Networks and Innovative Performance of the Korean Manufacturing Firms*

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Summary. – This paper estimates the effect of networks on innovative performance at the firm level, using Korean Innovation Survey (KIS) dataset. Product innovation, product improvement, and process innovation are used as proxies for innovative activity. The explanatory variables such as firm size, market concentration ratio, lagged profitability, foreign ownership, export ratio, firm's age, formal R&D activity, and industrial R&D intensity are yet other considerations. With two year-long (2000 and 2001) data from 1,124 Korean manufacturing firms, we estimated the logistic regression model. The research finding indicates that the external networks have a strong positive effect on innovative output regardless of type of innovation. However, the network effects by partner (other firms or research institutions) vary across the type of innovation. Especially, we found that the user-supplier linkage plays an important role in production innovation, product improvement, and process innovation.

Key words: innovation, networks, manufacturing firms, Asia, South Korea

* This paper is based on KIS (Korean Innovation Survey) 2002 published by the Science and Technology Policy Institute.

1. INTRODUCTION

In the modern economic and technological context, cooperation or networks among actors in promoting innovation became increasingly important, more so than the competition itself, although both are needed. This perception led to the system or networks perspective, which is a popular approach to the study of innovation (Sung and Carlsson, 2003). The perspective states that inter-firm network or cooperation among actors in an innovation system is a key determinant in the process of innovation

In the case of Korea, Meyer-Stamer (1995) argues in this Journal (World Development) that the Korean firms – especially medium-sized enterprises – had become competitive devoid of a strong networking component during the early stages of Korea' s economic development. He notes that the need to foster networking emerges at a later stage of the industrialization process. As he expected, recently, many Korean firms themselves are trying to build strong networks with other firms or research institutes to secure business survival and acquire greater technological competence. According to Suh (2004), networking among Korean companies, especially new technology-based firms (NTBFs), mostly small in size, is active and developing rapidly. Nevertheless, related empirical research on the Korean industrial organization is virtually untapped. This seems to be due to the absence of systematic database for innovative behavior at the firm level.

This paper uses recently released Korean Innovation Survey (KIS) 2002 database from Science Technology Policy Institute (STEPI) of Korea in order to analyze the relationship between networks and innovation at the firm level. The paper is organized as follows. Section 2 reviews briefly the literature on the determinants of innovative activity, focusing on the networks-innovation relationship. Section 3 discuses the data, model, and variables. We estimate the logistic regression model, using 1,124 companies taken from KIS 2002 database. Section 4 presents the empirical findings. In section 5, we summarize and conclude the paper.

2. A REVIEW OF FACTORS INFLUENCING FIRM'S INNOVATIVE BEHAVIOR

This section briefly reviews the determinants of innovative performance at the firm level, focusing on external networks. More in-depth discussions are found in literature survey articles such as Kamien and Schwartz (1982), Cohen and Levin (1989), Cohen (1995), Symeonidis (1996), and Rogers (2004).

(a) Networks

As noted above, one popular approach to the study of innovation is assuming the networks perspective. So far, various systems approaches to the study of technological change have been suggested in the economics literature: national innovation systems (Freeman, 1988; Lundvall, 1988, 1992; Nelson, 1988), sectoral innovation systems (Breschi and Malerba, 1995; Malerba, 2002), and regional innovation systems (Saxenian, 1994), technological systems (Carlsson and Stankiewicz, 1991), Michael Porter's 'diamond' (Porter, 1990). The economic network approach, especially as developed by Hakansson (1987, 1989 and 1992) and Hakansson and Snehota (1995), make it clear that firms can supplement their innovation process by leveraging their network relations or external resources.

In a series of the empirical study on the networks - innovation relationship, the role of networks has been confirmed worldwide. For example, Rogers (2004) found that small Australian Manufacturing firms exhibit positive association between networking and innovation. Oerlemans et al. (1998), in a study on the region of North Brabant (a province in the southern part of the Netherlands), found that models including both network variables and firm's internal resource variables explain innovative performance better than models including internal resources. Audretsch and Vivarelli (1994), in a study of patents in 15 Italian regions, shows that patent output depends not only on the level of R&D within the region, but also (it is ok to use also in this case) on the region's level of university research. Feldman (1994) reported the comparable results in the U.S. MacPherson (1997) found that support for external networks increase innovative activities in U.S. scientific instrument companies located in New York. Love and Roper (1999) also confirms that 'network intensity' has positive effect on the number of innovations in a sample pool consisting of 576 U.K. manufacturing firms.

