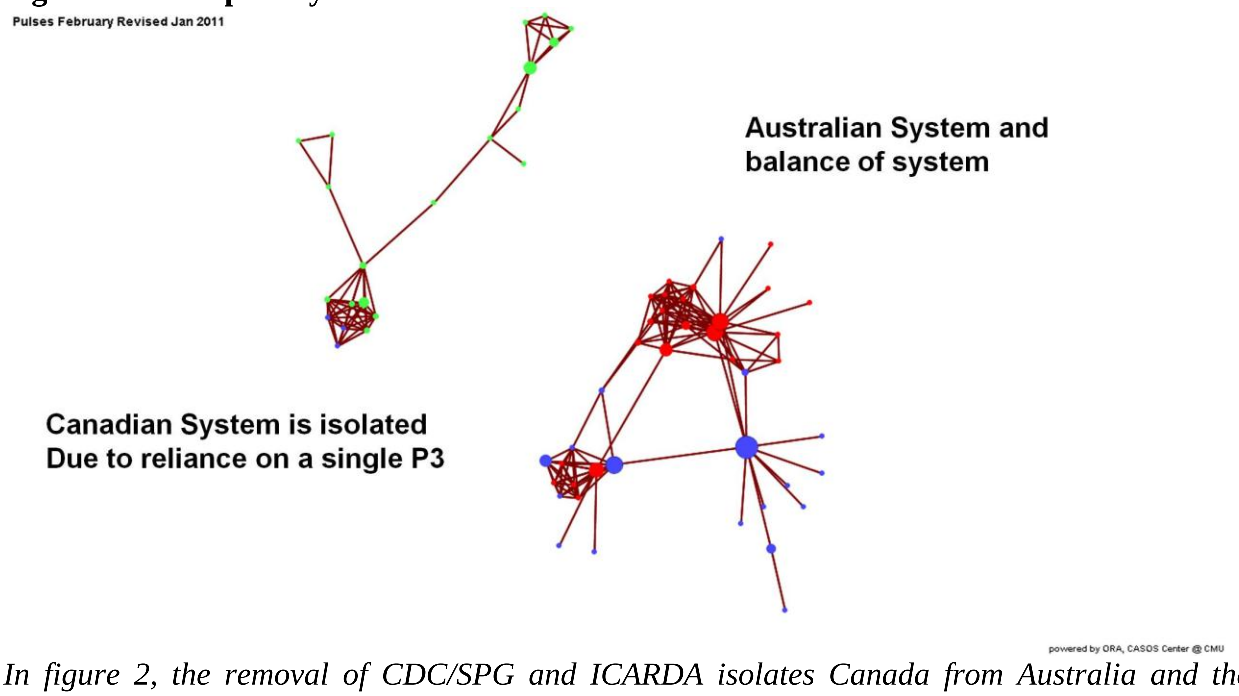
[2] The density, in this case, is the highest relative to the calculated values of other systems within the global network (EU and Developing) (Boland et al 2010).

Table 3: Export System Actors & Centrality Measures			
	Intra-Network Connectivity (TDC)	**Power (EC)**	**Influence (BC)**
CDC/SPG (P3)	0.3692***	-	0.4754***
GRDC (P3)	0.3231**	1.000**	0.1353*
CLIMA (P3)	0.2923**	0.9049**	0.1305*
ICARDA (P3)	0.2462*	0.7317*	0.1171*
Pullman-ARS	0.2000*	-	0.2265**
PBA (P3)	0.1846*	0.7482*	-
DAFWA	0.1846*	0.7428*	-
CSIRO	0.1846*	-	-
MSU	-	-	0.1245*
* number of standard deviations greater than the mean Source: Authors' calculations			

5.2 Sensitivity analysis

Sensitivity analysis demonstrates the impact of removal of key actors to the overall structure of a given network. In the case of the Export System, two key P3s are removed (CDC/SPG and ICARDA) from the 65 actor system and it fragments into an isolated Canadian network of 21 actors, an isolated and disconnected US system and a much reduced Export System centered on Australia (see Figure 2 below).

Figure 2 The Export System minus CDC/SPG and ICARDA



In figure 2, the removal of CDC/SPG and ICARDA isolates Canada from Australia and the balance of the system.

