11e CONGRES INTERNATIONAL DE GENIE INDUSTRIEL – CIGI2015
Québec, Canada
26-28 octobre 2015

# Open Innovation within Collaboration Network of Nanotechnology

EHSAN GHALAMZAN[1], ARMAN SADREDDIN[1], ANDREA SCHIFFAUEROVA[1,2]

[1] Concordia University, Concordia Institute for Information Systems Engineering,
1455 De Maisonneuve Blvd. W. Montreal, Quebec, Canada
e_ghala@encs.concordia.ca, a_sadre@encs.concordia.ca, andrea@encs.concordia.ca

[2] Masdar Institute of Science and Technology, Department of Systems Engineering and Management,
Masdar City, Abu Dhabi, UAE
aschiffauerova@masdar.ac.ae

***Résumé*** **- Récemment, un important corpus scientifique s'est intéressé aux réseaux de collaboration et à leur importance dans la production et la distribution des connaissances scientifiques. De nombreuses recherches ont également été effectuées au sujet de l'Innovation Ouverte (IO), et de son impact sur la capacité d'innovation des entreprises. Cependant, aucun de ces travaux ne prête attention à l'impact des pratiques d'Innovation Ouverte sur le rôle d'une société au sein de son réseau de collaboration. Cette étude vise à étudier la relation entre l'application de pratiques d'IO et la façon dont une entreprise se situe dans son réseau propre de collaborateurs. Pour parvenir à cet objectif, un réseau d'entreprises de nanotechnologies au Canada est construit et le degré de centralité de chaque entreprise est calculé. Un Indice-IO est proposé, se reposant sur une enquête conduite au sein de ces entreprises, pour quantifier l'application des pratiques IO par ces entreprises. Les résultats révèlent qu'une tendance de corrélation peut être observée entre l'application de pratiques IO dans les entreprises et leurs liens de collaboration dans leur réseau propre. Si une entreprise utilise plus fréquemment l'IO, elle tend à avoir plus de connexions collaboratives.**

***Abstract*** **– Recently, a substantial body of literature has been concerned about the collaboration networks and their importance in production and distribution of scientific knowledge. Also many research studies have been carried out in the domain of Open Innovation (OI) and its impact on the innovative power of the companies. But none of them pay attention to the relationship between Open Innovation practices and the role of the company within its collaboration network. This study aims to investigate the relationship between applying OI practices and the position which the company occupies in the network of its collaborators. For this purpose a network of Nano-tech companies in Canada has been constructed and Degree Centrality of each company has been calculated. Also an OI-Index has been created based on a survey conducted within these companies in order to measure how companies apply OI practices. By comparing the results, a trend of correlation can be seen between applying OI practices in companies and their collaboration linkages they have in the network. If one company uses OI practices more frequently, it may have more collaborative connections.**

***Keywords*** **– SNA, Collaboration network, Open Innovation, Nanotechnology.**

## 1 INTRODUCTION

In the economic globalization era and the transition to knowledge-based economy, a firm cannot survive in the competitive environment of new technology and new knowledge without any collaboration with other firms. Alone inventors and even R&D laboratories of individual firms have been gradually substituted with collaboration networks expanded through geographical areas and many scientific disciplines (Maggioni, Breschi et al. 2013). Thus, collaboration and innovation networks play a key role for firms to grow and compete in this environment (Malecki, Veldhoen 1993). When the knowledge becomes more sophisticated and complex and also more diffused, the pivotal innovations are formed in the network of several firms instead of insulated firms. As result the concept of

firm's networks has become more attractive and more relevant for the researchers to investigate.

Networks in which different firms are connected to each other are very important. Especially when the firms exchange their knowledge through these relations as a vital action to survive and improve the performance of their company in innovating. In fact this knowledge transfer is one of the major factors that gather innovative companies close to each other and shapes the geographical innovation clusters. The result will be the regional improvement of knowledge level that yields to economic growth.

These social networks are structured based on collaborations between actors, strategic alliances, co-authorships of scientific papers, co-patenting, co-directorship of the firms, etc. In the network, actors share their mutual interests and by means of this structure they support knowledge flow among the actors (Ingstrup, Freytag et al. 2009). Actors in the social networks can be universities, companies, research centers, hospitals, groups, persons, etc. In this article, companies are under focused as non-academic actors in the knowledge network.