In Korea, Shin et al. (2002), using the KIS 2002 dataset, reports that 41.2% of the responding companies had an external relationship with other companies or institutions. However, the econometric effect of networks on innovative activity at the firm level has never been studied.

(b) Traditional factors

Firm size has been regarded as the most important factor of innovation. The firm size-innovation relationship is summarized by the Schumpeterian hypothesis. The hypothesis suggests that large companies have advantages that enable them to pioneer into new technology areas in terms of production, marketing, financing, and R&D activity (Schumpeter, 1942). On the other hand, some argue that small companies are efficient in aligning their employees in terms of their direction for innovation and face less complexity in managing R&D projects (Scherer and Ross, 1990).

The Schumpeterian hypothesis about firm size has been tested by regressing some measures of innovative activity (input or output) on firm size at the firm or industry level. According to Cohen's (1995) literature survey, the empirical findings depend on the unit of analysis, definition of innovation variable, and type of industry. The consensus, however, is that either in majority of industries or when controlling for industry effects in more aggregate samples R&D rises monotonically - typically proportionately - with firm size among R&D performers, the number of innovations tends to increase less proportionately than firm size, and R&D productivity tends to decline with firm size.

For Korea, Kang's (1994) analysis at the industry level found that in industries with the comparable concentration ratio, R&D intensity has negative relationship with average firm size. Sung (2001) after studying 64 Korean machinery companies confirms the rejection of Schumpeterian hypothesis on the firm size. However, Kim (1992), in a study of raw material synthetic industry, shows that technology development/adoption is an increasing function of firm size. Sung (2003) found that firm size has positive influence on both R&D expenditure and number of patent in a sample of 337 Korean manufacturing companies listed on the stock market. Ryu (2003), in a study of 190 companies included in the scoreboard of Ministry of Science and Technology, found a strong positive relationship between firm size and R&D expenditure. In conclusion, empirical results yielded in Korea are also mixed, depending on industries, variables, samples, and estimation technique.

On the other hand, Schumpeter suggests that an oligopoly market structure and the possession of market power favored innovation. He claimed that an oligopoly market structure made rival behavior more stable and predictable, and thereby reduced the uncertainty associated with excessive rivalry that tended to undermine the incentive to invent. He also recognized that firms required the expectation of some form of transient market power to have the incentive to invest in R&D.

The empirical research of the relationship between market power and innovative activity shows no clear consensus of results. One explanation of this is the difficulty in controlling for endogenous relationships between market power and innovative activity.[†] A common finding, however, is that R&D

[†] Blundell et al. (1995) tries to control this simultaneousness problem. The work, using panel data on innovations by U.K. manufacturing firms, found that firms with strong market power

intensity or innovative output first increase, followed by decrease with rise in market concentration. For example, Scherer (1970) found that maximum R&D intensity occurs at the 50 to 60% concentration ratio. This result is confirmed by Scott (1984), using Federal Trade Commission data of the U.S.

There are some studies conducted in Korea on the relationship between market structure and innovation. These include Lee and Jung (1987), Ha and Jung (1988), Kang (1994), Sung (2001), and Shin (2003). All these reject the Schumpeterian hypothesis that implies positive relationship between concentration ratio and innovative activity. However, like the studies of western economies, Ha and Jung (1988), Kang (1994), and Shin (2003) found an inverse U-shaped relationship when it comes to concentration ratio and innovative activity.

(c) Other factors

The existing studies examine large number of other potential factors influencing firm' s innovative activities. One study is examines the role of exporting activity. Export performance and innovation are likely to be inter-related. Generally, innovative firms may seek to explore into overseas market, implying that innovation causes exports. In reverse, firms that export also need to undertake innovative activities in order to sustain international competitiveness. A strong orientation towards exporting should thus stimulate innovative activity. Empirical studies have shown that exporting activity causes innovation. Hobday (1995), in a study that analyzes the impact of

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have higher rate of innovation, while higher market concentration tends to reduce innovation.

firm' s exporting activity on their productivity and growth in South East Asia, argues that knowledge of how to innovate was effectively passed to exporting firms from overseas market. Bhattacharya and Bloch (2004) also found positive relationship between exporting and innovative activity. For Korea, Sung (2002), in a study of 337 Korean manufacturing firms, did not find any statistically significant relationship between export ratio and innovative activity (R&D intensity).

