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# Is Informal Networks Influence Technological Innovation of R&D Team Member: A Topology, Measurement, and Consequences

Chen Ming, Hung

Dept. of Information and Electronic Commerce, Kainan University.

7 Fl. 8, No. 112, Ta-Tung Rd, Taoyuan City 33065, Taiwan, ROC

Tel.: 886-3-338-0743 E-mail: frhung@libra.seed.net.tw

**Abstract**

The management of the social networks of individual technological innovation has been hampered by the lack of a comprehensive typology for categorizing of social networks. Based on social support and social exchange theory, this study develops a social networks typology that identifies three constructs type of social networks. This study also point to limitation with the measurement of individual innovation and outline the five constructs design to overcome these limitations. The study then examines the relationship between social networks and technological innovation. The results suggest that technological innovation was significantly influenced by the informal centrality and tie strength of all three social network types. Furthermore, the relationship can be explaining more variance by adding specificity asset as positive moderate variable. The theoretical framework of this study brings informal social network phenomenon into technological innovation management in individual level. Both the typology for conceptualizing the nature of social networks and the constructs for scaling the measurement of technological innovation of this study provide a solid foundation on exploring the application in new contexts.

**Keywords:** Technological Innovation, Social Network, Specificity Asset

## 1. Introduction

Innovation is no longer conceived as a discrete isolated event, but is rather considered as a knowledge-based interactive process (Landry et al., 2002). Literature has empirical indicated "social network" is optimum tool for accessing the latent knowledge (Hansen, 1999). The latent knowledge was transferred to new product manufacture procedure through interact learning and resource exchanging among strategic alliance partner (Deeds and Hill, 1996).

In the model of technological innovation proffered by sociology, one research goal is to demonstrate the influence of informal social network on technological innovation. But as often noted by sociologists, research issues were emphasized on qualitative study of organizational level (Siu and Bao, 2008; Higgins and Kram, 2001; Tsai and Ghoshal, 1998). Seldom researches pay attention to whether individual technological innovation was influenced by operating of informal social network. The management of the social networks of individual technological innovation has been hampered by the lack of a comprehensive typology for categorizing of social networks. Based on social support and social exchange theory, this study categorizes the concept of social network into three constructs typology that is job, consult, and trust.

This study points to limitations with measuring of individual innovation and outline the construct design to overcome these limitations. It also point out the explaining of individual innovation by network centrality and tie strength. Integrating vision image of macroscopic sociology theory (Wasserman and Faust, 1994) and sociometric analysis of microcosmic sociology theory (Scott, 2000), the present work confirms the effects of three constructs typology on technological innovation. Social network analysis (SNA) was used to analysis how technological innovation was quantitatively influenced by social network centrality and tie strength among team member. Furthermore, the relationship can be explaining more variance by adding specificity asset as positive moderate variable.

To these ends, the remainder of this paper is organized as follows. In next section, the variables with constructs were designed and the arguments sketched above were developed in more detail. After inferencing hypotheses about the relationship between social network and innovantion, a test is presented by using data from IC design house in Taiwan. Its global scale (only smaller than design house in U.S.A.) enhances the value of study. As explained below, test results strongly support the argument.

## 2. Literature Review and Variable Design

The literatures on relationship between social network and innovation outcomes were reviewed to develop the research variables and assign their constructs.

### *2.1 Literature Review and Variable Design*

The variables and conclusions of main researches on relationship between social network and innovation outcomes are presented in Table 1, where all literatures treated firm as variable level. Since, this study pays attention to whether individual technological innovation was influenced by his social network. So, individual team member was treated as variable level.

Table 1. Literature Review on Relationship Between Social Network (IV) and Innovation Outcomes (DV)

| Level | Social Network (IV) | Innovation Outcomes (DV) | Correlation | Scholar (year) |
|---|---|---|---|---|
| Firm | Number of tie | Patent outcome | Positive | Sampson (2007) |
| Firm | Number of tie | Patent apply | Positive | Ahuja (2000) |
| Firm | Number of strategic alliance | Patent apply | No | Deeds and Hill (1996) |
| Firm | Number of strategic alliance and patent | New product to market | Positive | Deeds and Hill (1996) |
| Firm | Social interaction and relationship trust | Product innovation | Positive | Tsai and Ghoshal (1998) |
| Firm | Relationship trust | New product development | Positive | Rindfleisch and Moorman (2001) |
| Firm | Network relational embeddedness | New product to market | Negative | Hansen (1999) |
| Firm | Relationship trust | New product development | Negative | Yli-Renko et al. (2001) |
| Firm | Trust | New product to market | No | Landry et al. (2002) |

Source：this research; IV: independent variable; DV: dependent variable;

For designing dependent variable, both patent (Ahuja, 2000; Deeds and Hill, 1996) and new product (Sampson, 2007; Deeds and Hill, 1996; Rindfleisch and Moorman, 2001; Tsai and Ghoshal, 1998; Yli-Renko et al., 2001; OECD, 2002) were treated as innovation outcome in Table 1. Since, patents legally play a supporting role to protect intelligence assets and new product plays the leading role of innovation (OECD, 2002) in firms. Thus, this study treat patent as construct of specificity asset and adopted technological innovation as dependent variable. While, New product development was treated as construct of technological innovation.

