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Three Actor View of Academic-Industry Research Centers: Towards a Taxonomy

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Abstract. This paper presents a theoretical taxonomy of academic-industry research centers based on the motivations of government actors, industry practitioners and academics to create such groups, the structure of these collaborations, as well as their formal and informal outputs. This taxonomy can be seen as a tool for improved theory building by providing a framework for further research. Additional, it provides insight for policy makers and members of these groups to improve the effectiveness of their collaborations.

Keywords. Academic-industry research centres, research processes, taxonomy, value creation.

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INTRODUCTION

In a context where business is increasingly knowledge-based, industries are forced to adopt more knowledge-intensive business processes and add new knowledge-centered services to their traditional product offerings. This paradigm shift forces companies to look outside their traditional boundaries for new sources of highly qualified personnel, knowledge and innovations. At the same time, universities and researchers are moving beyond their traditional roles of teaching and fundamental research to become "entrepreneurs" of their knowledge, skills and research results (Etzkowitz, 2003a). Both these trends have been supported and encouraged by governments and funding agencies through new research and development policies that encourage industry-academic collaborations (Landry, Amara, & Ouimet 2006a). Governments at all levels now look to universities to conduct research, teaching and play an active participatory role in the economic, social and cultural development of the region and nation (Arbo & Benneworth, 2007).

There are many types of academic-industry research centers that have resulted from this shift. The literature concerning these centers is wide and belongs to many different fields of study including, science policy, innovation studies, technology management studies, and interorganisational studies (Thune, 2006). Because of this, the terms used for these collaborations are varied and much work remains to be done to integrate the findings in these diverse domains.

The objective of this paper is to present a theoretical taxonomy of these centers using the literature and developed taxonomies from the fields of science policy, innovation, research collaborations, research joint ventures, knowledge and technology transfer and interorganisational studies. Additionally, propositions will be introduced to guide reflection and the discussion.

The proposed taxonomy is built on three aspects that reflect the defining characteristics of these entities. That is, the motivations of the three main actors of academic-industry groups to enter into collaborations, the structure of these groups and the formal and informal outputs these groups produce. The motivations of actors will influence their level of participation, resource allocation and expectations concerning outputs. The structure will help to define the type of knowledge and technology produced in the collaboration. Finally, the formal and informal outputs of the group help to identify the value created for the actors involved.

The contributions of this work are varied and have impacts in policy formation, theory and practice. The proposed taxonomy can be used as a tool for improved theory building by providing a framework for hypotheses and models for researchers to examine, test and build on. It can additionally provide insight to members of these groups and policy makers to examine and improve their effectiveness.

The paper is organized as follows. The first section provides the context of the taxonomy, through a review of the literature on the changing role of universities and academic-industry research centers. The second section presents current taxonomies in the literature of academic-industry research centers and integrates other taxonomies present in the general research center literature. Next, the third section presents the proposed taxonomy and the variables used to define the three classifying concepts. The fourth section presents the discussion of theoretical taxonomy and the propositions that result. Finally, the conclusion and discussion are presented in the fifth section and will include the future steps of a larger research project.

CONTEXT

Gibbons (1999) has pointed out that the very nature of science is changing. He writes that four processes are shaping science and its impact on society: co-evolution, contextualization, the production of socially robust knowledge and the construction of narratives of experts. Co-evolution denotes the open interaction of science and society that advances through experimentation and contextualization represents the iterative process of knowledge and technology production. Both these factors represent the complexity of science today and the need for multidisciplinary approaches to problems. The third factor, socially robust knowledge means that science is valid inside and outside the laboratory and it has been developed with experts from within and outside the academic world, which result in its acceptance as “truth”, rather than “theory”. Finally, narratives of experts are the informal outputs of science that are intended to aid decision makers, both policy makers and business people, in their decision making processes. In fact narratives are the opinions of researchers, intended to extend their knowledge into the realm of general problem solving.

These four aspects of the changes in science are reflected in the changing roles of universities, university-industry research centers and individual researchers. These changes are evident at both the macro and micro level, from participation in national innovation systems to direct transfer of research results to businesses (Arbo & Benneworth, 2007).

Changing roles of universities

Etzkowitz (2003b) provides a history of academic revolutions that maps the expansion of universities’ missions from an emphasis on teaching, to a shared emphasis of teaching with research and finally to the current mission of many universities around the world which includes an additional interest in social and economic development. Although land-grant colleges had been established in the United States with the Morill Act of 1862, these colleges were focused on agricultural and mechanical sciences and were intended for use as experimentation stations and extension activities; these were seen as establishing informal relationships between researchers and industry (Arbo & Benneworth, 2007).