The other concept that helps companies to elevate their innovation power and competitiveness in the market is Open Innovation strategies, which is coined by (Chesbrough 2003). Firms can share their own knowledge with other firms (inside-out) or catch knowledge from other firms into their own firm (outside-in). Both of the above concepts want to show the impact of collaboration on fostering firms' innovativeness. But the interactions between these two concepts (to the best knowledge of authors) are still untouched. This article tries to uncover the correlations between Open Innovation practices and connections between firm and its collaborators.

The rest of this article is organized as follows: In section 2, a brief background information about collaboration network and its types, a method of measuring the network characteristics called Social Network Analysis, and some basics of open innovation concept are discussed. Section 3, titled as methodology, describes three phases of the methods have been used for this study. Section 4 is dedicated to three categories of results have been reached in this study. Finally, a conclusion from these results is discussed.

## 2 LITERATURE REVIEW

This section reviews literatures of the collaboration networks and social network analysis as well as Open Innovation concept.

### *2.1 Collaboration networks*

Collaboration network is a network of different actors such as people, companies, universities, etc, which collaborate with each other to achieve common goals (Camarinha-Matos, Afsarmanesh 2005). These actors are geographically distributed. In the firms' environment, recent studies show that innovation processes are becoming more complex every day. So firms cannot innovate individually and just based on their internal knowledge. Nowadays, access to the external source of knowledge is a vital need of any firm to compete with others. This need forces firms to collaborate with the other firms and makes the collaboration network. These network structures are based on alliances, partnerships and collaborations (van Egeraat, Curran 2013). The trend of collaboration shows us that it is becoming more open and more distributed between firms, to extend to which some papers characterized this trend as a transition towards "Open innovation" (Chesbrough 2003) and "Distributed knowledge network" (Asheim, Coenen et al. 2007).

### *2.2 Types of collaboration*

There are several collaboration types between firms, some related to the commercial relations and some to knowledge relations. Co-partnership, co-ownerships collaborative agreements, co-patenting, co-funding, co-managing, strategic alliances, career affiliation networks and co-authorship are some types of collaboration among firms. Table 1 represents these types of relations with their definition.

**Table 1. Types of Collaboration and their Definitions**

| Type of collaboration | Description |
|---|---|
| Co-partnership | Partnership in the same research group or syndicate or alliance |
| Collaborative agreements | Agreements in Licensing, joint venture, supply, R&D, etc. |
| Co-ownerships | Some firms have the same owner |
| Co-patenting | Patents are registered with the names of several firms |
| Co-funding | Firms collaborate in a project or research that is funded by the same source. |
| Co-managing | Firms have the same manager |
| Strategic alliances | Firms collaborate with each other in a strategic alliance to increase their profit or decrease their risks |
| Career affiliation networks | Networks of persons who worked together at one or more firms during their careers |
| Co-authorship | Authors collaborate with each other to write a scientific article. |
| Informal social networks between managers | This kind of collaboration is like informal friendship between managers |

There is one additional type of collaboration which is informal social network between managers which relates to informal friendship between managers of firms. In this article, collaborations between firms in terms of co-authorship of nano-technology articles are discussed.

### *2.1 Social Network Analysis*

Social networks consist of nodes and edges. Nodes represent social actors and edges represent social relationship between each pair of actors in the network. Social networks are analyzed by different types of measures derived from graph theory to show the characteristics of the network. Most of these measures are under the special method called Social Network Analysis (SNA). This tool was just initially used in sociology, but nowadays it is also used as a more technical tool to perform empirical study in the field of social network. This tool maps the relationship between social actors like people, organizations, researchers and even computers. The main application of this method is measuring some metrics of the networks between social actors, such as connections, distributions and segmentation (Wasserman 1994).

There are many measures in the social network analysis. In this paper, one of the most important metrics of SNA called "Degree

Centrality" is used. Degree centrality is defined as the number of ties incident upon an actor or node. This measure indicates the direct collaborative connections between two nodes (companies). The other types of measures in this method can help us to observe the collaborative environment of companies in Canada from indirect perspective. Since the focus of this article is on the direct collaborations, here only degree centrality is used to show the number of direct connections of each company in the network.