For designing independent variable, both number of tie (Ahuja, 2000; Deeds and Hill, 1996; Sampson, 2007), relational embeddedness (Hansen, 1999), social interaction (Tsai and Ghoshal, 1998), and relationship trust (Landry et al., 2002; Rindfleisch and Moorman, 2001; Tsai and Ghoshal, 1998; Yli-Renko et al., 2001) were treated as independent variables in table 1. Analyses described in following section suggested that the last two variables "social interaction" and "relationship trust" (corresponds to type of social interaction) could be further reorganized as three constructs categories of social network that are job, consult, and trust interaction. According to social network theory (Burt, 1992; Coleman, 1988; Granovetter, 1973; Scott, 2000), the first two variables "number of tie" and "relational embeddedness" (corresponds to structure of social link that contain only quantity and roughly relationship information of social link) were replaced by "network centrality" and "tie strength" as two independent variables of this study. Such that both direction, quantity and strength information of social link can be further contained. Thus, the independent variable of this study consists of centrality and tie strength, each involves job, consult, and trust interaction of R&D member's social network.

For research conclusion, current literatures focus on two categories relationships that are number of tie and patent, trust and new product. For the relationship between number of tie and patent, positive correlation (Ahuja, 2000; Sampson, 2007) and no correlation (Deeds and

Hill, 1996) are supported by some scholarships. For the relationship between trust and new product, positive correlation (Rindfleisch and Moorman, 2001; Tsai and Ghoshal, 1998), negative correlation (Hansen, 1999; Yli-Renko et al., 2001), and no influence (Landry et al., 2002) are supported by some scholerships. Both prove that there is no consistency conclusion viewpoint in literatures for the relationships among variables. Thus, this study tries to identify the consistency relationship between social network (i.e., centrality, tie strength) and technological innovation in individual variable level.

### *2.2 Constructs of Social Network*

For definition, R&D team is the combination of two or more members with specialty technology, they join together and mutually coordinate to develop new product (or new manufacture procedures) (Cohen and Bailey, 1997). To provide a more suitable typology of social interaction among team member, the relationship between innovation process and social network theory (Burt, 1992; Coleman, 1988; Granovetter, 1973; Scott, 2000) was investigated. Innovation process is a knowledge-based problem-solving process (Dosi, G., 1982) that reaches the specifications of new product by providing new manufacture procedure. The social network theories of innovation are based on two old ideas and a new insight. The ideas are that innovation is determined by research (borrowed from the engineering theory of innovation), and by disorderly interaction processes among actors (borrowed from the technical network theory of innovation). The insight is that knowledge plays a more and more crucial role in fostering innovation (Landry, 2002).

In this study, three constructs job, consult, and trust network were proposed to echo the ideas and insight:(1) job network corresponds to engineering theory of innovation, involving process flow of R&D job; (2) consult network corresponds to technical network theory of innovation, involving solution providing of R&D bottleneck problem; and (3) trust network corresponds to knowledge share, involving psychological or emotional comfort due to social support and resource exchange.

The job network that builded by engineering flow path is the most basic construct of social network to influence the problem-solving process of technological innovation. The specialty technology of IC design build high search and dialogue cost that can be reduced by consult network and trust network. The consult network that interacts through technical network contributes the path of social support to reduce the search cost of technological innovation. The trust network that builded by ability, reputation, and integrity contributes to knowledge share and exchange that reduce the dialogue cost of technological innovation (Rindfleisch and Moorman, 2001; Tsai and Ghoshal, 1998). Hence, job, consult and trust network were treated as three networks constructs that influence technological innovation in this study.

### *2.3 Constructs of Specificity Asset*

The organization level specificity asset in current literatures consists of physical assets and intelligence capital. Individual level specificity asset lays more emphasis on the importance of the intelligence capital (that is patent, thesis, and seniority) rather than physical assets that create little value on individual level of specificity asset (Landry, 2002; Blind et al., 2009).

Though, both patent and thesis were treated as objective criteria to evaluate the intelligence capital of IC design house (Lee and Tunzelmann, 2005). But, literature shows an innovation process occurring primarily from patent cited rather than thesis cited (Blind et al., 2009). Moreover, the interviews of this study show the development of patent requires deeply involving in present manufacture procedure that facilitate to better technological innovation performance. Hence, this study excludes thesis and treated patent as one construct of specificity asset.

The growing importance of seniority as a determinant of specificity asset can be explained by long-term accessing internalized technology and deep introspecting on problem-solving process (Landry, 2002). Specialist stager always has competitive advantage to identify the similarities between current knowledge and innovation problem. That facilitates to accumulate the specialty knowledge and sense making to integrate better resource on innovation (Haldin-Herrgard, 2000; Ibarra and Andrews, 1993). Hence, this study treated seniority as another construct of specificity asset.

### *2.4 Constructs of Technological Innovation*

The technological innovation used in current literatures consisted of both individual and organization level. In individual level literatures, "depth, correlation, contribution, and satisfaction" were adopted to design the constructs of technological capacity for new product development (Clark and Wheelwright, 1993). As satisfaction represents pure subjective perceiveness that has little relationship with objective measurement of technological innovation. Thus, "depth, correlation, contribution" were considered some associated with individual member's technological innovation. According to the "annual survey and analysis report of IC design house in Taiwan" surveyed by "electronics engineer collection" on website http://www.eettaiwan.com, the top two item (i.e., "schedule reduce" and "cost down") of "design challenge count down of IC engineer" were picked to enhance the concrety and fitness of "contribution".

In organizational level literatures, "technological capacity, time to market, competition, profit rate, market development, market share, technological authorization, technology award, medium exposure, etc" were adopted to design the constructs of new product development (http://www.eettaiwan.com; Song, et al., 2008). The last seven items (that is profit rate, …, medium exposure) come from the cooperation by all team members were be excluded from individual level construct. While "technological capacity" and "time to market" corresponds to "depth, correlation, and schedule reduce" in the above paragraph, "competition" were added as constructs of new product development associated with current competititor. And "Growth" was further added corresponds to show the innovation potential compare with future competititor (Clark and Wheelwright, 1993; Deeds and Hill1, 1996). Therefore, "depth, correlation, contribution, competition, and growth" consists of overall constructs of the technological innovation in this study.