However, in the United States during the late seventies and early eighties, American policy makers adopted two aspects of Japanese technology policy to respond to the ‘Japanese challenge’. These policies encouraged universities and researchers to place a stronger emphasis on collaborative research and also provided government support for early-stage research in targeted areas (Poyago-Theotoky, Beath, & Siegel, 2002).

The Triple Helix concept has often been used to describe this changing environment and role of universities and researchers. Etzkowitz, (2003a) suggest that there is a triple-helix of university, industry and government interactions that is increasingly responsible for innovation. This model of innovation is not linear and is based on the relationships of the three groups of actors. Industry acts as the source of production, government provides regulations, stability and rules of play and universities are the suppliers of new knowledge and technology. A Triple Helix will form when there are formal reciprocal relationships that develop between the three spheres. These relationships are formed to capture synergies that will enhance the performances of all three.

According to Etzkowitz & Leydesdorff (2000), there are three types of institutions (or members) in the triple helix at the meso level (or intersect of the three spheres):

- Hybrid innovation agents (responsible for production and use of knowledge)
- Innovation interfaces (between firm and research institute)
- Hybrid innovation coordinators (provide support in coordination between actors).

This triple-helix can be considered as the environment in which research and transfer activities of universities, through researchers and research centers, are accomplished.

Aside from the United States (Phan & Seigel, 2006), these new formal relationships have been encouraged and established around the world. Many examples have been given in the literature, and include Canada (Van Horne, Frayret, & Poulin, 2005), in Great Britain (Ankrah, Burgess, & Shaw, 2007), Finland (Thune, 2006), Italy (Coccia, 2006), providing descriptions of academic-industry research centers as the operationalization of national or regional science policy.

Changing roles of researchers and their research centers

There are numerous forms of collaborative relationships between universities and industry: research contracts or consulting, commercialization of knowledge or technology agreements, collaborations to produce a specific product or technology (can be informal or formal relationships), university research chairs, small consortia, large consortia, etc. (Carayol, 2003; Poyago-Theotoky et al., 2002). Often these collaborations are not individual researcher-firm, but rather research group-firm. This is in part due to the shift in the emphasis from the individual researcher to groups of researchers (Etzkowitz, 2003b). In fact, the author suggests that research universities should be considered as consisting of a series of research groups that have firm-like qualities. These groups have similar qualities to start-up firms (and can in fact result in spin-offs and spin-outs).

Another shift has been in the focus on interdisciplinary research to tackle large, complex, often industry-wide problems. This can be seen in industry focused centers such as centers of expertise described in Van Horne et al. (2005). They define a center of expertise as a center, whether virtual or physical, that gathers experts from multiple disciplines to study complex and multidimensional contextual problems in a team environment, in order to create and transfer new knowledge and insights to concerned stakeholders. A center works in collaborative networks with researchers from other centers and universities, government agencies and practitioners from the industry to advance science and stimulate continuous knowledge development and innovation in the industry. However, the tools and methods used to develop and implement this new knowledge and innovation have changed over the years as companies have changed their focus from innovations in products, to processes (Just in Time, Total Quality Management) and most recently to innovations in business systems (Enterprise Resource Planning, Advanced Planning and Scheduling Systems, etc.).

Many times these centers are formed to address a need in an important industry in a country or region. These centers are focused in their research and operate within a specific context. Centers of expertise do more than research. Extension activities play a vital part of their role in the industry. The transfer of technologies and innovative knowledge and assisting in the implementation of innovations to create effective value is an important part of their work.

Another type of research center is described by Adams, Chiang and Starkey (2000), and their overview of the literature on Industry-University Cooperative Research Centers (IUCRC). These centers are small academic centers (based at American universities) that depend on industry support for their operations. The research done in these centers is mostly applied and therefore their scientific contributions, in the form of scientific articles, are often considered as delayed.

R&D inputs are measured as the number of scientists and engineers, the number of PhD scientists and engineers and the laboratory's budget. R&D outputs are measured by patents, hybrid patents and sales from new products originating in the laboratory, by member firms. The main channels used for the transfer of research results to member firms are: faculty consulting, joint research with industry and the hiring of graduate students. The return for researchers includes increased funding (through consulting) and joint authorship of scientific articles based on data from partners and the application of research (Adams et al., 2000).

The Faraday Partnership Initiative was established in the UK in 1997 with the goal to promote improved interactions between British industry and the science, engineering and technology base of the country. A focus was placed on knowledge and technology transfer through technology translation processes (Ankrah et al., 2007). In 2005 there were 24 such partnerships in operation.

These academic-industry research centers, rather than universities as institutions, operationalize the vision of governments, academic and industry practitioners. These centers are the source of many services and technologies for the local, regional, national and global academic community.

