The Influence of R&D Partnership Network on Firm Performance Based on the Perspective of Social network: The Case of Taiwan LED Sector

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***Abstract*--cholars have drawn on network literature to highlight the importance of external resources available to the firm through its networks. This purpose of this study is to investigate whether the position of R&D partnership network affect the firm performance. Based on this perspective, we examine the effect of the government-sponsored R&D consortia in Taiwan. This kind of policy encourages firms to take part in innovative technology fields, to develop technologies with strong potential for huge economic benefits, and to encourage academia and industry to collaborate and ultimately increase industrial competitiveness. We construct the R&D partnership network in Liquid crystal display (LED) industry by using 140 firms and test the hypothesis by using 60 listed public firms. The results show that firm joined in government-sponsored R&D consortia has better centrality and the structure hole than the others. Result also indicates a positive relationship between centrality, and patent number and structure hole and patent number but the network position of firms did not influence the firm financial performance. This study may lead to better understanding of effect from the government-sponsored R&D consortia and of the relationship between the firm network position and firm performance. The article concludes with implications for theory, research, and practice.**

I. INTRODUCTION

In today's fast-paced advanced technology industries, the innovative capability of a firm cannot be studied without the other external organizational relationships that firms maintain with numerous kinds of partners such as universities, public laboratories, other firms, investors, etc. Academics argue that one of the reasons behind management theory's interest in network today is because of the emergence of 'the new competition' [1]. This concept alludes to the competitive rise over the last two decades of small entrepreneurial firms, of regional districts such as Silicon Valley in California and Prato or Modena in Italy. According to the characteristic of the LED industry in Taiwan, the firms cooperate with external partners is critical to gaining access to information in Taiwan. A firm's partners bring the knowledge and experience they gained from their interactions with their other partners to their interactions with the focal firm and vice versa.

LED sector in Taiwan is an industry that is knowledge based and predominantly composed of small firms involved in R&D. In this field, the formation of alliances is a key factor explaining the survival and growth of smaller LED firms. The old model of organizational form was the large hierarchical firm. These new organizational forms are appealing because of their greater flexibility, adapt ability, and their capacity to circulate intangible strategic resources such as information, knowledge, and skills. Few innovation scan be assigned to a single specific technological field or even a specific firm [2], as it is increasingly recognized that innovation requires the convergence of many sources of knowledge and skills, usually linked in the form of a network. In this respect, innovation networks are widely considered as an effective means of industrial organization of complex R&D processes.

Whereas therefore raises the question that is studied here of how a firm can position itself to access useful knowledge from other organizations to gain innovation benefits and collaboration opportunities. Network position is an outcome of the relationships between actors and is considered a key variable in social network analysis. Social network analysis views the social environment as patterns or regularities in relationships among interacting units. In social network analysis, the observed attributes of social actors (such as innovation, access to resources, and strategy) are interpreted as a function of their location in the network [3].

The goal of positional analysis is to represent patterns of complex social network data in a simplified form in order to reveal access to information and innovation benefits from being centrally embedded in networks. In an attempt to measure differences in the LED sector, the research presented in this article examines specifically the effect of being located in the position of a R&D partnership network on innovation output. This article proposes that while a firm observes benefits from R&D alliances supported from government funds. In this respect, the R&D Partnership network position of a firm could be considered as one of its intangible strategic resources.

In the first portion of this research paper, a theoretical framework revolving around network position and performance is built on the basis of social network and innovation management literature. The theoretical framework then ends with two research hypotheses. The second part of this research proceeds to explain methodological issues. Third, a discussion suggests that by occupying a central position in a R&D partnership network by using social network analysis to measure. To test the hypotheses about the firm is more likely to access useful knowledge from its direct partners and increase performance by using regression analysis.

II. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

A. Network position and firm performance

One important aspect to studying social network is their information collection and processing benefits. These linkages of actors act as a channel of information between the firm [4]. The firms cooperate with external partners is critical to gaining access to information. A firm's partners bring the knowledge and experience they gained from their interactions with their other partners to their interactions with the focal firm [5].