## 3. Research Design

### *3.1 Inference for Relationship Between Social Network and Technological Innovation*

Based on innovation process, the research design inference that how constructs of each independent variable explaining the influence of social network on innovation. Since within a team all members located in same environment to achieve same project such that this study assume job complexity and environment uncertainty did not result in any difference between individual member.

3.1.1 Social Network Centrality

In Table 1, some researches point out the quantity of strategic alliance conduces to new product development (Deeds and Hill, 1996; Tsai and Ghoshal, 1998). This study applies the relationship to individual level technological innovation of R&D team member. Moreover, based on engineering theory (corresponds to job network) and technical network theory (corresponds to consult network), technological innovation was further explained by combinations of direction information of social link in conjunction with quantity information of social link (Dosi, G., 1982; Edquist, C., 1999; Landry, 2002; Haldin-Herrgard, 2000; Ibarra and Andrews, 1993).

Quantity information describes the position of R&D member in technological network (Burt, 1976; Coleman, 1988; Granovetter, 1973; Scott, 2000). Fewer quantity of social link corresponds to edge position that conduce invalid path to acquire new technology. Larger quantity of social link corresponds to central position that conduce shorter path to acquire resource that facilitate to solve design problem effectively.

Direction information of social link describes the synergy of knowledge on problem solving. Though, direction information of network centrality contains "indegree centrality" and "outdegree centrality" each adopted by some literatures (Freeman, 1979; Tsai, 2001). "Indegree centrality" was adopted in this study because it agrees with problem-solving process that needed for technological innovation.

Hence, this study adopted network centrality as independent variable such that direction information was added into quantity information to describe the relationship between social network and the flow efficiency of technological knowledge that is higher network centrality facilitate to better innovation performance. Therefore, the hypothesis of social centrality in matter of innovation is that:

$H_{1a}$ ($H_{1b}$, $H_{1c}$)：Greater job (consult, trust) network centrality among R&D team member will be associated with higher technological innovation.

3.1.2 Social Network Tie Strength

Though, previous researches strong suggest that innovation was influenced by social tie (Hansen, 1999; Yli-Renko et al., 2001; Rindfleisch and Moorman, 2001; Tsai and Ghoshal, 1998; Scott, 2000). However, it raising the concerns whether strong tie theory or weak tie theory play the key role to influence innovation.

Weak tie advantage theory point out the low maintain cost of weak tie may expand the scope of network and possess larger information benefit that increasing the performance of new product development (Granovetter, 1973). Some literatures in Table 1 support weak tie advantage theory (Hansen, 1999; Yli-Renko et al., 2001), consider the technology was negatively influenced by tie strength of social network.

Strong tie advantage theory point out the basis of mutual trust among team member results in effective communication and brings better social support. Table 1 has literatures respond to strong tie advantage theory, considering interaction of trust among organizations positively influence on new product development (Rindfleisch and Moorman, 2001; Tsai and Ghoshal, 1998).

This study considering the within team interaction behavior is strong tie with fixed scope of network such that social support positive influence the performance of new product development. So, the strong tie advantage theory was adapted to inference the relationship between tie strength and innovation. Hence, hypothesis $H_{2a}$, $H_{2b}$, $H_{2c}$ were proposed correspond to job, consult and trust social network：

$H_{2a}$ ($H_{2b}$, $H_{2c}$)：Greater job (consult, trust) network tie strength among R&D team member will be associated with higher technological innovation.

*3.2 Inference for Moderate Effect of Specificity Asset*

The inference in previous section was solely based on the influence of social network on innovation that can be further inferenced by considering the synergy of interact effect between specificity asset and social network. The individual member's specificity asset can be identified through consistent and recurring social relations. That increases the legitimate of high pay (Tsai and Ghoshal, 1998) and inspires his motivation of innovation. The member with high specificity asset is easy to occupy central position in network and possess more social interactions (Freeman, 1979).

The innovation problem solving process requires looking forward to other specialist stager for knowledge supporting and resource exchanging. To reduce search cost and dialogue cost, R&D member himself also needs specificity asset. The efficiency of social support and resource exchange among R&D members contribute the main role to technological innovation (Williamson, 1975). Thus, ''facilitate to better innovation performance".

Therefore, the overall description of specificity asset in the matter of innovation is that "specificity asset sufficiently influences the strength of relationship between network centrality (or tie strength) and technological innovation". Hence, this study inference：

$H_{3a}$ ($H_{3b}$, $H_{3c}$)：Greater job (consult, trust) network centrality among R&D team member will be associated with higher technological innovation with specificity asset as positive moderate variable.

$H_{4a}$ ($H_{4b}$, $H_{4c}$)：Greater job (consult, trust) network tie strength among R&D team member will be associated with higher technological innovation with specificity asset as positive moderate variable.

### *3.3 Qualitative Interview and Operational Definitions*

Twenty-five respondents in-depth semi-structured of qualitative interviews were conducted in accordance with three applications categories: computer, consumer, and communication throughout the IC design houses in Taipei Neihu Technology Park and Hsinchu Science Park area. Ten among the sample were owners or manager; the remainders were R&D team members. Discussions focused on areas including company profiles, new product roadmap, innovation processes, and social relations of teamwork mechanisms. Responses were recorded during the interviews and extensive observations were made by multiple visits. Responses and observations were then coded and categorized into the following topic areas: the R&D member's use of and reliance on networks, links among team member, the ways to establish trust in team cooperation, and recent innovations in the firm's operations.