### *2.2 Open Innovation*

The concept of open innovation has been defined by Henry Chesbrough in 2003. Based on Chesbrough and Bogers (2014) the definition of Open Innovation is "*a distributed innovation process based on purposively managed knowledge flows across organization boundaries, using pecuniary and non-pecuniary mechanism in line with each organization's business model*." These flows of knowledge may involve knowledge inflows to an organization, knowledge outflows from an organization or both (coupling external knowledge sources and commercialization activities).

#### *2.2.1 Types of Open Innovation*

There are some practices for applying open business model in a firm. These practices are categorized into three different types. The first type of open innovation practices is inside-out (outbound) practices, which allows the firm let unused and unutilized ideas and technologies to be used by other firms and companies for their businesses. The second type is outside-in (inbound) practices, which involves opening up company's own innovation to other companies for any kinds of contribution (Chesbrough 2003). The last type of practices is combined coupled type (Gassmann, Enkel 2004) which is a combined knowledge inflows and outflows between actors in the innovation process. Also, Dahlander and Gann categorized them into two different types of pecuniary and non-pecuniary (Dahlander, Gann 2010).

#### *2.2.2 Open Innovation Practices*

According to different categories of open innovation practices which were discussed in part 2.2.1, there are several practices which companies are applying in their firms to have a higher degree of openness and better impact on the performance of their companies (Chesbrough, Bogers 2014).

#### *2.2.3 Recent studies*

Laursen's research findings suggest that firms who are using more number of sources will be more open than the firms which are not doing so. Also firms who apply search strategies and invest in their R&D are more likely to collaborate with universities than other firms (Laursen, Salter 2004). Firms which are open to external knowledge and search channels are likely to have a higher level of innovative performance.

Vareska van de Vrande et al. (2009) investigate the application of open innovation practices in small and medium sized enterprises (SMEs). They found that SMEs are involved in applying many open innovation practices during the last seven years. They did not find any major differences between manufacturing and service industries. However, medium sized firms are more involved in applying open innovation practices than small sized firms. The reason that SMEs are involved in open innovation is mostly because of meeting customer demands or keeping up with competitors (Van de Vrande, De Jong et al. 2009).

Chesbrough and Brunswicker (2013) designed a survey and in order to understand the main practices, challenges, outcomes, partners, etc. of large firms in United States.

This research will focus on open innovation in Canadian nanotechnology industry. It combines survey data analysis and social network analysis in order to investigate new aspects of open innovation concept.

## 3 METHODOLOGY

This study has been performed in four phases. The first phase consists of collecting Nano-scientific articles information. Using Google Scholar and Scopus, articles in the field of Nano-technology were identified. These data were stored in a SQL database. Focusing on the authors' affiliations, name of the authors who are affiliated with a non-academic institution were extracted. In the second phase, a database were created for Nano-tech companies based on the authors' affiliations. The co-authorship collaboration between each two authors were identified. For each of the co-authorship collaboration between two researchers, this studies assumes that their affiliated companies are collaborating with each other. Based on this data, the collaboration network of researchers from Canadian companies has been constructed. Then, social network analysis has been performed on this network and degree centrality of each company has been measured to compare with the results of the second phase.

In the second phase, using the nanotechnology articles database, the name of authors and their company of affiliation were extracted by MySQL queries. Then the contact information of the non-academic authors' affiliation has been gathered. A stratified sampling method were applied to select the participants of our survey. This sampling method was based on the size of the firms, Large Enterprise (LE) and Small-Medium Enterprises (SMEs). The proportions of each size are almost the same in our sample. A questionnaire has been designed based on Open Innovation concept and was sent to the sample of firms. A survey administration system (Survey Monkey) was used to send the questionnaire and gather the results. A descriptive and inferential statistical analysis have been performed and presented on the responses using SPSS. A new concept is created to measure the importance and frequency of applying OI practices. This index is consist of two parts. The first part is the Likert scores based on the questionnaire, and the second part is based on the answers gathered from the companies. For calculating an index for frequency of applying open innovation practices (OI-Index), the Likert scores were multiplied to weight of each practice which was calculated by factor analysis, Principal Component Analysis (PCA) and added together to reach to a final score for each firms frequency of applying open innovation practices.