Academic-industry research centers as sources of services and technologies

As mentioned, governments of all levels are encouraging universities to act as the engines, breeding grounds, hubs, and spearheads for regional economic, social and cultural growth (Arbo & Benneworth, 2007). As a result of these new environmental influences new relationships and collaborations have developed to achieve these various goals in the form of academic-industry partnerships and research centers.

These collaborations provide both technologies (new products, processes, business models, etc.) and services (in the form of knowledge training, consulting, recruitment of highly qualified personnel, interns, etc.) to partner firms (Adams et al., 2000; D'Este & Patel 2007; Etzkowitz & Leydesdorff, 2000) and the general business community, especially targeted at local small and medium sized enterprises (SME). In addition, services are provided to governments through economic and social development (Etzkowitz, 2003a) and to universities and researchers through additional funding, access to industry research problems and data, increased reputation, etc. (D'Este & Patel, 2007).

These services and technologies are now "for sale" as universities and researchers become "entrepreneurs" (Etzkowitz, 2003a) of their knowledge, skills and research results. Government has also played a role in encouraging this new role for universities. For example, the Bayh-Dole Act came into force in 1980 in the United States. This allowed universities to own patents arising from federal grants and was intended to encourage commercialization of new technologies, promote economic development and entrepreneurial activity on the part of universities and individual researchers (Phan & Siegel, 2006).

Technology transfer offices (TTO) set up to organize these formal transfers, such as fee and royalty generation, commercialized inventions, signed licensing agreements and awarded patents (Carayol, 2003) rarely break even, even in the United States. The gross average revenue for TTO from 2001-2004 was $US 75 million, yet cost $US 60 million to run. These formal transfer activities are the focus of many policy changes around the world, even to the neglect of informal transfer activities (Hughes, 2007).

Although there is much attention paid to the number of patents or licensing agreements, many researchers have found that informal transfer activities are the foundation for the fulfillment of many of the goals of these partnerships (Ankrah et al., 2007; Arbo & Benneworth, 2007; Chompalov, Genuth, & Shrum, 2002; Hughes, 2007; Inkpen & Tsang, 2005). These informal activities include the creation of a "neutral playing field" (Lester & Piore, 2004) for competitors to work together to discover solutions to common problems, network formation, and increases both radical and incremental innovation (Ankrah et al., 2007). Additionally, as all industries become increasingly knowledge based, and as products, processes and business systems become more complex, companies are turning to academic research groups to assist them in their innovation processes (Van Horne, Frayret, & Poulin, 2006).

TAXONOMIES IN THE LITERATURE

Theoretical taxonomies

According to Rich (1992), taxonomies provide a means for ordering and comparing organizations and clustering them into categorical types without losing the richness and diversity of each type. It is an empirical method for classification and a hierarchical system. Taxonomies are also regarded as important and basic step in scientific enquiry (Carper & Snizek, 1980). Doty and Glick (1994) also suggest that a taxonomy is a classification system that categorizes observable data into mutually exclusive and exhaustive sets.

The taxonomy proposed in the present work has been constructed using theory and deduction derived from the reviewed literature. This is in comparison to empirical taxonomies which use empirical data and analysis to construct the taxonomy. As Carper and Snizek (1980) note, a theoretical taxonomy is a first step towards a system of classification and is not intended to represent a final taxonomy. Its purpose is to provide hypotheses, propositions and models for researchers to examine, test and build on.

In this way, we can consider taxonomies as tools for researchers to classify and compare similar groups. These classifications can then be used to measure and qualify the performance of individual groups and comparisons can be used to improve performance. In particular, as academic-industry research centers continue to grow in importance, classification and measurements schemes need to better reflect the nature of these centers and groups.

At the present time there are a plethora of terms and names for these research centers which vary from region to region, country to country and industry to industry. Another goal of this taxonomy is to provide a framework for theoretical development in the field.

Taxonomies in the academic-industry research centers literature

There are several taxonomies of academic-industry research centers, networks and/or consortia available in the literature. However, these taxonomies use quite diverse constructs for classification purposes as they come from many different theoretical backgrounds. These taxonomies have been based on the types of research relationships (Bonaccorsi & Piccaluga, 1994), the inputs and outputs of groups (Coccia, 2006), sources of financing (Balthasar, Battig, & Wilhelm, 2000), environmental influences (Crow & Bozeman, 1987), the structure and outputs (Carayol, 2003) and interdependence and network embeddedness (Thune, 2006). The lack of homeogenity of taxonomies in academic-industry groups encouraged the authors to look to additional taxonomies available in the literature of research partnerships and research joint ventures (Chompalov, Genuth, & Shrum, 2002; Hagedoorn, Link, & Vonortas, 2000; Revilla & Acosta, 2004) which also cover academic-industry collaborations as types of groups in their developed taxonomies.

The following section provides a review of the taxonomies present in the literature based on the variables that have been used to classify the different groups. Six main categories of variables were present in the reviewed taxonomies: members, motivation for collaboration, inputs, environmental influences, structure and outputs.