The operational definitions were adapted from both the theory of sociology, the second edition of the Oslo Manual, and included the specifically defined by qualitative interview. Both social network centrality and tie strength contain three constructs, job, consult, and trust. Each operational definition corresponds to "The colleague who you must closely communicate, coordinate, co-operate for R&D work", "The colleague that inquire technological problem to you" (Ibarra, 1993), "This colleague is a partner with stable and reliable cooperation".

The operational definition of five construct (i.e., depth, correlation, contribution, competition, and growth) of technological innovation corresponds to "solve important problem", "outcome can drive new product development", "outcome can drive cost down and schedule reduction", "outcome can make product leads competitor", "relative higher growth in technological innovation".

Specificity asset contains two constructs, patent and seniority. Quantity and citation were designed as two operational definitions of patent. Citation means to cite other people's IP, authorization, or know how. Team seniority, firm seniority, IC design seniority were designed as operational definitions of seniority. Based on operational definitions, the questionnaire was developed in individual level of social network construct. A trial team was used to adjust the content of each question item.

## 4.Data Collection, Coding, Analysis, and Hypothesis Test

Statistical associations were analysis to test the influence of social networks on innovantion. Beyond these associations, a moderate effect was constructed based on interaction of each member's specificity asset and the quality of his social networks.

### *4.1 Data Collection*

The data this study used was provided by collection of 247 IC design houses listed on Taiwan semiconductor almanac 2006. Sampling was achieved through direct contact to each firm's owner or manager listed on the almanac. Having excluded firms that were impossible to reach after more than 5 touches, or respondents go abroad for long periods of time, the actual population firms was 121. Out of this effective population, 107 firms refused to answer the survey for confidence concern, questionnaires of 4 firms were not completed. From November 2007 to March 2008, questionnaires of 10 firms were completed and usable.

The questionnaire contains not only items describing answer's own attitude, but also items describing social interact among the answers. The confidential concern explaining many firms refused to answer the questionnaire. Different from attitude scale item, all team members need answer social network item at same time. Due to industry competition, most IC design engineers are with heavy job and on critical schedule. The difficult that coordinate all team members to answer the questionnaire at the same time also explained why so many firms refused to answer the survey.

Double blind design is adopted for validity consideration. A prompt card marked code of each team member is provided with questionnaire, such that each member can used concert code to answer the social network item.

The questionnaire data were coarsely coded in relation to numerical sociomatrix (Scott, 2000). A second pass through the initial codes was then used to calculate scores representative the measure data of independent variables (i.e., centrality and tie strength), moderate variable (i.e., asset specificity) and dependent variable (i.e., technological innovation). Detail criteria and methods used to code and score particular variables are provided below on the variable measurement section.

*4.2 Variable Measurement*

Centrality and tie strength were measured by question items of social network. Each member cross compares the interactive behavior's priority order of all other members, then select top three to answer the social network item in ordinal scale. So, the answer of social network item contains link and order information. Link information was used to measure centrality and order information was used to measure tie strength. Specificity asset was measured by question items of Likert five scales. The value of overall Cronbach's α was 0.69 which confirmed reliability of the Likert five scale items. The data among specialty seniority, firm seniority, team seniority confirmed logicality of seniority items.

The measurement developed for the moderate variable, specificity asset of *i'th* team *j'th* member, $M_{ij}$ is:

$$M_{ij} = \sum_{l=1}^{m} \varpi_l P_{ijl} + \sum_{k=1}^{3} \varpi_k S_{ijk} \qquad (1),$$

where $m$ is quantity of the apply patent; $P_{ijl}$ is the $l$'s patent with contribution ratio $\omega_l$ as weighting factor; $S_{ijk}$ is seniority with weighting factor $\omega_k$; Subscript $k$ is assigned as 1,2,3 corresponds to specialty seniority, firm seniority, and team seniority. According to result of interview, the recent year was treated as the measurement time interval for technological innovation, social network, and patents apply.

The measurement of independent variable, used the link information in items of social network, network centrality of *i'th* team *j'th* member, $C_{ij}$ is

$$C_{ij} = \sum_{k=1}^{N_i} \frac{Z_{ijk}}{N_i - 1} \qquad (i = 1,2,\ldots N, j = 1,2, \ldots, N_i, k = 1,2, \ldots, N_i, j \neq k) \qquad (2),$$

where $N$ is quantity of total team; $N_i$ is quantity of total team member of *i'th* team; $Z_{ijk}$ denotes the link relationship between team member $j$ and $k$, while $j \neq k$ exclude the link with himself. For example, the item used to access link relationship of consult network is: The colleague that inquire technological problem to you. If member $k$ ask technological problem to member $j$, $Z_{ijk}$ denotes 1, otherwise, the value of $Z_{ijk}$ is 0.

The measurement of independent variable, tie strength, used order information of the same item as question of centrality. The tie strength of *i'th* team *j'th* member, $T_{ij}$, is

$$T_{ij} = \frac{1}{N_i - 1} \sum_{k=1}^{N_i} \frac{1}{O_{ijk}} \qquad (i = 1,2,\ldots N, j = 1,2, \ldots N_i, j \neq k) \qquad (3),$$

where $O_{ijk}$ is the value of ordinal scale denotes by member $k$. Higher priority contributes stronger tie strength.