The results of sensitivity analysis, illustrated in Figure 2, demonstrate how dependent the Export System is on a small group of actors. The removal of two key actors fragments this regional network into two national systems, one each in Canada and Australia, and a number of isolates. The two critical actors are the CDC/SPG and ICARDA, both P3s. Their removal has an injurious effect on the composition of the network as highlighted in table 6. Despite CDC/SPG and ICARDA representing less than 5% of the individual actors in this network, their deletion causes a reduction in the physical structure of the network ranging from 16% to 97% depending on the function. As discussed earlier, innovation, the driver of economic growth, is derived from linking into the global pipelines and flows of knowledge. If this is the case, then the disintegration of the Export System into two national systems and a number of isolates would inhibit knowledge production.

Table 4: An estimate of the vulnerability of the Export System

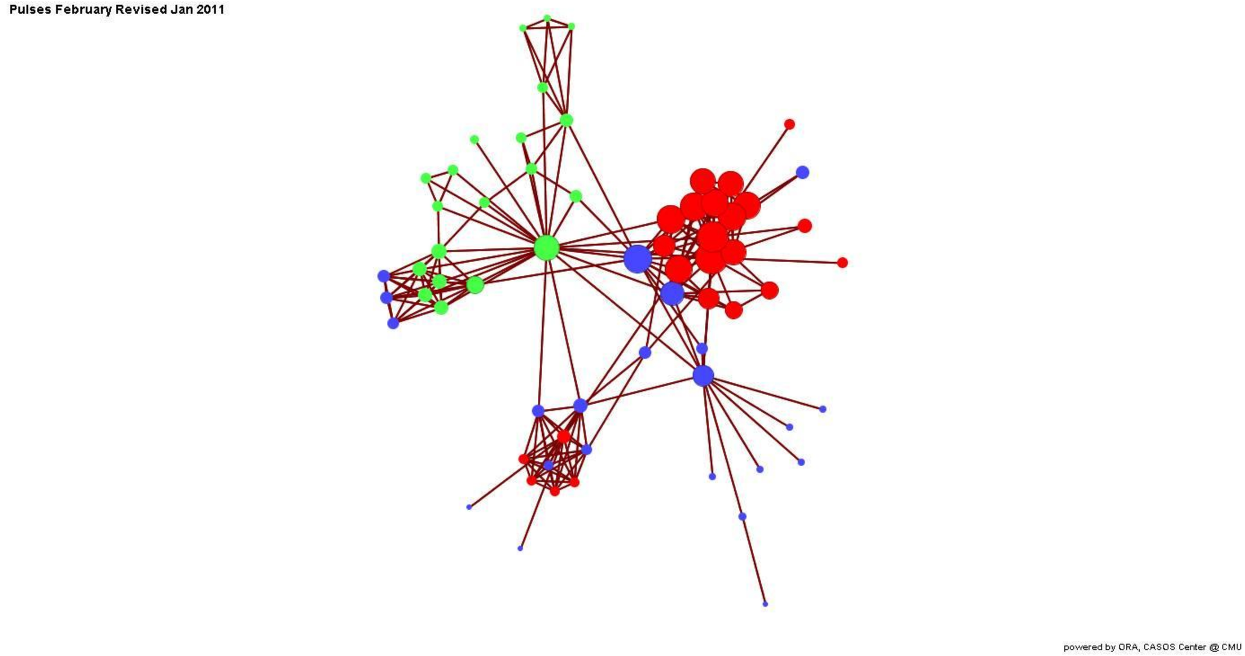
	With CDC/SPG and ICARDA	**Without CDC/SPG and ICARDA**	**% effect of loss of 2 central actors**
# nodes	65	63	-.3.0%
# links	448	370	-17.4%
Density	0.108	0.090	-16.6%
Network centralization	0. 276	0. 202	-26.8%
Betweenness centralization	0. 460	0. 164	-64.4%
Closeness centralization	0. 439	0. 015	-96.5%
Fragmentation (#components)	1	2	+100.0%
Characteristic path length	2.6712	2.6252	-1.72%

Authors' calculations

5.3 The Unique Status of Australia in the Export System

The sensitivity analysis confirms the results of the social network analysis regarding the key role of the CDC/SPG P3 and of the central role of the Australian R&D network. Canada's pulse breeding network becomes isolated from the Export System with the removal of the CDC/SPG P3, while the remainder of the Export System remains centered on the Australian system. The resiliency of the Australian system is noteworthy. As Figure 3, below, demonstrates, when viewed with the nodes sized based upon the eigenvector measure, the Australian system appears to be so deeply embedded into the Export System that all centrally ranked Australian actors are connected to all the powerful actors in the system. In theory, this confers first mover and first adopter status, or the right of first refusal to do so, to the entire Australian system over ideas and technologies emanating from within or outside of the system. As noted the three top eigenvector actors in this regional system are the three Australian P3s, GRDC, CLIMA and Pulse Breeders Australia (PBA).