Another issue is the role of foreign ownership in innovation. Some arguments suggest positive effect, whereas product cycle model implies that innovative activities are conducted close to domestic markets. Empirical studies also show mixed results. While Love and Roper (1999) suggest that foreign ownership has negative correlation with innovation for the U.K., although Love et al. (1996) found positive relationship for a sample of Scottish manufacturing plants. For Korea, Huh (1996) found negative relationship of foreign ownership and R&D activity in Korea. Cho et al. (2002) and Ryu (2003), however, report positive correlation between foreign ownership and R&D intensity.

The relationship between profit and innovation is another issue of importance. Since innovative activity is one of the core strategic tools of businesses, high profit, a proxy of internal financial capability, may induce subsequent innovations. Branch (1974) and Grabowski (1968) found positive relationship between profitability and R&D. Audretsch (1995) suggests that positive influence of profitability on innovative activity is limited to high-tech industries. Kraft (1989), in a study analyzing the determinants of product innovation by West German companies, did not find any statistically significant relationship in terms of cash flow and product innovation. For Korea, Lee (1992) shows that retaining profit is one key determinant of R&D investment. Sung (2001), in a study for the Korean machinery companies, found that cash flow has positive coefficient on both R&D intensity and patent, but is insignificant.

Lastly, the age of firm has been included in the study of innovation. I expect that the relatively younger companies will try to innovate more intensively for product than the old, *vise versa* for process. Shin (2003), in a study of the Korean manufacturing companies, found that years of company operation has positive relationship with innovative activity for both product and process innovation.

3. EMPIRICAL ANALYSIS

(a) The KIS 2002 Dataset

Our analysis is based on the data taken from the KIS 2002 surveyed by Science and Technology Policy Institute (STEPI) of Korea. The dataset was designed to provide information on various innovative activities at the firm level. The survey includes information on inputs into the innovation process, outputs from innovative activities, and institutional and environmental factors that influence firm' s innovative behavior. The response rate over the survey period was 60.6 percent, covering 3,775 manufacturing firms. Among these, I took 1,124 samples, after discounting missing and incomplete data.

(b) Dependent variables

The dependent variable is a binary (0, 1) one defined on the basis of the answers to the question, "Did your company, in the two years (2000~2001), develop and sell any products developed with new technology?" If the company answered 'Yes', then we let the value of dependent variable 1. Otherwise, the value is 0. In the comparable way, we consider product improvement and process innovation, respectively.

(c) Independent variables

Cooperation for innovative activity (NETWORK): We take a dummy variable (NETWORK) for external networking. If external networking for the two years (2000-2001) is used, then we equate the variable with 1. Otherwise, the value of a "No" is 0. In addition, we take six points scale measure for whether the firm uses 'formal networking with other companies or institutions' for the two years. If networking is not used, then we equate the variable with 0. Otherwise, the value of the variable is between 1 and 5 according to its importance. The other firms or institutions include affiliates, user firms, part suppliers, machine or equipment suppliers, rivals, joint venture companies, consulting firms, universities, public research institutions, technological centers, industrial associations, research associations, private research institutions, etc.

Firm size (SIZE): We equate number of firm's employees as a proxy of firm size, instead of other possible ones, such as sales or volume of assets. We normalize the value by average number of employees of the entire sample. As it were,

SIZE = number of the company' s employees/ average number of the employees of the entire sample.

To test the inverse U-shaped hypothesis, we include size square (SIZE_square) variable.

Concentration ratio (CR): Both CR_3 and Herfindahl Index as a market structure variable are available. We take Herfindahl Index released by Korea Development Institute (2002), according to KIS industrial classification.

Lagged profit margin (PROFIT): Among various kinds of profit indicators, we take net profit before tax to total sales. Since profit influences the R&D activities of company with some time lag, we use the profit indicator in 1999.

Export activity (EXPORT): We use export to sales ratio as a proxy for firm' s export activity. This is also a lagged variable (in 1999) like profit margin.

Foreign ownership (FOREIGN): This is a dummy variable for some level of foreign ownership in company. If any foreign owner has more than 1% of total share, we let the value of FOREIGN 1.

R&D activity (RD): This variable is also a dummy one for whether any expenditure on R&D occurred during the 2000-2001. If R&D activity is done, we equate the variable with 1. Otherwise, the value of the variable is 0.

Age of firm (AGE): This is the age of firm (years) in 2001. The age of a company is 2001 minus the established year of t33he company.

R&D intensity by industry (IN-RD): This value is R&D expenditure divided by total sales at an industrial level. The industry includes 21 industries defined in KIS dataset. The source of the data is Ministry of Science and Technology (2004) of Korea. We use the variable in order to control the level of technological opportunity by industry. Table 1 presents the descriptive statistics (mean and standard deviation) of the sample.