The measurement for dependent variable, technological innovation, contains self-evaluation items, $Q_{ijl}$ and cross-evaluation items, $R_{ijm}$. The technological innovation of *i'th* team *j'th* member, $Y_{ij}$, was calculated by

$$y_{ij} = \omega_1 \sum_{l=1}^{L_{ij}} Q_{ijl} + \omega_2 \sum_{k=1}^{N_i} \sum_{m=1}^{5} \frac{1}{R_{ijm}} \qquad (i = 1,2,\ldots N, j = 1,2, \ldots N_i, j \neq k) \qquad (4),$$

where $\omega_1$ shows weighting of self-evaluation item; $L_{ij}$ shows total number of new product; $Q_{ijl}$ shows contribution percentage ratio on *l'th* new product; $\omega_2$ shows weighting of cross-evaluation item. $R_{ijm}$ denotes ordinal scale of the team member for the *m'th* construct (i.e., “depth, correlation, contribution, competition, growth”).

### *4.3 Sociogram*

Consisting of node (i.e., R&D team member) and connection line, the sociogram provided key role to understand macro-level structure of social network and micro-level interactive behavior among each team member (Wasserman and Faust, 1994). The connection line in sociogram primarily involves the link and direction interact relationship between nodes. The arrow point shows the accept side of interaction. No connect line between two node means no interact relationship (Cohen and Bailey, 1997). Loading the data in sociomatrix into the worksheet of UCINET SNA software (Borgatti, 1999), then using its plot function to plot sociogram and summarizes in Figure 1 for all team with three network types in this study. Where, the numerical text beside node marked team code following by member code.

Using the sociogram of team 6 as an example to describe the link between macro-level structures of social network and micro-level interact among team member. The connection line shows job network concentrate on member 4,5,8,9,11 (figure 1: work_6), while consult and trust network concentrate on member 5,7,8,9,11 (figure 1: consult_6b, consult_6c). The intensity of connection line shows job and consult network owns more interact behavior than trust network. That confirms the core concept of "constructs of social network" section that is trust network was builded through long-term good interaction in job and consult network.

*4.4 Hypothesis Test*

SPSS statistics software was used for hypothesis test. Results of the regression analysis of hypothesis 1 and 2, that is the support test about whether social network influence on technological innovation, are summarized in Table 2. Overall, all values of F test are larger than 45 that indicates there are enough difference between variation among group and variation within group. Likewise, all t value are larger than 6.7. That shows compare with variation, there is enough difference between the average values of each group.

The P values in first three row of Table 2 are all smaller than 0.01. The value of corresponding standardized coefficient $\beta$ are larger than 0.615. The values of adjusted $R^2$ are quite reasonable for more than 37% variation explanation. All these values suggest that network centrality influence on technological innovation with positive correlation relationship. Consequently, the regression analysis shows hypothesis 1 is supported at 1% significant level.

As can be seen in the last three row of Table 2, three P value are smaller than .05 with the corresponding standardized $\beta$ coefficient greater than 0.671. That shows positive correlation between three independent variable (i.e., TSJ, TSC, TST) and technological innovation. The adjusted $R^2$ take values of 64.1%, 44.2%, and 62.4%, respectively. That provides the variation of tie strength has stronger explanation ability to the variation of technological innovation than centrality does. Hence, hypothesis 2 is supported at 5% significant level.