Figure 3 The Export System Revisited



In figure 3, the nodes are sized according to the eigenvector measure, visually demonstrating the embedded nature of the Australian system (in red) within the Export System.

5.4 P3s in the Export System

In this section, we summarize the role of P3s in the Export System. In particular, we provide commentary and information on key P3s collected through in-depth interviews and augment this information with qualitative quotes from informants (see Appendix B for a list of interviewees)[3].

With the exception of ICARDA, all centrally ranked P3s in the Export System are producer-formed and governed P3s. ICARDA, from a structural perspective, is critical to the integrity of the Export System. ICARDA is primarily a supplier of raw, undeveloped technology, in the form of germplasm[4]. All of the centrally ranked actors in the Export System have germplasm uptake relations with ICARDA, and are also suppliers of advanced breeding technologies and finished varieties to ICARDA, often incorporating the genetic material from ICARDA into the finished technologies.

In Australia, P3s form both the structural foundation for three independent and interconnected pulse R&D systems and link these three systems into a national pulse innovation system. The first national system is formed around the GRDC and PBA, the second is formed around CLIMA and the third around the Center for Innovative Legume Research (CILR), an international R&D consortium headquartered and managed in Australia. Collectively, the result of the innovative use of P3s is a global R&D cluster formed around the Australian national system.

The GRDC is a partnership between the Government of Australia and the 45,000 producers of Australia represented through the Grains Council of Australia (GCA).

[3] To date, interviews have only been conducted with informants representing Canada and Australia.
[4] Germplasm is the living tissue of a plant that contains the plant's genetic information.

> *"…[The GRDC] will invest in Blue Sky R&D [research and development]. We have a balanced portfolio. It's about managing risk and not being so risk averse…but we do it with an aim that it's going to deliver…[W]e must have a pathway to market technologies…[W]e're not investing if there's not a market…"*

The CGA is responsible for about 50% of GRDC's funding through a national levy program. The rationale for the creation of the GRDC came from the international arena. The development of large multinational corporations (MNCs) with their proprietary plant breeding technologies (including enabling and vector technologies) inhibited the ability of Australian plant breeders to compete with international competitors (Lindner, 2004). Australian producers and regulators viewed the monopoly power of international life sciences competitors as a threat to the viability of the Australian grains industry. PBA was formed by the GRDC to perform two specific functions for the Australian pulse sector. First, to prevent intellectual property rights (IPRs) from impeding national technological development and second, to prevent the duplication of R&D efforts related to pulse breeding.

A late 1980s report noted that R&D spending in Australia, as a percentage of GDP, had been falling, while rising in the rest of OECD countries (Buller & Taylor, 1999). The report indicated that R&D spending was 50% higher in other OECD countries as compared to Australia. As a result of this report, the government of Australia created the Cooperative Research Centres (CRC) program for the purpose of increasing collaborative research between the public and private sectors in Australia. CLIMA was originally established as a pulse breeding CRC in 1992 and has expanded into a producer managed national pulse breeding center. The Council of Grain Growing Organizations (COGGO) represents producers. CLIMA is an integrated multi-disciplinary research facility built upon four - once separate - small breeding programs.

The CILR was created by and is partially funded by the Australian Research Council and consists of CILR, a P3, and seven other partners.[5] The objective is to create cutting edge pre-competitive breeding technology using legumes as a base species for research.[6] Although centered on Australia, CILR is a global R&D enterprise consisting of pulse research centers on four continents, permitting the Australian system to access to global stocks and flows of pulse related technologies.

The origins of the Canadian-based CDC/SPG P3 come from the opening of the Crop Development Centre in the early 1970s to develop a new crop for Saskatchewan producers who were suffering from low prices on wheat and barley. The Saskatchewan Pulse Growers was created in the late 1970s, and in 1983 became permanently involved in the direct financing of R&D with the implementation of legislation and a positive producer vote supporting a non-refundable production levy. Pulse production has increased by 36 fold since 1985 and has made Saskatchewan and Canada the dominant global exporter of pulse crops (SPG and FAO, 2011). Spending reductions by government led to the partnership being formalized in the early 1990s through a number of exclusive R&D agreements. As a part of the R&D agreement, the SPG is the exclusive and royalty free distributor of CDC pulse varieties, providing the SPG with a price and technology advantage (SPG, 2011). The SPG R&D portfolio is approximately $CDN 25 million, with around 80% focused on genetic improvements. The CDC/SPG P3 uses R&D to link

[5] The seven partners of CILR are: The John Innes Center, KDNARI in Japan, North Carolina State and four Australian universities.
[6] Pulse crops are a part of the legume species.

producer funded and managed research with consumer focused market outcomes in a globalized economy, as over 90% of Canadian pulse production is exported. The CDC/SPG P3 consists of approximately 18,000 producers.