Individual firms can pursue only a limited number of technologies and lines of research, but R&D Partnership network can increase a firm's pool of information and provide important benefits. For example, in R&D Partnership network each additional partner for a firm has can serve as an information filter to absorb, sift, and classify new technical developments in a manner that goes beyond the information-processing capabilities of a single firm [5]. The information collection and processing benefits can influence a firm's innovation capacity and performance. Thus, firms should strategically locate themselves in network positions that allow them access to various types of useful information.

Position describes the pattern of relationships in which an individual actor is involved and that characterizes his/her location relative to other actors in the network. In this research, the positions of LED firms are examined within a network and then related to each individual actor. A very useful method that attempts to describe and measure properties of 'actor location' in a social network is centrality and structure hole.

1. Centrality and Firm Performance

According to the absorptive capacity showed from [6], we assume that actors in social network that are more centrally located accumulate greater knowledge and in a better position to convert this knowledge into further innovations. Powell [7] thought that a network serves as a locus of innovation because it provides favourable access to knowledge and resources. From this study, the result showed that strong-performing LED firms have larger, more diverse alliance networks than weak-performing firms. Centrally located firms, especially within R&D Partnership networks, have access to a greater variety of activities and are better able to locate themselves in information-rich positions. Thus the information that passes through networks is influenced by each participant's position in the network structure. Network centrality measures which organizations are in the flow of information and exchange of knowledge within the network structure. It is generally assumed that R&D Partnership networks foster the conditions for innovation by allowing information sharing and knowledge transfer. Therefore, firms that are more centrally located in R&D Partnership networks have greater access to innovation enhancing knowledge and skills, thus yielding greater probability of innovation output. According to the mention above, this study proposed the first hypothesis in the following:

Hypothesis 1: The centrality of a firm's network position within an R&D Partnership network positively related to its firm performance.

2. Structure Hole and Firm Performance

In a study of alliances over a 20-year period, Gulati [8] examined the main factors that led firms to enter into alliance with one another. His results provided evidence that indirect ties lead to useful information benefits. The results found that firms who were directly unconnected where more likely to enter into an alliance if they had a common partner or were less distant from each other in the R&D partnership network. Thus, indirect ties create a dynamic system for the formation of alliances. Granovetter [8] also argued that structure hole between the partners with weaker ties give greater access to new information and opportunities in his classic article. He also proposes that weak ties serve as bridges to other social groupings holding information and resources. Thus, firms with many weak relations gain speedy advantages in learning about and taking advantage of new opportunities. Hence, a major benefit of structure hole is that they provide a strong form of social capital for access to knowledge and skills and increase the firm performance.

Hypothesis 2: The structure hole of a firm's network position within an R&D Partnership network positively related to its firm performance.

III. RESEARCH METHODOLOGY

This study posited the methodology, sample and data collection in this section at first, and then pointed out the measurement of every variable.

A. Sample and data collection

This research was conducted in the firms of the LED industry in Taiwan. There are 140 Taiwan LED companies to construct the R&D partnership network in the sample of this study. We collect the R&D alliance of each firm from 2001 to 2010. Network affiliation data were collected by search the newspaper and prospectus web of each firm for their strategic partnerships and collaborations (with universities, venture capitalists, manufacturing firms, public and private labs, consultants, equipment suppliers, distributors). We used 60 listed public firms to test those hypotheses. Data were collected on strategic partnerships and collaboration, intellectual property strategy, number of patents, strategic direction, R&D capabilities and projects, and demographic variables.

B. Measurement

1. Dependent variable: firm performance

a. Operative profit margin

The dependent variable of this study is 'operative profit margin'. The data of operative profit margin in this study

were acquired from TEJ database in Taiwan.

b. Patent Counts

Two hypothesis required the linear regression between centrality or the structure hole and the dependent variable firm performance. This variable was obtained by collecting data on the number of patent counts. The patent data of this study was gathered from the United States Patent and Trademark Office (USPTO). These patent data of this study had sufficient information about names of assignees, technical fields, and the issued dates and so on. Patents are a meaningful measure in this industry because they are directly related to inventiveness and they represent an externally validated measure, even if not perfect.