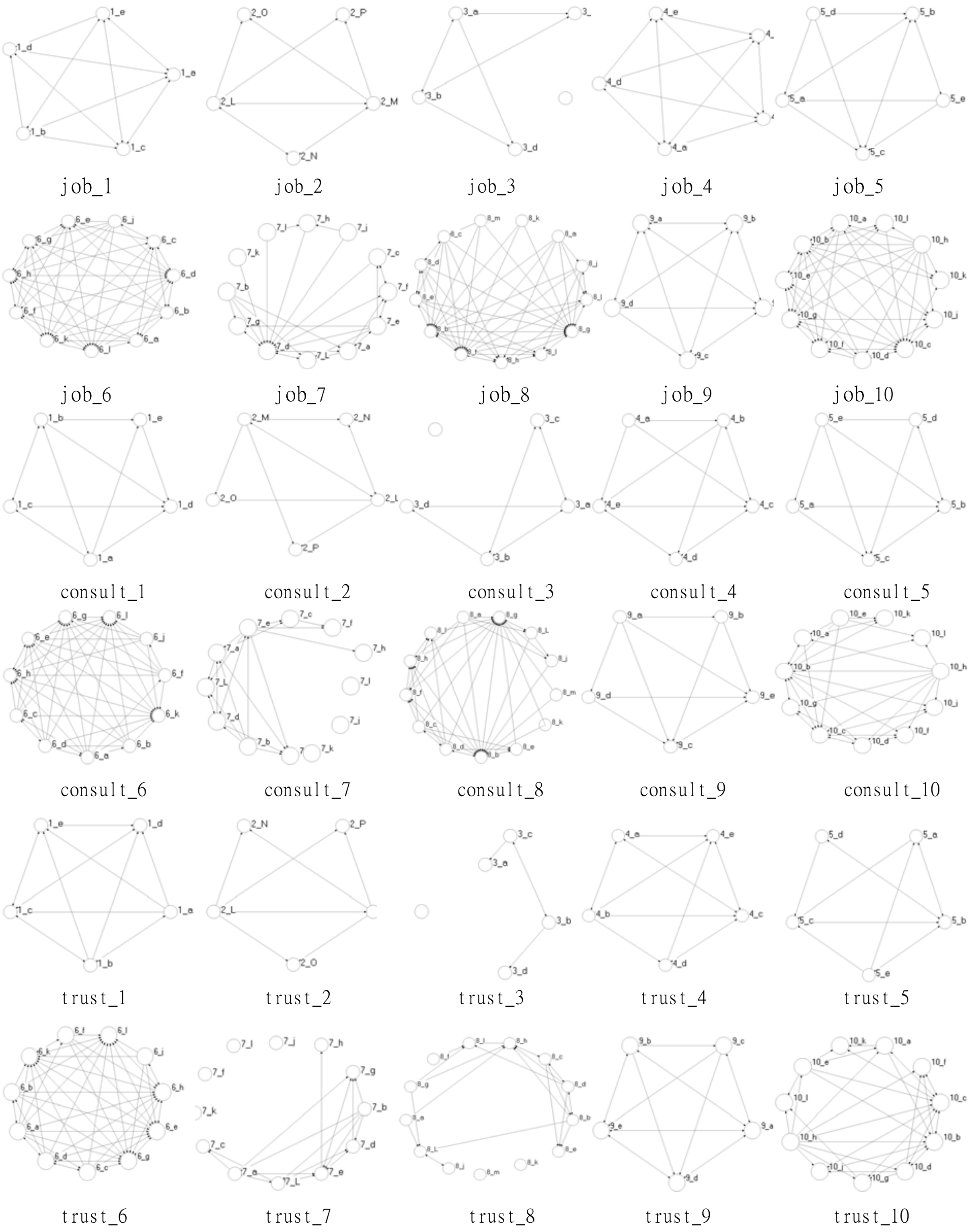


Figure 1. The Sociogram of Each Team for This Study

Table 2. Regression Analysis for the Influence of Social Network on Technological Innovation

| DV | IV | β | t | Adjusted $R^2$ | F | Significant | Test result |
|---|---|---|---|---|---|---|---|
| TI (Y) | Constant | | 14.003 | 0.37 | 45 | 0 | Support $H_{1a}$ |
| | CJ ($X_{111}$) | 0.615 | 6.708 | | | | |
| TI (Y) | Constant | | 18.176 | 0.498 | 75.408 | 0 | Support $H_{1b}$ |
| | CC ($X_{112}$) | 0.71 | 8.684 | | | | |
| TI (Y) | Constant | | 16.165 | 0.386 | 48.124 | 0 | Support $H_{1c}$ |
| | CT ($X_{113}$) | 0.628 | 6.937 | | | | |
| TI (Y) | Constant | | 2.38 | 0.641 | 135.059 | 0.02 | Support $H_{2a}$ |
| | TSJ ($X_{121}$) | 0.804 | 11.621 | | | | |
| TI (Y) | Constant | | 3.205 | 0.442 | 60.445 | 0 | Support $H_{2b}$ |
| | TSC ($X_{122}$) | 0.671 | 7.775 | | | | |
| TI (Y) | Constant | | 2.453 | 0.624 | 125.26 | 0 | Support $H_{2c}$ |
| | TST ($X_{123}$) | 0.793 | 11.192 | | | | |
| CJ: centrality of job network; CC: centrality of consult network; CT: centrality of trust network; | | | | | | | |
| TSJ: tie strength of job network; TSC: tie strength of consult network; TST: tie strength of trust network; | | | | | | | |
| TI: technological innovation; | | | | | | | |

To study the moderate effect, two multi-regression equations were preceded for hierarchical regression test. Equation 5 consisted of two independent variables (i.e., social network $X_1$ and specificity asset $X_2$) and one dependent variable (i.e., technological innovation, $Y$). Adding interaction term $X_{1ij}X_2$ (the product of centrality $X_{1ij}$ and specificity asset $X_2$) into equation 5, equation 6 becomes multi-regression equation with three independent variables.

$$Y = \beta_{0ij} + \beta_{1ij}X_{1ij} + \beta_{2ij}X_2 + \varepsilon_{1ij} \qquad (i = 1,2; j=1,2,3) \quad (5);$$

$$Y = \beta_{0ij} + \beta_{1ij}X_{1ij} + \beta_{2ij}X_2 + \beta_{3ij}(X_{1ij}X_2) + \varepsilon_{2ij} \qquad (i = 1,2; j=1,2,3) \quad (6);$$

Where subscript *i* is assigned as 1,2 corresponds to network centrality ($X_{11j}$) and tie strength ($X_{12j}$); Subscript *j* is assigned as 1,2,3 corresponds measurement of job, consult, trust network; $\varepsilon_i$ denotes the error term; $\beta_0$, $\beta_1$, $\beta_2$ are the coefficients.

In case regression test accept equation 5 and 6, and $R^2$ value of equation 6 is larger than $R^2$ value of equation 5 (i.e., $\Delta R^2 > 0$), the moderate effect of $X_2$ on relationship between $X_{1ij}$ and $Y$ was tested and verified. Positive $\Delta\beta$ (i.e., $\beta$ value of equation 6 is greater than $\beta$ value of equation 5) corresponds to positive moderate effect. Negative $\Delta\beta$ corresponds to negative moderate effect.

For each construct of social network, the regression analysis for both equation 5 and 6 were preceded separately. Table 3 summarizes moderate effect test results of specificity asset.

For variation analysis, all F values are lie in interval 18~69.4. That shows there is enough difference between variation among group and variation within group.