As mentioned previously, nearly all centrally ranked P3s in the Export System are producer-formed and governed P3s. Unlike canola and wheat, pulse breeding and research is set up and handled by public enterprise such as universities and government departments. Pulse breeding on an endpoint royalty basis, in the case of Australia, cannot be justified, according to the Managing Director of the GRDC. The pulse industry in Australia is small – and returns are lower – and private investment by multinationals or other private entities is not anticipated for the near future. As one interviewee states: *"It would be a very, very tall order to actually get a significant level of traditional private investment in a [pulse breeding] company… so ['public-private'], in this case, has to operate under a different model than has been used in canola or wheat that both employ a proprietary limited company with shareholders…"* And: *"…[P]ulse breeding is pretty young... it's not like wheat where we have 100 years of research and development…"*[7]

There is a minimum cost to run a breeding program, as there are costs associated with breeding that are similar regardless of the species or area grown. This creates a dilemma for break crops where an annual investment of $1 million can be difficult to justify and is certainly not met by income generated from end point or seed royalties (MacLean 2010). In addition to the pulse sector's relatively small size, an interviewee pointed to 'the dilution factor' that also characterizes the pulse industry: *"…[T]here are so many of them [pulse types]… they all have their little niches and they are all adapting in a slightly different place."*

It appears that P3s dominate the Export System in pulse R&D. It is apparent that some form of a public-private partnership model *can* work well, particularly in jurisdictions such as Australia and Canada. However, according to the information gathered through the interview process, informants stated this is not the case of a 'one size fits all'. Models must be differentiated according to context. Additionally, objectives and mandates must be clearly stated and there must be firm commitments on the part of all vested parties (public and private). *"There have been cases of partnerships [P3s] where they have been fraught with difficulty… because, often, the objectives were not clearly articulated..."*

Public-private partnership models [P3s] need to be flexible in order to accommodate different types of people, coming from different institutional backgrounds, that have different skills sets and in contexts that involve different crop types. Significant cultural differences exist between the public and private sectors in terms of working environments, output measures and reporting expectations. In the case of Australia, in particular, the 'corporate structure' (or some form of it) – appears to provide key incentives for pushing productivity[8].

6. Conclusions

As demonstrated, P3s anchor and connect disparate systems of innovation into coherently organized national, regional and global innovation systems. In Australia and Canada, the P3 anchors the individual national systems and link these two systems into the Export System.

[7] Wheat and canola breeding in Australia is almost completely privatized at this point.
[8] One interviewee (public-private breeder) noted that their organization had significantly reduced the breeding cycle under the P3 model.

The innovative use of P3s has led to the development of a research cluster in Australia as demonstrated graphically and statistically by the eigenvector centrality measure in Figure 3 in section 5.3. Three relatively autonomous networks, each with different objectives, each centered on at least one P3, together form a national system of innovation that is deeply embedded into the regional system. From a theoretical perspective, this implies that as a national system, and through well connected individual actors, primarily P3s, Australia has a competitive advantage over its the rest of the world regarding awareness of and access to new flows of knowledge, of all forms, and new forms of technology. This suggests that Australia possesses first mover and first adopter status regarding technological innovation within the broader global pulse R&D system (Boland et al 2010).

7. Policy Implications

The role of the P3 as an organizational structure to manage an R&D intensive technology transfer process can be differentiated. In the Export System, the three primary P3s, CDC/SPG, the GRDC and CLIMA, are producer-managed and financed P3s, which came into existence in the institutional void created by the retrenchment of public financing of R&D activities. The producer P3 is an organic, bottoms-up response to a changing economic and political environment. This P3 closely resembles a demand pull R&D organization, linking the research to market needs. ICARDA occupies central position, both in the Export System and in the broader global pulse R&D network (Boland et al 2010). This position demonstrates ICARDA's unique status relative to other P3s. Along with ICRISAT, ICARDA sustains the germplasm needs of the pulse world, without which the majority of the global pulse system could not exist, highlighting the global dependency on ICARDA in particular and ICRISAT in general. For the developing world, ICARDA and ICRISAT have two roles: the supply of new cultivars and technologies to expand production, and capacity building from both a network/regional perspective by creating connections between countries and from within the individual national agriculture research systems. This study suggests more than one model of P3 is be necessary to achieve efficient operations.