Members. Membership is an important factor in most taxonomies, and is used as a defining characteristics of research groups. For example, Hagedoorn et al., (2000) divide members into either belonging to the public or private sector. The public sector includes universities and government/public research centers and the private sector are individual firms. In the often cited work of Bonaccorsi and Piccaluga (1994), although members are not a defining characteristic, only universities and firms are considered as members of these collaborations. Therefore, in general only two types of members are currently accounted for in the reviewed taxonomies, members of university (either researchers or TTO personnel) or enterprises.

In contrast, there is much general agreement in the literature of university-industry research centers that there are three groups from which membership (through active participation or through provision of inputs) is drawn: governments, universities, and firms (Adams et al., 2000; Decter, Bennet, & Leseure, 2007; Etzkowitz & Leydesdorff, 2000; Etzkowitz, 2003a). Government membership can be represented through government research labs, granting agencies, etc., and can represent governments on a regional (i.e. European Union), national, provincial\state, or local level. University membership is generally represented by individual researchers, or representatives from the university's TTO (Carayol, 2003) and research groups and firm membership is represented by individual firms. However, there are also instances in the literature where there is industry wide membership in these university-industry research centers (Van Horne et al., 2005).

In this way, there is a need for a taxonomy to take into consideration the three categories of members that participate in academic-industry research centers.

Motivation for collaboration. The motivation, or objectives, of members to participate in these organizations is an important factor for classification used by authors (Bonaccorsi & Piccaluga, 1994; Carayol, 2003; Hagedoorn et al., 2000). The motivations given for firms to join academic-industry research centers include: gaining access to scientific frontiers, delegating selected development activities, lack of resources (Bonaccorsi & Piccaluga, 1994), broadening the effective scope of activities, increasing efficiency, synergy, and power through the creation of networks, accessing external complementary resources and capabilities to better exploit existing resources and develop sustained competitive advantage (Hagedoorn et al., 2000). Additional factors include the promotion of organizational learning, internalizing core competencies, enhancing competitiveness and the creation of new investment options in high-opportunity, high-risk activities (Hagedoorn et al., 2000).

Motivations for governments to finance and encourage these types of collaborations through policy include: correcting market failures in R&D investment, particularly in the presence of highly non-appropriable research, speeding up technological innovation, aimed at increased international competitiveness and increasing technological information exchange among firms, universities and public research institutions (Hagedoorn et al., 2000).

The reviewed taxonomy literature rarely considers the motivations of research centers and individual researchers to join (or create) such collaborations, with the exception of Bonaccorsi and Piccaluga (1994) who consider that increasing the predictive power of science and a lack of resources are both motivations for researchers. However, motivations in the general literature include: securing additional research funding, accessing research equipment, accessing "real" research problems and data, contributing to economic development of the region, etc. (Etzkowitz & Leydesdorff, 2000; Thune, 2006; Van Horne, 2006). More details of the motivations cited in the general literature on these collaborations will be provided in the next section.

Inputs. Inputs that are generally used for classification purposes are financial and human resources (Balthasar et al., 2000; Coccia, 2006). Financial resources can be provided by universities and basic research funds, governments and co-op projects with industry, enterprises, contracts (i.e. training contracts) and general public financing. Human resources can be classified according to the number of personnel and researchers working for the academic-industry research center or their associated salary. These inputs would appear incomplete, as they do not include the physical assets that are provided, such as lab space and equipment, which are both considered as motivating factors for collaboration (Bonasccori & Piccaluga, 1994).

Environmental influence. Crow and Bozeman (1987) consider the influence of the environment when classifying academic-industry research centers. The authors consider the level of government influence (high, moderate or low) and the influence level of markets, measured by the nature of R&D projects. Generic products indicate a low level of market influence, a balanced product indicates a moderate influence and proprietary products which indicates a high degree of market influence. Physical environment and proximity has also been a factor found in the more general literature on academic-industry research centers. Carayol (2003) includes many aspects in the general environment of the collaboration including, common history of members, distance, government financial inputs, technology transfer involved, strategy of the academics and the time given for the collaboration to develop its knowledge and technology.