Table 1. *Descriptive statistics of the explanatory variables*

Explanatory variable	Mean	Standard Deviation
SIZE	1.0019	4.442
CR	184.63	72.34
RD	0.91	0.29
AGE	14.89	11.04
FOREIGN	0.0961	0.29
PROFIT	0.12	0.401
EXPORT	0.29	1.07
IN_RD	2.5216	1.5954
NETWORK		
Affiliates	0.74	1.53
User firms	1.13	1.81
Part suppliers	1.01	1.62
Machine suppliers	0.87	1.50
Rivals	0.68	1.36
Joint ventures	0.44	1.13
Consulting firms	0.55	1.22
Universities	0.86	1.56
Research institutes	0.73	1.44
Technological centers	0.67	1.33
Industrial associations	0.48	1.10
Research associations	0.39	0.98
Private institutes	0.43	1.06

(d) The estimation technique

As the dependent variable is a dichotomous dummy, we use a binominal logistic regression model. The suitability of the estimation technique is derived from the nature of the dependent variable (qualitative and dichotomous) and of explanatory variables (where continuous variables are combined with categorical variables). It is applicable for any combination of continuous and categorical independent variables (Affifi and Clark, 1990).

Logistic regression analysis allows us to estimate the probability that a firm is carrying out innovative activities as a function of explanatory variable. The regression coefficients estimate the impact of the explanatory variables on the probability of performing innovative activities, with positive sign for the coefficients meaning that variable increases that probability. In the mathematical form,

$$\text{Prob. (INNOV=1)} = 1/[1+ e^{(-(\alpha + \beta iXi))}$$

where, Prob. (INNOV=1) is the dependent variable, the probability of carrying out innovative activities; Xi is the independent variables; βi is the estimated coefficients; α is a constant; e is the base of the natural logarithm.

The model was adjusted according to the method of estimation by maximum likelihood. We use the statistical software SPSS v. 12 for the estimation.

4. EMPIRICAL FINDINGS

Table 2 and Table 3 summarize the overall network effects and the effects by partner, respectively. The first column contains the estimated coefficients on each independent variable (in column ' B'). The Wald statistic‡ allows us to prove the null hypothesis that each coefficient is 0. EXP (B) is e (2.718) raised to the value of the regression coefficient, which means Prob. (INNOV = 1) divided by Prob. (INNOV = 0).

To evaluate the model' s suitability, SPSS software provides the Chi-square statistic for the set of variables included in the equation. It shows the difference between -2 logarithm of likelihood for the full model and for the model that only has the constant. This statistic is used to verify the null hypothesis consisting of the coefficients of the variables being equal to 0. As it can be seen in all tables, the log-likelihood ratio test produced Chi-square value in significant with the 1 %. Its significance indicates the logistic regression models have an explanatory power.

(a) The overall network effect

Table 2 shows the results of the logistic regression analysis when we take a dummy for the variable, NETWORK. The external networks, our main focus, manifest strong positive effect on product innovation, product improvement, and process innovation, respectively. This means that cooperation or networks among actors – firms or research institutions – in promoting innovation became more important in the

‡ Wald statistic = (coefficient /standard deviation) ^{2}

Table 2: *Results of the logistic regression analysis: the overall network effect*

Dependent variables: Innovative status in 2001~2002

	Product Innovation			Product Improvement			Process Innovation		
	B	Wald	E (B)	B	Wald	E (B)	B	Wald	E (B)
Constant	-1.218***	16.042	0.296	-0.341	1.274	0.711	-0.304	1.049	0.738
NETWORK	0.629***	24.614	1.875	0.630***	21.047	1.877	0.712***	30.618	2.038
SIZE	0.077	2.233	1.081	0.169**	5.046	1.184	0.311***	14.515	1.364
SIZE_Square	0.000	0.304	1.000	-0.001	1.067	0.999	-0.002***	6.820	0.998
CR	0.000	0.114	1.000	-0.001	1.248	0.999	-0.001	1.219	0.999
RD	0.990***	18.677	2.692	0.806***	13.972	2.239	0.032	0.022	1.033
AGE	0.005	0.669	1.005	0.001	0.012	1.001	0.002	0.056	1.002
FOREIGN	0.075	0.121	1.078	0.369	2.170	1.446	0.676***	7.945	1.967
PROFIT	-0.192	1.325	0.826	0.001	0.000	1.001	0.597**	5.779	1.817
EXPORT	-0.034	0.346	0.967	0.066	0.588	1.068	0.095	1.187	1.100
IN_RD	0.082**	4.053	1.085	0.049	1.286	1.050	0.004	0.009	1.004
Sample number	1,124			1,124			1,124		
-2 Log likelihood	1474.983			1344.160			1441.285		
Chi-square	69..058***			64.015***			97.892***		

Note: *** significant at the 1% level. ** significant at the 5% level. * significant at the 10% level.