As the Chief Economist for the Department of Food and Agriculture in Western Australia stated during discussions: *"The likelihood for increased public funding in agriculture is close to zero…so the future of agriculture in Australia – whether agriculture likes it or not – is going to be more about strategic partnerships."*

P3s appear to the new reality in agriculture, despite experiencing some growing pains. Nevertheless, and based upon a preliminary examination of both network analysis and interview data, the pulse industry – in fact, the larger agriculture industry overall –appears to conform most closely to what is termed as an innovation system, particularly in Australia (Boland 2010). The associated innovation theories posit that universities have a role to play in facilitating the collaborative development and transfer of knowledge between the public, private and academic spheres—to link science and technology with needs of the marketplace. A similar view suggests that innovation is dependent on connecting to the global flows of knowledge, in particular sources of intellectual property rights (IPRs) and patents. Both viewpoints emphasize a key requirement for innovation is the absorptive capacity of a country or region (Boland 2010). Our preliminary network analysis shows that actors in the pulse industry are both well-connected nationally and internationally. As one Australian interviewee states: "We're at the rear end of the world down here so we are dependent upon being resourceful for ourselves and finding international connections…"

8. Directions for Further Research

This research has adapted and adopted social network analysis to the study of P3s in global innovation systems, tested it against a single system and validated the results through qualitative interviews. More work can and should be done. First, the methodology could be refined further, investigating other measures of centrality and testing the bounds of systems theory in innovation systems. Second, more and different cases could and should be investigated to validate the methods and results. Third, a set of quantitative output measures could be developed and correlated to system dynamics to determine if and how different actors contribute to innovative outcomes. Finally, if and when enough complementary studies are complete, it should be possible to develop a database and undertake a meta-analysis that sets benchmarks for optimal network density and central institutional placement, which would then provide the basis for proactively operationalizing P3s in a more systematic way.

Bibliography

Agricommodity Prices. (2010). "Pulses Production in Australia." Available online at: http://www.agricommodityprices.com/futures_prices.php?id=93. Accessed May 3, 2011.

Allan, J. R., 2000. Public – Private Partnerships: A Review of Literature and Practice. Saskatchewan Institute of Public Policy website. Downloaded on 11 March 2011 from www.uregina.ca/sipp/publications.htm.

Alston, J. M., Pardey, P. G., (1998). Principles for Public Investment in Agricultural and Natural Resources Research. In: Persley, G.J. (ed) Investment Strategies for Agriculture and Natural Resources. CABI Publishing, Wallingford, UK, 221-248.

Arrow, K. 1962. Economic Welfare and the Allocation of Resources for Invention. In Rate and Direction of Inventive Activity, Princeton University Press Princeton NJ.

Bathelt, H., Malmberg, A., Maskell, P., 2004. Clusters and Knowledge: Local Buzz, Global Pipelines and the Process of Knowledge Creation. Progress in Human Geography 28, 31-56.

Binenbaum, E., Pardey, P. G., Wright, B. D., 2001. Public-Private Research Relationships: The Consultative Group on International Agricultural Research. American Journal of Agricultural Economics, 83, 748-753.

Boase, J. P., 2000. Beyond Government? The Appeal of Public-Private Partnerships. Canadian Public Administration 43, 75-92.

Boland, W., Peter W.B. Phillips and Camille D. Ryan (2010). "Public Private Partnerships for the Management of National, Regional and International Innovation Systems: A Network Analysis of Knowledge Translation Systems. Available online at *CAIRN* at: http://www.ag-innovation.usask.ca/cairn_briefs/publications%20for%20download/CAIRN%20Paper%20Boland%20Phillips%20Ryan%20March%2031%202010.pdf

Bonacich, P., 1972. Factoring and weighting approaches to status scores and clique identification. Journal of Mathematical Sociology. 113-120.

Brennan, J. P., Mullen, J D. (2002) "Joint Funding of Research through Producer Organizations". In: Byerlee, Derek, and Ruben G. Echeverria (Eds) Agriculture Research Policy in an Era of Privatization. CABI Publishing, Wallingford, UK.

Buller, C., Taylor, W., 1999. Partnerships between Public and Private: The Experience of the Cooperative Research Center for Plant Science in Australia. AgBioForum. Downloaded on 11 March 2011 from http://www.agbioforum.org/v2n1/v2n1a04-buller.pdf.