Based on the literature review, there are 4 types of open innovation practices, Outside-In Pecuniary (OIP) practices, Outside-In Non Pecuniary (OINP) Practices, Inside-Out Pecuniary (IOP) Practices and Inside-Out Non Pecuniary (IONP) Practices. Since, eleven of the practices which were mentioned in the survey are from pecuniary practices, this research will be focusing on them. Table 2 shows these practices:

**Table 2. Open Innovation Practices**

| Outside-In Pecuniary | Inside-Out Pecuniary |
|---|---|
| Buying a License (P1) | Joint-Venture Agreement (P7) |
| Contract with other companies for R&D services (P2) | Sell New Knowledge developed in R&D to another company (P8) |
| Buying any innovative ideas from start-up companies (P3) | Participating in a business incubator programs (P9) |
| Consulting with any specialized Open Innovation companies (P4) | Selling R&D market ready by-product (P10) |
| Collaborating with students in a research agreement with a university (P5) | Selling license of innovations (P11) |
| Assigning a research fund to an academic institute (P6) | |

The last phase of this research is combining the two previous phases. The aim of this phase is exploring the impact of applying open innovation practices on the number of collaboration of the companies. A regression method has been applied to investigate the OI-Index of each company on its degree centrality.

### *3.1 Data*

There are two sets of data which were used in this research. The first one is the database of Nanotechnology articles extracted from SCOPUS. Based on the affiliations of the authors, we identified the location of the authors and their affiliation type whether it is academic or non-academic. Running a SQL query, only the articles with at least one Canadian-based co-author were selected from our database. By using these records, the co-authorship network of the nanotechnology firms was built. Gephi (a social network analysis software) has been used to analyze the structure of this network.

The frequency of open innovation practices in Canadian nanotechnology industry has been calculated by sending the online questionnaire to the targeted recipients in Canada. The target of this survey was scientists or researchers who are working in nanotechnology field and they have co-authorship collaborations.

There were three main parts in the questionnaire. Size of the firm, asking about the number of employees of each firm and firm's annual revenue range, Frequency of applying inside-out and outside-in practices (Likert scale: Always, Sometimes, Rarely), Change in the outcome of the firms (Likert scale: Increased, Remained the same, Decreased). Twenty four firms, which were in network database, participated in the survey. Figure 1 describes the flowchart of the questionnaire (Sadreddin & Schiffauerova, 2015).

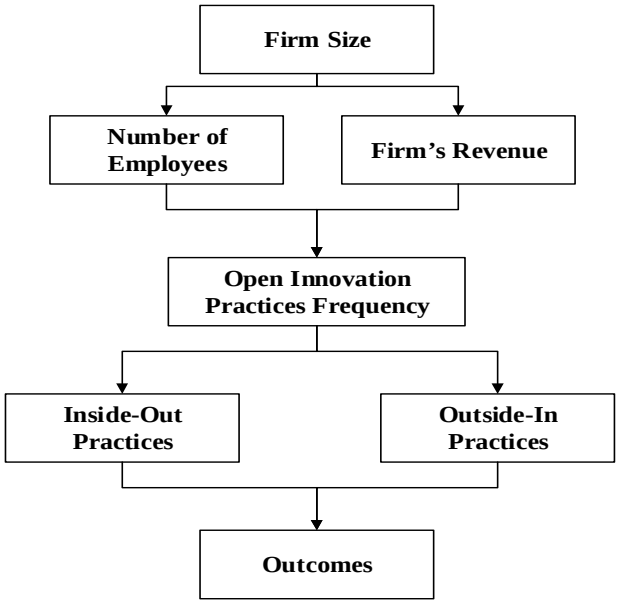


**Figure 1. Questionnaire structure**

## 4 RESULTS

The results of this study are categorized in three parts:

### *4.1 Network characteristics*

The collaboration network was created based on the co-authorship of articles. It is supposed that if researchers from different companies wrote an article together it means that their companies collaborate with each other. The co-authorship data was gathered from 1996 to 2011 across Canada. Finding these co-author relationships resulted in the co-authorship network of Canadian companies. Figure 2 shows this co-authorship network.

**Figure 2. Canadian Nano-tech collaboration network**

In Figure 2 the red nodes represent the companies. The number of companies in our database for constructing the network is 56. However, only 20 companies in our database responded to our questionnaire. Since there are some responses from the same companies, and they should be considered as one response, we consider the average of responses from the same companies.
The green nodes represent academic institutions in this domain which collaborate with the Nano-tech companies in the network. As it can be seen in Figure 2, the network is not connected and there are some sparse collaborations. But the giant component is very big and highly connected.

### *4.2 Descriptive results of survey*

Based on the type of sampling, the proportion of participants in this research according to their firm size is presented in Figure 3.