Structure. The structure of academic-industry research groups is a common factor for classification in many of the studied taxonomies (Bonasccori & Piccaluga, 1994; Carayol, 2003; Chompalov et al., 2002; Revilla & Acosta, 2004; Thune, 2006). Carayol (2003) considers the size of the center, whether it is a consortium (large or small) or a bilateral agreement and the types of research being conducted. Chompalov et al. (2002) focus on the governance of these centers and base their taxonomy on the three dimensions of bureaucracy (formalization, hierarchy and division of labor). The locus or focus of the research is important for many authors and can be measured on a basic versus applied research continuum along a tacit – explicit dimension (Revilla & Acosta, 2004). However the characteristics of the knowledge transfer and management process is also considered (Bonasccori & Piccaluga, 1994; Thune, 2006). These characteristics include the type of knowledge and technology developed and transferred (i.e. the transferability of the knowledge) and the types of transfer methods used (i.e. the use of communication and information technologies). In particular, Bonasccori and Piccaluga (1994) classify groups according to the legal form of the relationship and the coordinating procedures that are put in place. These procedures are measured through the perceived importance of the relationship to the members, the information exchanges, the conflict resolution procedures and the formal and informal rewards that are expected by all members.

Outputs. The reviewed taxonomies rarely considered the outputs of these academic-industry research centers for classification purposes in their taxonomies. Coccia (2006) considers the academic outputs of the centers through the number of peer reviewed articles and conferences attended. The only output to industry members that is used for classification is the number of training courses taught by member researchers. Although not explicated taken into consideration by the reviewed taxonomies, the output of these centers to firms and policy makers is a major focus in the general literature of academic-industry research centers (D'Este & Patel, 2007).

Summary of existing taxonomies

For clarification purposes Table 1 provides a summary of selected taxonomies discussed in the literature review. These taxonomies have had the most influence on the theoretical taxonomy presented in the next section. Although membership and motivation are common variables for all the taxonomies, there are many other factors that are not common to all taxonomies. In addition, many of the concepts present in the general literature are not well accounted for. More importantly, the concept of transfer is greatly under developed in the current taxonomies.

TABLE 1
Summary of selected existing taxonomies

Author	Basis of taxonomy	Types
Bonaccorsi & Piccaluga, 1994	- Motivations of members - Characteristics of the knowledge transfer process - Organizational structure - Coordinating procedures	1) Personal informal relationships 2) Personal formal relationships 3) Third parties (relationships developed through intermediary associations) 4) Formal targeted agreements 5) Formal non-targeted agreements 6) Creation of focused structures
Balthasar et al., 2000	- Modes of financing	1) The Science type 2) Practical research 3) Problem solving 4) Rapid response
Carayol, 2003	- Organizational solutions - Consortia size - Volume of research produced - Duration of partnership - Nature of research	1) Contractual research 2) Bi-lateral agreements, low risk and high novelty research 3) Small consortia 4) University chairs 5) Large consortia
Chompalov et al., 2007	- Formalization - Hierarchy - Division of Labor	1) Bureaucratic 2) Leaderless 3) Non-specialized 4) Participatory
Coccia, 2006	- Inputs - Outputs	1) Low-Input, High-Output: 2) High-Input, High-Output 3) Low-Input, Low-Output 4) High-Input, Low-Output
Hagedoorn et al., 2000	- Partners in research partnership - Organizational structure	1) Public 2) Public/Private 3) Private

Given the limitations of the taxonomies currently offered in the literature and the importance of theory building in this field, the next section presents a taxonomy that integrates some of the variables listed above, but places greater importance on formal and informal transfer from the academic-industry research center to other members and external communities (i.e. academic community).

PROPOSED TAXONOMY

The theoretical taxonomy proposed in this work builds on the existing taxonomy literature by integrating the key aspects using three main concepts: the motivations of the main actors for the formation of the research center, the structure of the academic-industry group and its formal and informal outputs. In a triple-helix environment there are three basic types of members which are recognized: government, industry and academic. This taxonomy only covers centers with members drawn from these three larger groups.

The basic concepts of motivation, structure and outputs are developed using additional descriptive variables not found in current taxonomies. In particular, the informal transfer activities of these groups will be taken into consideration for classification purposes. Structure is measured on a continuum from a fixed structure with many pre-defined processes and a concentration on basic research to flexible or / applied research. Motivations are measured on a continuum from general to specific and outputs are measured from an emphasis on formal outputs to an emphasis on informal outputs. Of course, each concept can have a "mixed" measure when there is a true balance between the continuums. A visual representation of the proposed taxonomy is presented in Table 2.

TABLE 2:

Theoretical taxonomy of academic-industry research groups

Structure	Fixed / Basic research → Flexible / Applied research		
	Academia	**Government**	**Industry**
Motivations	General → Specific	General → Specific	General → Specific
Outputs	Formal → Informal transfer	Formal → Informal transfer	Formal → Informal transfer

Structure of the relationship

The structure of an academic-industry research group is formal, that is it involves the creation of a separate entity from the university, private firm, or government institution. However, within this structure there are variables that are important for classification purposes, and which can be considered as being on a continuum from fixed (formal, high degree) to flexible (informal, low degree) structure and from basic to applied research. The variables used in this taxonomy are the characteristics of the knowledge to be generated, the characteristic of the knowledge transfer processes, the characteristics of the knowledge management processes, the coordinating procedures that are used for management purposes, and the inputs of the collaboration.