Campbell, J. L. 2004. Institutional Change and Globalization. Princeton University Press.
Charih, M. . Lucie R., (1997). The New Public Management in Mohamed Charih and Arthur Daniels. (Eds), New Public Management and Public Administration in Canada, IPAC, Canada.
Consultative Group on International Agricultural Research, 2010. Downloaded on 11 March 2011 from http://www.cgiar.org/centers/index.html.
Crookshanks, R. and P.W.B. Phillips., 2010. A Comparative Analysis of Access and Benefit Sharing Systems. Working Paper, *www.agbio-management.org.*
Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., Trow, M. 1994. The new production of knowledge: The dynamics of science and research in contemporary societies, Sage, London.
Gilpin, R. 2001. Global Political Economy: Understanding the International Economic Order, Princeton University Press, Princeton.
Grains Nutrition. (2011). "How much is produced in Australia." Available online at: http://www.gograins.com.au/grainsnutrition/ie/ie2frame.html. Accessed April 26, 2011.
Hagedoorn, J., Link, A. N. Vonortas, N. S. 2000. Research partnerships. Research Policy. 29, 567-586.
Hall, A. 2006. Public–private sector partnerships in an agricultural system of innovation: concepts and challenges. International Journal of Technology Management and Sustainable Development. 5, 3-20.
Hajer, M. 2003. Policy without Polity? Policy Analysis and the Institutional Void. Policy Sciences. 36, 175-195.
Hartwich, F., Tola, J., Engler, A., González, C., Ghana, G., Vazquez-Alvarado, J. M. P., Silva, J. A., Espinoza, J. d. J., Gutter, M. V., 2008. Building Public-Private Partnerships for Agricultural Innovation. Downloaded 11 March 2011 from http://www.ifpri.org/publication/building-public-private-partnerships-agricultural-innovation.
Hird, J. 2005. Policy Analysis for What? The Effectiveness of Nonpartisan Policy Research Organizations. Policy Studies Journal. 33, 83-105.
Huffman, W. E., Just, R. E., 1998. The organization of agricultural research in western developed countries. Staff General Research Papers 1386, Iowa State University, Department of Economics.
ICARDA. 2009. ICARDA and International Public Goods. (downloaded 11 March 2011 from http://www.icarda.org/PDFs/Research_Pages/IPGs2.pdf).
Kingwell, R. 2005. Institutional Change and Plant Variety Provisions in Australia. Australian Agribusiness Review Paper 5, February 25th, 2005.
Klijn, E. H., Teisman, G. R. (2000). Governing Public-Private Partnerships: analysing and managing the processes and institutional characteristics of public-private partnerships. In (ed) Stephen P. Osborne. Public-Private Partnerships: Theory and Practice in International Perspective. Routledge, New York pp. 84-102.
Knoke, D., Kuklinski, J. 1982 Network Analysis, Series: Quantitative Applications in the Social Sciences, Sage University Paper Series on Quantitative Applications in the Social Sciences, no. 07-028. Sage, Newbury Park, CA.
Krugman, P. 1998. What's new about the New Economic Geography? Oxford Review of Economic Policy. 14, 7-17.
Lindner, B. 2004. Economic Issues for Plant Breeding-Public Funding and Private Ownership Australasian Agribusiness Review, 12, paper 6.