Table 3. Moderate Effect Test on Specificity Asset

| | Regression analysis of equation 5 | | | | | | | Regression analysis of equation 6 | | | | | | | Test result |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DV | IV | β | T | P | $R^2$ | F | P | IV | β | T | P | $R^2$ | F | P | |
| TI | Constant | | 13.96 | 0 | | | | Constant | | 10.59 | 0 | | | | Support $H_{3a}$ ($\Delta R^2$=.029 Increase7.5%) ($\Delta\beta$=.295 Increase 53.2%) |
| | CJ | 0.554 | 5.763 | 0 | | | | CJ ($X_{111}$) | 0.849 | 5.08 | 0 | | | | |
| | SA | 0.177 | 1.84 | 0.07 | 0.389 | 24.9 | 0 | SA ($X_{21}$) | 0.744 | 2.64 | 0.01 | | | | |
| | | | | | | | | $X_{111}*X_{21}$ | 0.748 | 2.137 | 0.036 | 0.418 | 18.9 | 0 | |
| | | | | | | | | | | | | | | | |
| TI | Constant | | 16.44 | 0 | | | | Constant | | 13.1 | 0 | | | | Support $H_{3b}$ ($\Delta R^2$=.014 Increase2.8%) ($\Delta\beta$=.163 Increase23.5%) |
| | CC | 0.695 | 7.392 | 0 | | | | CC ($X_{112}$) | 0.858 | 6.56 | 0 | | | | |
| | SA | 0.032 | 0.345 | 0.731 | 0.492 | 37.3 | 0 | SA ($X_{21}$) | 0.299 | 1.69 | 0.096 | | | | |
| | | | | | | | | $X_{112}*X_{21}$ | 0.4 | 1.767 | 0.081 | 0.506 | 26.6 | 0 | |
| | | | | | | | | | | | | | | | |
| TI | Constant | | 14.46 | 0 | | | | Constant | | 11.69 | 0 | | | | Support $H_{3c}$ ($\Delta R^2$=.023 Increase6.0%) ($\Delta\beta$=.202 Increase34.2%) |
| | CT | 0.59 | 5.653 | 0 | | | | CT ($X_{113}$) | 0.792 | 5.43 | 0 | | | | |
| | SA | 0.078 | 0.744 | 0.459 | 0.382 | 24.2 | 0 | SA ($X_{21}$) | 0.412 | 2.06 | 0.043 | | | | |
| | | | | | | | | $X_{113}*X_{21}$ | 0.5 | 1.951 | 0.055 | 0.405 | 18 | 0 | |
| | | | | | | | | | | | | | | | |
| TI | Constant | | 2.657 | 0.01 | | | | Constant | | 1.464 | 0.148 | | | | Support $H_{4a}$ ($\Delta R^2$=.012 Increase1.9%) ($\Delta\beta$=.14 Increase18.2%) |
| | TSJ | 0.768 | 10.5 | 0 | | | | TSJ ($X_{121}$) | 0.908 | 8.752 | 0 | | | | |
| | SA | 0.103 | 1.411 | 0.162 | 0.646 | 69.4 | 0 | SA ($X_{21}$) | 0.05 | 0.459 | 0.647 | | | | |
| | | | | | | | | $X_{121}*X_{21}$ | 0.211 | 1.88 | 0.065 | 0.658 | 49.1 | 0 | |
| | | | | | | | | | | | | | | | |
| TI | Constant | | 3.904 | 0 | | | | Constant | | 1.72 | 0.09 | | | | Support $H_{4b}$ ($\Delta R^2$=.036 Increase17.6%) ($\Delta\beta$=.237 Increase138.5%) |
| | TSC | 0.616 | 7.039 | 0 | | | | TSC ($X_{122}$) | 0.853 | 6.735 | 0 | | | | |
| | SA | 0.196 | 2.239 | 0.028 | 0.471 | 34.4 | 0 | SA ($X_{21}$) | 0.144 | 0.905 | 0.368 | | | | |
| | | | | | | | | $X_{122}*X_{21}$ | 0.411 | 2.52 | 0.014 | 0.507 | 26.7 | 0 | |
| | | | | | | | | | | | | | | | |
| TI | Constant | | 2.832 | 0.006 | | | | Constant | | 1.228 | 0.224 | | | | Support $H_{4c}$ ($\Delta R^2$=.026 Increase4.1%) ($\Delta\beta$=.163 Increase21.6%) |
| | TST | 0.754 | 10.13 | 0 | | | | TST ($X_{123}$) | 0.917 | 9.554 | 0 | | | | |
| | SA | 0.117 | 1.567 | 0.121 | 0.631 | 65.1 | 0 | SA ($X_{21}$) | 0.104 | 0.924 | 0.359 | | | | |
| | | | | | | | | $X_{123}*X_{21}$ | -0.29 | -2.56 | 0.013 | 0.657 | 48.9 | 0 | |
| SA: specificity asset | | | | | | | | | | | | | | | |

In Table 3, all P value correspond regression equation 5 and 6 were significant at 1% level. At the same time, all value of $\triangle R^2$, and $\triangle\beta$ are greater than zero. That suggested the positive moderate effect of specificity asset was tested and verified. Hence, hypothesis 3a, 3b, 3c and hypothesis 4a, 4b, 4c were supported. The increasing breadth of $\triangle R^2$ and $\triangle\beta$ were listed in the last column of table 3. Averagely, the variation explanation ability increases 5% and the standardized coefficient $\beta$ increase 31.5%. That confirms positive moderate effect of specificity asset on relationship between social network and technological innovation.

## 5. Conclusions and Future Research

This study makes three primary contributions to bring informal social network phenomenon into technological innovation management in individual level. First, this study provides a typology of the social networks of technological innovation that identifies three types: job, consult, and trust network. Job network primarily involving process flow of R&D job; Consult network involving process flow to find solution of R&D bottleneck problem; and trust network involving psychological or emotional comfort due to social support and resources exchange.

Second, the constructs of technological innovation were proposed to evaluate the innovation ability of R&D member. The validated scales to measure those constructs were proposed for both self and cross-evaluation. Self-evaluation contains item name and contribution ratio of new product development. Cross-evaluation contains five constructs, i.e., depth, correlation, contribution, competition, growth.

Third, this study provides theoretical framework of relationship between social networks and technological innovation. The results suggest that technological innovation was significantly influenced by network centrality and tie strength. Furthermore, the variance can be enhanced explaining by adding specificity asset as positive moderate variable. While this does not suggest that firms should abandon the pursuit of formal control, it does highlight the need to understand, measure, and manage social networks.