2. Independent variables

a. Degree Centrality

One of the most of used measures of centrality is degree centrality. Degree centrality refers to a count of the number of ties an actor has, meaning the number of organizations the actor is in contact with. An actor with a high centrality level, as measured by its degree, is where 'the action is' in the network. For the structural analysis of the LCD cluster, informants were asked to refer to a list containing all cluster companies, and to indicate which companies they associated with. Based on this information UCINET, a professional software for social network analysis, was used to compute the two sociometric indices "degree centrality" and "coreness", as well as to visualize the network structures. Degree centrality (DC) refers to the extent to which an actor is central to the network, based on the number of ties that it has directly established with other network members. Degree centrality is therefore computed as $DC(n_i)=\Sigma x_{ij}$

b. Structure Hole

The hypotheses required analysing firm centrality within the R&D Partnership network (Salman, 2002). In order to measure the hypotheses, centrality variables for Degree Centrality were calculated using UCINET (Borgatti et al., 2002), a network analysis program that computes network variables using dyadic data. Dyads were measured using the raw data collected about organizational ties between each LED firm and its partners. Firstly, the analysis began by creating two mode data sets of the firm by alliance partner data. Then binary adjacency matrices were manually created for each category of collaboration partner (universities, venture capitalists, public labs, LED firms, consultants, private labs, equipment suppliers, trader, public development organization, distributor, raw materials supplier and manufacturers). Transferred to UCINET, these data were converted into a firm by- firm adjacency matrix by creating ties if firms had alliances with the same third parties. Interestingly, out of these matrices, four had significant information on network ties revealing the main actors of the LED firms' direct networks. These four matrices (Universities, Venture Capital Firms, Manufacturers, and Public Labs) were added together to form one combined matrix. With UCINET, this combined matrix was used to calculate Degree Centrality and Structure hole at the individual level, as well as a network measure of 'centralization' and 'structure hole'. In order to compute regression analysis of Hypotheses 1 and 2, the centrality and structure hole scores of each firm were imported into SPSS to be used for linear regression analysis. And

C. Control variable

The control variable of this study was firm size and R&D intensity. Additionally, firm size is measured by the logarithm of sales and the logarithm the number of employee each firm in this study. Firm size can demonstrate the economies and diseconomies of scale. This study acquired the data of Taiwan LED companies from TEJ.

IV. RESULT

For each of the following regressions performed, the independent variables were Centrality and Structure Hole and the control variables were Logcapital, Logemplogyee and R&D intensity. In addition, the dependent variables were firm performance (measured by number of patents and operational profit margin).

In order to test Hypothesis 1and 2, hierarchical regression analysis was performed using the control variables on the Innovation and then another regression was performed with the centrality and structure hole variables. Results from table 2 reveal a positive relationship between innovation performance and centrality variables and structure hole but not significance positive relationship between operative profit margin and centrality variables and structure hole. The more central a firm in the LED R&D Partnership network, the

TABLE 1 RESULT OF SPEARMAN CORRELATION ANALYSIS

	Centrality	Structure Hole	OPM	Patent counts	Logcapital	Logemployees	R&D intensity
Centrality	1						
Structure Hole	.957**	1					
OPM	0.082	0.054	1				
Patent counts	.455**	.520**	0.095	1			
Logcapital	0.21	.297*	-0.211	0.242	1		
Logemployees	0.172	.297*	-.259*	0.21	.840**	1	
R&D intensity	-0.184	-0.144	.353**	-0.017	-0.166	-0.146	1

$^{+}p<0.1$ $^{**}p<0.05$ $^{***}p<0.01$

TABLE 2 RESULTS OF HIERARCHICAL REGRESSION ANALYSIS

Varialbes	Operating Profit Margin		Patent counts	
	Modle1	Modle2	Modle3	Model4
Centrality	1.415		**3.691*****	
	(.163)		**(.001)**	
Structure Hole		1.308		**4.280*****
		(.196)		**(.000)**
LogCapital	**3.946*****	**4.128*****	-.172	.374
	(.000)	**(.000)**	(.864)	(.604)
Logemployees	**-2.454****	**-2.576****	.821	.199
	(.017)	**(.013)**	(.415)	(.710)
R&D intensity	**3.066*****	**2.993*****	.650	.522
	(.003)	(.004)	(.518)	(.843)
F-value	**62.028*****	**61.647*****	**16.280*****	**18.323*****
P-value	(.000)	(.000)	(.000)	(.000)
$\mathbf{R^2}$	.816	.815	.538	.567
$\mathbf{\Delta R^2}$	.803	.802	.505	.536