**Table 3. Firm Size of Sample**

| | | Frequency | Percent |
|---|---|---|---|
| Valid | SME | 12 | 60.0 |
| | LE | 8 | 40.0 |
| | Total | 20 | 100.0 |

In this part, the result of a descriptive statistical analysis on the data has been shown and top open innovation practices with high frequency of applying has been identified.

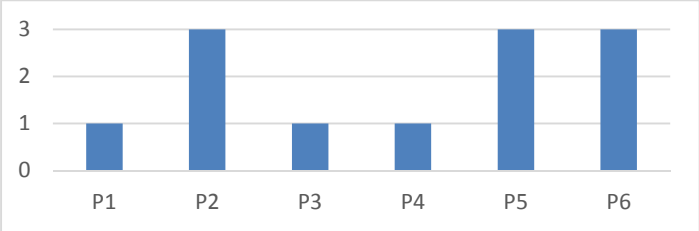


**Figure 3. Outside-In Open Innovation Pecuniary Practices Frequency – Mode**

Figure 4 presents the frequency of applying outside-in open innovation practices. Among 6 outside-in open innovation pecuniary practices, "contract with other companies for R&D services", "collaborating with students in a research agreement with a university" and "assigning a research fund to an academic institute" have the highest frequency of applying in nanotechnology firms.

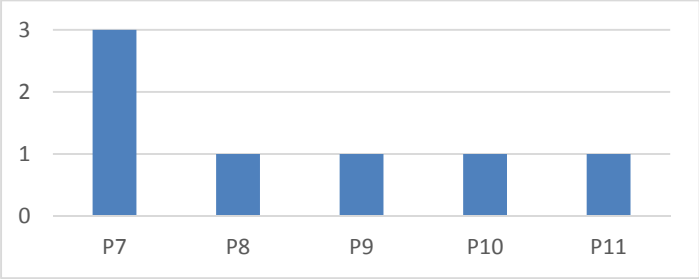


**Figure 4. Inside-Out Open Innovation Pecuniary Practices Frequency – Mode**

Figure 5 presents the frequency of applying inside-out open innovation practices. Among 5 inside-out open innovation pecuniary practices, "joint venture agreement" has the highest frequency of applying in nanotechnology firms.

### *4.3 Open innovation vs Degree centrality*

Polynomial regression applied to the data from open innovation practices of each company and the degree centrality data from their collaboration network. Figure 6 shows the trend of relation between OI-Index which is extracted from applying Open Innovation practices and degree centrality for 20 companies in Nano-technology industry within Canada. The $R^2$ for this regression is more than 0.6 which is acceptable. As it can be seen in the figure the trend is increasing. We conclude that the more Open Innovation practices a company applies in their innovation strategy, the more collaboration with other companies and academic institutions it enjoys.

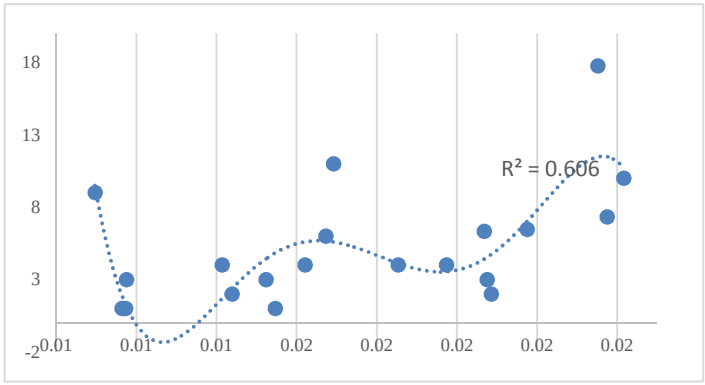


**Figure 5. Open innovation (OI-Index) vs Degree centrality**

## 5 CONCLUSION

The main objective of this study was to investigate the relationship between applying OI practices and the position the companies occupy in the network of their collaborators. We find that a company which uses OI practices more frequently will have more collaborative connections with other companies or universities. This suggests that there is a relation between openness of companies, their readiness to share their knowledge and/or technologies and their interest in collaboration with others. Another interesting conclusion of this study is related to the characteristics of the network of nanotech companies in Canada, which was found to be very sparse, and it was noted that most of the connections are of academia-industry type as opposed to industry-industry type.

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