Both the typology for conceptualizing the nature of social networks and the constructs for scaling the measurement of technological innovation of this study provide a solid foundation on exploring the application in new contexts. Additional research will focus on two questions. First, which type of social network contributes more influence on technological innovation? Second, whether formal organizational control or informal social networks contribute more influence on technological innovation of R&D team member. Studies providing answers to such questions will extend our ability to manage technological innovation more effectiveness.

**Reference**

Ahuja, Gautam, (2000). The Duality of Collaboration: Inducements and Opportunities in the Formation of Interfirm Linkages. *Strategic Management, (Journal* 21), 317-343.

Blind, K., Cremers, K., & Mueller E., (2009). The influence of strategic patenting on companies' patent portfolios. *Research Policy*, 38(2), 428-436 (March).

Borgatti, S. P., Everett, M. G. & Freeman, L. C., (1999). *UCINET 5: Software for social network analysis, Natick, MA: Analytic Technologies*.

Burt, R. S. (1976). Positions in Networks. *Social Forces*, 55, 93-122.

Clark, K. & S. Wheelwright (1993). *Managing New Product and Process Development*. NY.

Cohen, S. G. & Bailey, D. E., (1997). What makes teams work: Group effectives research from the shop floor to the executive suite. *Journal of Management*, 23(3), 239-290.

Coleman, J. S.,. (1988). Social Capital in the Creation of Human Capital. *American Journal of Sociology*, 94, 95-120.

Deeds, L.D. & Hill, C.W.,. (1996). Strategic alliances and the rate of new product development: and empirical study of entrepreneurial biotechnology firms. *Journal of Business Venturing*, 11, 41-55.

Dosi, G., (1982). Technological paradigms and technological trajectories. *Res. Policy*, 11(3), 147–162.

Edquist, C., I. Hommen, (1999). Systems of innovation: Theory and policy for the demand side. *Technol. Soc*, 21(1), 63–79.

Freeman, L. C., (1979). Centrality in social networks: Conceptual clarification. *Journal of Social Networks*, 1, 215-239.

Granovetter, M. S., (1973). The Strength of Weak Ties. *American Journal of Sociology*, 78, 1360-1380.

Haldin-Herrgard, T. (2000). Difficulties in Diffusion of Tacit Knowledge in Organizations. *Journal of Intellectual Capital*, 1(4), 357-365.

Hansen, M.T., (1999). The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge Across Organizational Subunits. *Administrative Science Quarterly*, 44, 82-111.

Higgins, M.C. & Kram, K.E., (2001). Re-conceptualizing Mentoring at Work: A Developmental Network Perspective. *Academy of Management Review*, 26(2), 264-288.

Ibarra, H., (1993). Network Centrality, Power, and Innovation Involvement: Determinants of Technical and Administrative Roles. *Academy of Management Journal*, 36(3), 471-501.

Ibarra, H., & Andrews, S.B., (1993). Power, social influence, and sense making: effects of network centrality and proximity on employee perceptions. *Administrative Science Quarterly*, 38(2), 277-303.

Landry R., Amara, N., & Lamari, M., (2002). Does social capital detrermine innovation? To what extent? *Technological Forecasting and Social Change*, 69, 681-701.

Lee T. L., & Tunzelmann N. V., (2005). A dynamic analytic approach to national innovation systems: The IC industry in Taiwan. *Research Policy*, 34(4), 425-440 (May).

OECD, (1994). *Organization for Economic cooperation and Development, Definitions of Science and technology Statistics Terminology, Frascati Manual* (2002), *Oslo Manua*l (1996), *Patent Manual* (1994).

Rindfleisch, A. & Moorman, C., (2001). The acquisition and utilization of information in new product alliances: A strength-of-ties perspective. *Journal of Marketing*, 65(2), 1-18.

Sampson, R. C. (2007). R&D Alliances and Firm Performance: the Impact of Technological Diversity and Alliance Organization on Innovation. *Academy of Management Journal*, 50(2), 364–386.

Scott, J., (2000). *Social Network Analysis – A Handbook.* London: Great Britain.

Siu, W. S. & Bao, Q. (2008). Netowrk Strategies of Small Chinese High-Technology Firms: A Qualitative Study. *The Journal of Product Innovation Management*, 25, 79-102.

Song, M., Podoynitsyna, Bij, H. V. D., & Halman, J. I. M. (2008). Success Factors in New Ventures: A Meta-analysis. *The Journal of Product Innovation* Management, 25, 7-27.

Tsai, W., (2001). Knowledge Transfer in Intraorganizational Networks: Effects of Network Position and Absorptive Capacity on Business Unit Innovation and Performance. *Academy of Management Journal*, 44, 996-1004.

Tsai Wenpin & Sumantra Ghoshal, (1998). Social capital and value creation: The role of intrafirm networks. *Academy of Management Journal*, 41(4), 464-476.

Wasserman, S., & Faust, K., (1994). *Social Network Analysis: Methods and Applications.* Cambridge: Cambridge University Press.

Williamson, O.E., (1975). *Markets and Hierarchies: Analysis and Antitrust Implications: A Study in the Economics of Internal Organization.* New York: Free Press.

Yli-Renko, Helena, Erkko Autio, & Harry Sapienza. (2001). Social Capital, Knowledge Acquisitions, and Knowledge Exploitation in Young Technology-Based Firms. *Strategic Management Journal*, 22, 587-613 (June/July).

Industrial Technology Research Institute, Electronics & Optoelectronics Research Laboratories (2006). *Taiwan semiconductor almanac*. Taiwan, Hsinchu: Institute Press.