Lindquist, E. 2006. Think Tanks, Foundations and Policy Discourse: Ebbs and Flows, Investments and Responsibilities. (downloaded on 31 March 2011 from http://www.cprn.org/documents/45986_en.pdf).
Lundvall, B. 1992. National Systems of Innovation: Towards a Theory Innovation and Interactive Learning. Pinter, New York.
MacLean, B. (2010). "One Size Does Not Fit All." *Pulse Breeding Supplement: Groundcover.* Issue 84. Available online at: http://www.grdc.com.au/director/events/groundcover?item_id=CFCC5AE6D3FD7312C3F3636D8B60EFA1&article_id=CFF38C46CBCFD10B0F0A7A4E7EE37C08.
Mead, S. 2001. Using social network analysis to visualize project teams. Project Management Journal, 32, 32-38.
Milward, H. B., Provan, K. G. 2000. Managing the Hollow State: Contracting and Collaboration. Public Management Review, 5, 1-18.
Mote, J. 2005. R&D Ecology: Using 2-Mode Network Analysis to Explore Complexity in R&D Environments. Journal of Engineering and Technology Management, 22, 93-111.
Nelson, R. (1988). Institutions Supporting Technical Change in the United States, in: Technical Change and Economic Theory. Dosi, G. C., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds) Pinter Publishers, London.
North, D. 1990. Institutions, institutional change, and economic performance. Cambridge University Press, New York.
Nowontny, H., Scott, P., Gibbons, M. 2003. 'Mode 2' Revisited: The New Production of Knowledge, (downloaded on 31 March 2011 from http://www.prescott.edu/faculty_staff/faculty/scorey/documents/NowotnyGibbons2003Mode2Revisited.pdf).
OECD. 2000. Governance in the 21st Century. (downloaded on 31 March 2011 from http://www.oecd.org/dataoecd/15/0/17394484.pdf).
Pal, L., Maxwell, J. 2003. Assessing the Public Interest in the 21st century: A Framework, (downloaded on 31 March 2011 from http://www.cprn.org/documents/25967_en.pdf).
Phillips, P. W. (2002). Regional Systems of Innovation as a Modern R&D Entrepot: The Case of the Saskatoon Biotech Cluster. In Innovation and Entrepreneurship in Western Canada: From Family Business to Multinationals. University of Calgary Press, Calgary.
Phillips, P. W. 2007. Governing Transformative Technological Innovation: Who's in charge? Edward Elgar, Oxford.
Phillips, P. W. 2001. The biotechnology revolution in global agriculture: innovation, invention, and investment in the canola industry. CABI, New York.
Phillips, P. W. 2009. Centerless Governance for the Management of a Global R&D Process: Public-Private Partnerships and Plant-Genetic Resource Management (downloaded on 31 March 2011 from http://opensiuc.lib.siu.edu/pn_wp/14/).
Picciotto, R. 1995. Putting institutional economics to work: from participation to governance, World Bank Discussion Paper 304, (downloaded on March 31 2011 from http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1995/09/01/000009265_3961219115337/Rendered/PDF/multi_page.pdf).
Porter, M. 1990. Comparative Advantage of Nations. Free Press, New York.
Rhodes, R. 1995. The New governance: Governing without Government, The State of Britain Seminar II of a joint ESRC/RSA seminar series, January 24.
Ryan, C. 2008. Evaluating Performance of Collaborative Research Networks: a socio-economic framework for assessing funded research projects. VDM Verlag, Germany.

Romer, P. 1990. Endogenous Technological Change. Journal of Political Economy. 98, S71-102.
Salamon, L. (2002b). The tools approach and the new governance: conclusions and implications. In: L. Salamon and O. Elliot (Eds), The tools of government: a guide to new governance, Oxford University Press, Oxford, 1-43.
Saskatchewan Pulse Growers (SPG). 2011. Website. Available online at: http://www.saskpulse.com/. Accessed on: February 21, 2011.
Spielman, D. J., Hartwich, F., Grebmar, K. v. 2007. Sharing Science, Building Bridges, and Enhancing Impact: Public-Private Partnerships in the CGIAR. IFPRI Discussion Paper 00708. (downloaded on March 31 2011 from http://www.ifpri.org/publication/sharing-science-building-bridges-and-enhancing-impact).
Spielman, D., Grebmer, K. v. 2004. Public-Private Partnerships in Agricultural Research: An Analysis of Challenges Facing Industry and the Consultative Group on International Agricultural Research. International Food Policy Research Institute EPTD Discussion Paper 113. (downloaded on March 31 2011 from http://www.ifpri.org/publication/public-private-partnerships-agricultural-research).
Teisman, G. R. 2000. Models For Research into Decision-Making Processes: On Phases, Streams and Decision-Making Rounds**,** Public Administration, Vol. 84, 937-56.
Solow, R. 1954. A Contribution to the Theory of Economic Growth. Quarterly Journal of Economics, 70, 65-94.
Valente, T. 1995. Network Models of the Diffusion of Innovations. : Hampton Press Inc., Cresskel, New Jersey.

Appendix A: Institutional Coding of Export System Actors

Actor	**Location**	**Institution Type**	**Network**
GRDC	Australia	P3	Export
PBA	Australia	P3	Export
SARDI	Australia	Government	Export
VDPI	Australia	Government	Export
NSWDPI	Australia	Government	Export
QDPIF	Australia	Government	Export
DAFWA	Australia	Government	Export
ICARDA	CGIAR	P3	Global
ICRISAT	CGIAR	P3	Global
CLIMA	Australia	P3	Global
ACIAR	Australia	Government	Export
COGGO	Australia	P3	Export
CDC/SPG	Canada	P3	Global
Pullman-ARS	USA	Government	Export
CSIRO	Australia	Government	Global
U of Adelaide	Australia	University	Export
NPBP	Australia	P3	Export
Muresk Inst.	Australia	University	Export
NDSU	USA	University	Export
GCI-S Africa	S Africa	Government	Export
MSU	USA	University	Export
Prosser-ARS	USA	Government	Export
U of Wis	USA	University	Global
CIAT	CGIAR	P3	Global