Characteristics of generated knowledge. The generated knowledge and technology of the group is an important classification tool. There is a continuum of research from basic (i.e. idea exploration and advancement of science) to applied (i.e. uses scientific knowledge to solve specific problems). Of course, with these types of academic-industry research centers there is often a mix of goals (Van Horne et al., 2005). For example, researchers working in these groups need to fit their work into a specific research paradigm, but at the same time need to respond to the more immediate needs of industry and government members. There are also the aspects of domain of research, industry, themes explored, and the radical to incremental nature of the innovations being developed and transferred (Carayol, 2003).

This measure would be slightly subjective, and would consider if the center produced mainly basic and theoretical research (which would indicate, novel research and an aim towards radical innovations), mainly practical research (incremental innovations, immediate problem solving) or mixed.

Characteristics of the knowledge and technology transfer processes. Bonasccori and Piccaluga (1994) use four variables to characterize the knowledge transfer process: the time span of process, the appropriability of the generated knowledge, the tacitness of knowledge and the universality of knowledge. Additionally, Revilla and Acosta (2004) consider both the techno-structure of the process (use of communication and information technologies) and the behavioral (person to person) patterns of the process. All six of these aspects will be used in the proposed taxonomy.

The time span of the process would appear to indicate the closeness of the relationship and could be a good indicator of the social capital that would grow amongst members over time. Social capital (within the developer-receiver context and network) is regarded as an important prerequisite and facilitator of knowledge and technology transfer (Inkpen & Tsang, 2005). Social capital is defined by the authors as "the aggregate of resources embedded within, available through, and derived from the network of relationships possessed by an individual or organization".

The appropriability of the generated knowledge would influence the ability of firms to understand and apply the knowledge and technology generated by the research center. This would be influenced by the use of "actionable messages" that synthesis research results into explicit directives and guidelines (Landry, Amara, Pablos-Mendez, Shademani & Gold, 2006b). If the generated knowledge is tacit in nature, this would suggest a close relationship between the researchers of the center and individuals in member firms, as the generated knowledge would have had to have been translated into terms that are familiar to the members receiving the actionable message. This type of tacit knowledge is transferred through person to person contact and joint activity (Nonaka, 1991).

The number of actionable messages can be measured with a fixed number. The number of interactions amongst members can also be measured by counting the formal meetings amongst members, the numbers of calls or email exchanged, etc.

The universality of the knowledge generated would be influenced by the absorptive capacity of the receiving members, which would have an effect on the success of the transfer processes of the center. Todorova and Durisin (2007) suggest that this capacity consists of the capabilities of the organization and its members to recognize the new value of knowledge, to assimilate it, and to apply it to commercial ends. In contrast, Zahra and George (2002) suggest a more general view of absorptive capacity as a "a set of organizational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organizational capability". These capabilities not only allow a firm to recognize the importance of the new knowledge and apply it to existing structures, but more importantly to reconfigure its resource base and adapt to changing market conditions.

These processes can be mainly fixed, with a great degree of structure, mainly flexible with much trial and error, or can exhibit a mix of behaviors.

Coordinating procedures. Bonasccori and Piccaluga (1994) use four items to capture the coordinating procedures of the group, which need to be used for classification purposes. That is the perceived importance of relationship, the information that is exchanges, the conflict resolution procedures that are in place and the expected rewards of the members (both fixed and flexible).

The perceived importance of the relationship for the different members can be measured by: the importance of internal resources allocated; the support from top management and the human resource allocation to the direct interface function (gate keepers in both academic and industry organizations are key elements in any collaboration). This can be measured as either high importance or low importance.

Expected rewards can be expressed in both formal and informal terms. Formal rewards, which are more easily quantified, can be expressed in terms of expected monetary returns, equipment use, goods and/or services, etc. However, these expected rewards can also be informal such as pleasure, gaining approval and status or personal objectives (i.e. recognition in international scientific community). These informal aspects are more difficult to measure, yet would appear as important factors in any academic-industry research group as the personal efforts and commitment of individual researchers would intuitively have a great impact on the functioning of the group.

All of these coordinating procedures have an impact on the inputs that will be allocated by the different members of the academic-industry research group which are presented in the next subsection.

Inputs. University-industry networks and knowledge and technology transfer activities are varied and depend on the assets at the researcher's disposition. These activities involve both not-for-profit, contractual (i.e. consulting agreements) and commercialization efforts.

Using a resource based view of the firm, Landry et al. (2006a) demonstrate that an increase in resources available to the academic researcher supports an increase in knowledge and technology transfer activities. The resources (assets) are outlined in Table 3 with examples and the correlation with outputs.