$^{*}p$ <0.1 $^{**}p$ < 0.05 $^{***}p$ <0.01

more innovative output it is likely to be. Furthermore, some findings worth noting regarding the control variables were found (refer to Table 2). Firstly, when regression was performed between the control variables and operative profit margin, Logcapital, Logemployee and R&D intensity also had a significant relationship with innovation implying that the greater the firm size, the greater the firm performance. However, regression was performed between the control variables and patent counts, Logcapital, Logemployee and R&D intensity had not a significant relationship with innovation implying that the R&D expense did not influence patent grant of firm.

This research demonstrated that different aspects of being centrally located increased the innovation of a firm. Firms that are high in degree centrality simply have the highest number of connections in the network. Thus, the significant relationship between degree centrality and innovation shows that the number of direct ties significantly increases a firm's innovative capability. The higher a LED firm's degree centrality the more potential knowledge sources the firm has. This external information and knowledge is necessary to generate new ideas and produce innovations. Since innovation is an information intensive activity, highly central LED firms may generate more innovation.

The results of this study suggest that by occupying a central position in an R&D Partnership network, a firm is more likely to access complementary knowledge (scientific and technological expertise) from its direct partners and increase innovation [10].

The theoretical framework suggested that R&D Partnership networks play a significant role in the innovation process. According to this framework, indirect ties serve primarily as a potential channel of communication and interaction between the focal firm and many other firms in the network. Furthermore, according to Granovetter [9], weaker ties can be seen as a tool for monitoring the external environment for complementary knowledge and new opportunities. Theoretically, LED firms with high degree centrality should have access to more knowledge than other actors. This means that LED firms, who are most active in the network in the sense that they have the most ties to other firms, are more likely to gain access to complementary knowledge.

V. CONCLUSION

A growing number of research is under way to examine the impact of network structures on firm performance on the other hand. This study proposed two hypotheses to explore the relationship between firms' position of R&D partnership network and their performance in the Taiwan LED industry. This study found that the firm position indicators mainly represented the quantitative aspect of network benefit, such as centrality and structure hole by using real data. The results of this study indicated that centrality and structure hole of firm in the R&D partnership network was positively associated with its innovative output. Therefore, hypotheses, H1and H2 were significantly supported in this study. This study advances existing knowledge by proposing a framework which sees a firm's innovation performance as an outcome of both its network managerial abilities and network location.

TABLE3 THE RESULT OF THE INFLUENCE OF FIRM POSITION ON PERFORMANCE

H0	Relationship	Test Result	Result
H1	Degree Centrality→ Operating Profit Margin	**Accept Ho**	**Partial Supported**
	Degree Centrality→ Patent count	**Reject Ho**	
H2	Structure Hole→ Operating Profit Margin	**Accept Ho**	**Partial Supported**
	Structure Hole→ Patent count	**Reject Ho**	

The ability to access this information is an effective source of competitive advantage. By examining the pattern of R&D Partnership network interactions between firms, this research shows that being located in a central position and have much structure hole leads to have more patent. Although previous research has elaborated the concept of organizational learning, this research adds little systematic understanding of the social processes that underlie how firms learn from each other and how firms activate this intangible resource of being centrally but indirectly linked to strategic sources of knowledge.

Innovation also requires the development of informal structures such as indirect ties to other firms, which create access to information and skills beyond those available from the immediate alliance partner. All together then networks in the LED sector combine rational and natural elements of organization to produce innovation outcomes.

One limitation of this study was that not all patentable inventions were patented. In some cases, firms protect their innovations with other alternatives such as trade secrets. When technologies are very difficult to copy, patenting is not always worthwhile and adopting trade secrets is a good alternative. Future studies can focus on this issue, and fill this research gap.

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