CSU	USA	University	Export
U of Idaho	USA	University	Export
U of Guelph	Canada	University	Export
NRC	Canada	Government	Export
AAFC-Saskatoon	Canada	Government	Export
AAFC-Morden	Canada	Government	Export
AAFC-Lacombe	Canada	Government	Export
IH AAFC	Canada	Government	Export
IOA	Australia	Government	Export
WAHRI	Australia	P3	Export
FFICRC	Australia	P3	Export
Tasmanian Inst Agr Res	Australia	Government	Export
Punjab Agr Univ	India	University	Export
UWA	Australia	University	Export
U of NFLD	Canada	University	Export
Guelph AAFC	Canada	Government	Export
MII AAFC	Canada	P3	Export
SC AAFC	Canada	Government	Export
Purdue	USA	University	Export
New Mexico	USA	University	Export
Montana State Univ	USA	University	Export
Scott AAFC	Canada	Government	Export
Univ Manitoba	Canada	University	Export
Univ Alberta	Canada	University	Export
AAFRD	Canada	Government	Export
ACIDF	Canada	P3	Export
APGC	Canada	P3	Export
WGRF	Canada	P3	Export
Northern Pulse Growers	USA	P3	Export
CILR	Australia	P3	Export
John Innes	UK	P3	Global
NC State	USA	University	Export
Queensland U	Australia	University	Export
ANU	Australia	University	Export
U of Newcastle	Australia	University	Export
U of Melbourne	Australia	University	Export
KDNARI	Japan	Government	Export
USDA-STPaul	USA	Government	Global
University of Frankfurt	Germany	University	Global
University of Hannover	Germany	University	Global
UC Davis	USA	University	Global
TIGR	USA	Private	Global
CSIC	Spain	Government	Global
IFAPA	Spain	Government	Global
Wageningen University	Netherlands	University	Global
INRA HQ	France	Government	Global

Appendix B: Schedule of Interviewees		
Aust	**Title**	**Affiliation**
1	Senior Plant Breeder	Department of Agriculture and Food, Western Australia
2	Winthrop Research Professor / Director of Research	The University of Western Australia/Canola Breeders Western Australia
3	Director	Centre for Legumes in Mediterranean Agriculture / International Centre for Plant Breeding Education and Research
4	Chairman	Plant Health Australia / Crawford Fund (Victoria)
5	Project Leader	Grower Group Alliance
6	Chief Economist / Professor	Department of Agriculture and Food, Western Australia / School of Agriculture and Resource Economics, UWA
7	Program Manager	Pulses, Oilseeds and Summer Crop Breeding, Grains Research and Development Corporation (GRDC)
8	Research Assistant, Professor	School of Agriculture and Resource Economics, University of Western Australia
9	Chairman	Council of Grain Growers Organizations Ltd (COGGO)
10	Chief	Innovative Food and Plants, South Australian Research and Development Institute
11	Managing Director	Grains Research and Development Corporation (GRDC)
12	Chair	Grains Research and Development Corporation (GRDC) Western Panel
13	Chief	CSIRO Plant Industry
14	Executive Chairman	Canola Breeders Western Australia
15	Founder and Chief Executive	CAMBIA
16	Emeritus Professor	School of Agricultural and Resource Economics, UWA
17	Freelance Ag Economist / Former Chief Research Economist / Senior Lecturer	Independent /Australian Bureau of Agricultural and Resource Economics / Agricultural Economics, University of Melbourne
18	Executive Director / Director / Professor (Adjunct)	Biosciences Research Division of the Victorian Department of Primary Industries (DPI) / Plant Biotechnology Centre / Department of Botany, La Trobe University
19	Chief Executive Officer	Intergrain
20	Biotechnology Coordinator / Professor	Department of Microbiology and Immunology, University of Melbourne
Can	**Title**	**Affiliation**
1	Director of Research	Saskatchewan Pulse Growers
2	Executive Director	Manitoba Pulse Growers
3	Provincial Specialist, Specialized Crops / BASF Pulse Promoter of the Year	Saskatchewan Ministry of Agriculture, Government of Saskatchewan
4	Chairman	Alberta Pulse Growers Commission
5	Executive Director	Alberta Pulse Growers Commission
6	Director of the Agriculture Research Branch	Saskatchewan Ministry of Agriculture, Government of Saskatchewan
7	Pulse Crop Breeder	Crop Development Centre, University of *Saskatchewan*