TABLE 3:
Positively related assets implicated in knowledge and technology transfer (adapted from Landry et al. 2006a)

	Embodied in:	Examples	Positive/negative correlation with output
Financial assets	- private funding - government funding	- research contracts - grants, research chairs	- positively related to transfer
Organizational assets	- university size - research unit size	- existence of doctoral program - supporting faculty/university physical and technological infrastructures	- positively related to size
Relational assets	- linkages with potential non-academic users	- active membership/ participation in non-academic networks - contracts, consulting experiences	- significant positive relationships
Personal assets	- years of experience	- experience as researcher - experience in industry	- level of seniority not related - years of experience positively related

These inputs can be measured in a general way. A center has a high degree of inputs (i.e. many resources at its disposition) or a low degree of inputs.

Motivations

The motivations of members to support and take part in these collaborations have been extensively researched and documented in the literature (Ankrah et al., 2007; Arbo & Benneworth, 2007; Carayol, 2003; Hughes, 2007; Thune, 2006). A recent systematic review of the literature on the motivations of members by Ankrah et al. (2007) pointed out that little attention has been paid to the differences in motivations of the different actors. Table 4 lists the different motivations cited in the literature for the three actors taken from the literature (Ankrah et al., 2007; Arbo & Benneworth, 2007; Bonasccori & Piccaluga, 1994; Carayol, 2003; Hagedoorn et al., 2000; Hughes, 2007; Thune, 2006).

While in general, motivations can be either specific or general, there are many differences amongst the different objectives for the different actors. An analysis of any research center would need to "match" the different motivations to ensure there was a fit. A mismatch of motivations among the three members would surely lead to disappointment and conflict and in this way hinder all other aspects of the collaboration.

TABLE 4: Motivations (Value perceived)

	Specific	General
Academia	- Additional funding - Patents - Licensing agreements - Spin-off creation - Respond to government policies-initiatives - Employment opportunities for graduate students - Publication of papers - Access relevant research problems	- Access to additional resources - Gain insight into own research - Test research with real problems - Increase strategic institutional power - Provide feedback to government and contribute to policy - Future business opportunities - Improve curricula developments - Ensure research is cutting edge - Service to industry/community - Access to research networks
Industry	- Recruit highly qualified personnel - Get training and support for in-house skills - Solving specific problems - Access university facilities (for SME) - Respond to government policies-initiatives - Access R&D funding - Commercialize university-based technologies	- Gain access to scientific frontiers - Knowledge exchange between university and firm -Benefit from serendipitous events - Risk sharing - Cost savings - Improve corporate image - Broaden scope of activities - Create new investment opportunities - Increase absorptive capacity - Access to research networks
Government	- Increase employment - Increase absorptive capacity of firms - Create a regional/national innovation system - Increase productivity of firms - Increase wealth creation	- Correct market failures in R&D investment - Speed up technological innovation - Create research networks - Increase information exchange among firms and universities - Economic, social and cultural development and performance

These motivations represent some of the diverse values that members perceive in creating and participating in these collaborations. The outputs of these groups represent the value created and are further detailed in the next subsection.

Outputs

Thune (2006) writes that there are three general purposes to university-industry collaborations. That is: generation of new knowledge, transfer of knowledge, and absorption of knowledge. The outputs of these research centers represent the new knowledge that has been created for members. This new knowledge can then be transferred to each member, but will have to be "translated" in the appropriate language and format for the target audience (Landry et al., 2006b). As the motivations of members to participate represent the perception of value, these outputs represent the value created by these research centers. Value is captured when the knowledge is absorbed or used by members or the region at large. These values are both tangible and intangible in nature and are achieved through both the formal and informal outputs of these centers.

Formal outputs have traditionally been used to measure outputs by universities and academic-industry research groups (Coccia, 2006; Landry et al., 2006a). In fact, university transfer literature concentrates on the set-up of technology transfer offices (TTO), (200 in the United States in 2006), patent applications and spin-offs and spin-outs, (1,252 patent applications and 64 spin-off companies in Canada in 2003), and intellectual property right management ($55.5 million to Canadian universities in 2003) (Landry et al., 2006a; Phan & Siegel, 2006).

However, these formal and explicit transfer activities are only a small part of the total transfer effectuated by researchers and research groups and only represent part of the value that is created by increased collaboration between university-based researchers and industry. Informal and tacit transfer activities are also a large part of the value, often intangible, that is created by these centers.

Academic-industry research groups are increasingly important tools that universities and researchers can use to transfer research results. Table 5 provides details some formal and informal transfer activities that these groups can use and the target of the transfer. These which have been documented in the literature (Beaudry et al., 2006; Coccia, 2006; Landry et al., 2006a; Phan & Siegel, 2006; Van Horne et al., 2005).

TABLE 5: Outputs (Value created)

Target of transfer	Formal / Explicit	Informal / Tacit
Academia	- Peer reviewed journal articles - Peer reviewed conference articles - Patent applications - Patents - Research contracts	- Academic conferences - Working group membership - Social networking activities - Joint research projects - Science fair

	- Production of academic books - Spin-off or start-up	
Industry	- Patent applications - Patents - Production of instruction manuals - Spin-off or start-up - New products/processes - Newsletters	- Student interns - New business models - Presentations - Consultation - New graduate hires - Science fair - Training courses
Government	- Production of manuals - Newsletters - New regulations	- Working group membership - Policy advise - Job creation - Public presentations

This list is not complete. Moreover, innovative transfer activities or tools should be taken into consideration. For example, websites (as information sources and knowledge repositories), intranets, online forums, online courses (e-learning); learning games, (e-) newsletters, science fairs, etc., need to be considered as transfer or "output" activities and therefore need to be included in the taxonomy.

Types of centers

These three main characteristics: motivation, structure and outputs are measured on continuums. While there will be differences in the exact motivations of the different members, the overall "score" will take into consideration the motivations of each. Outputs will also be different for each member and the overall "score" for this factor will take into consideration the outputs "received" by each. The authors suggest that to have a proper "fit" these measures would all be in similar positions for each member. In this way there are three types of university-industry research centers that result from this theoretical taxonomy.

Type 1. "Boundary pushers" are university-industry research centers that generally have a more fixed structure, emphasis theoretical research and have formal transfer processes in place. The motivations are more general in nature, that is, there are few specific problems to be solved. The center uses mainly formal outputs to disseminate the value it creates for its members.

Type 2. "Expertise builders" are university-industry research centers whose measures tend toward the middle of the continuums. These centers perform both theoretical and applied research, their transfer processes are fixed, yet much effort is made to develop new transfer tools and methods to better reach the target markets. There are both specific and general motivations and outputs are both formal and informal.

Type 3. "Problem solvers" are university-industry research centers that generally have more of a flexible structure, emphasis applied research and while there are transfer processes in place they are less structured. Motivations are more specific in nature and the centers can be considered as "problem solvers" for industries or regions in need. The center produces more informal outputs to meet the expectations of its members.

PROPOSITIONS

In the literature, the least developed of the characteristics used above is how to measure and assess the transfer processes and the outputs of these centers. Increased attention to this will need to be made to further develop the taxonomy. While formal and more traditional outputs can be measured (i.e. number of scientific articles, h-index, number of citations, cumulated impact factors, etc.), less formal and indirect outputs could be just as, if not more valuable, for the actors involved. This hinders measuring the real value created for the different members and stakeholders of the research center. The following propositions are intended to identify gaps in the current literature in this field and to guide future research.

Proposition 1(a)
The type of research group influences the transferability of outputs.

Proposition 1(b)
The transferability of outputs increases with the active participation of all actors implicated in the innovation process.

Proposition 1(c)
A high degree of motivation of the involved actors positively influences transfer processes.

Proposition 2(a)
The value of any particular output will be different for each actor and institution.

Proposition 2(b)
The value created by outputs is both tangible and intangible in nature, and both need to be captured to fully measure the benefits of the output from each actor's point-of-view.

Proposition 3(a)
In the new university-industry-government environment, the needs of all actors and institutions require new transfer processes and outputs of research results.

Proposition 3(b)
The innovative and multidisciplinary nature of the knowledge and technology developed in these centers often requires innovations in regards to outputs and transfer processes used.

Proposition 3(c)

Measures will need to be flexible to be capable of measuring "tailor made" and innovative transfer processes and outputs.

CONCLUSION AND FUTURE WORK

A theoretical taxonomy is only a first, but valuable, step towards building an empirical taxonomy based on observations and documentary data collection. The taxonomy proposed in this paper is based on three aspects that reflect the three defining characteristics of these entities. The three types of centers each have different reasons for existence. Boundary pushers are expected to advance science and produce leading edge research. Problem solvers are expected to solve pressing problems and address lacunas in regional or industrial development through applied research and many informal outputs. Expertise builders are expected to do both, advance science and contribute to regional, industry and business development.

This proposed taxonomy can be used as a tool for improved theory building by providing a framework for hypotheses and models for researchers to examine, test and build on. It can additionally provide insight to members of these groups and policy makers to examine and improve their effectiveness.

Future work to further develop this taxonomy and to build theory will be to develop comparative case studies to explore the phenomena in greater detail. The rich data from these studies will be used to on the one hand, to test the robustness of the taxonomy and on the other, to modify the theoretical taxonomy based on the terrain. Once this has been done, a survey of research centers based on the taxonomy is envisioned that will further test the validity of the taxonomy and from which group types will emerge.

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