Korean manufacturing sector. The result also confirms Meyer-Stamer (1995)' s expectation that the need to foster networking arises at a later stage of the industrialization process.

The effect of firm size on innovation differs according to type of innovation. In the case of product innovation, there is no any relationship between firm size and innovation. However, Schumpeterian hypothesis is accepted for product improvement. As it were, the probability that larger companies report more product improvement is high. For process innovation, the inverse U-shaped hypothesis is accepted.

Whether a company has undertaken R&D activity plays a role in product innovation and product improvement. This means that although formal R&D expenditure is prerequisite for product-related innovation, process innovation can be conducted without formal R&D activity.

Foreign ownership has positive sign for only process innovation. This indicates that the companies with higher foreign ownership concentrate their efforts on OEM rather than in-house product innovation. Lagged profitability is also an important determinant of process innovation, with positive sign for the coefficient meaning that profit-maximizing companies minimizes their production cost through process innovation. In contrast, the result shows that product innovation can be undertaken without taking account of the level of profit.

Lastly, firm' s age, export ratio, and market concentration ratio have no significant influence on innovative activity regardless of type of innovation

(b) The network effect by partner

Table 3 shows the results of the logistic regression analysis when we take six points scale measure for whether the firm uses 'formal networking with other firms or institutions' according to its importance. Except external networks, all other explanatory variables show the comparable signs and statistical significance regardless of type of innovation.

However, the network effects by partners (other firms or research institutions) differ according to type of innovation. In the case of product innovation, user firms, part suppliers, and private institutes have positive effect on innovative activity. User firms and technological centers play a role in product improvement. On the other hand, affiliates, machine suppliers, and consulting firms have positive influence on process innovation. In common, user-supplier relationship plays an important role in any kind of innovation.[§]

[§] The importance of user-supplier networking is reported in the Korean machinery industry, especially in the machine tool industry (Lee, 1996)

Table 3: *Results of the logistic regression analysis: the network effects by partner*

Dependent variables: Innovative status in 2001~2002

	Product Innovation			Product Improvement			Process Innovation		
	B	Wald	E (B)	B	Wald	E (B)	B	Wald	E (B)
Constant	-1.231***	15.945	0.292	-0.371	1.447	0.690	-0.364	1.448	0.695
SIZE	0.071	1.948	1.073	0.162**	4.725	1.176	0.326***	14.978	1.385
SIZE_Square	0.000	0.211	1.000	-0.001	0.910	0.999	-0.002***	7.469	0.998
CR	0.000	0.001	1.000	-0.001	0.981	0.999	-0.001	1.792	0.999
RD	0.978***	17.700	2.659	0.783***	12.607	2.189	0.105	0.223	1.111
AGE	0.005	0.644	1.005	0.000	0.000	1.000	0.004	0.342	1.004
FOREIGN	0.104	0.210	1.109	0.337	1.680	1.401	0.576**	5.343	1.779
PROFIT	-0.193	1.330	0.825	-0.011	0.005	0.989	0.610**	5.871	1.841
EXPORT	-0.045	0.580	0.956	0.071	0.584	1.074	0.090	1.448	0.695
IN_RD	0.089**	4.678	1.093	0.055	1.594	1.057	0.018	0.188	1.018
NETWORK									
Affiliates	0.010	0.030	1.010	-0.040	0.353	0.961	0.106*	3.070	1.112
User firms	0.097*	2.964	1.102	0.150**	5.366	1.024	0.094	2.644	1.099
Part suppliers	0.156**	4.893	1.168	0.023	0.096	1.105	-0.025	0.127	0.975
Machine suppliers	-0.002	0.001	0.998	0.100	1.488	1.105	0.173**	0.281	1.189
Rivals	-0.208***	8.754	0.812	-0.016	0.038	0.984	0.033	0.205	1.033
Joint ventures	-0.075	1.045	0.928	0.081	0.774	1.084	-0.034	0.186	0.967
Consulting firms	0.043	0.400	1.044	0.028	1.129	1.028	0.152**	4.372	1.164
Universities	0.017	0.089	1.017	0.097	2.068	1.101	0.002	0.001	1.002
Research institutes	0.015	0.053	1.015	-0.161**	4.695	0.851	-0.037	0.300	0.963
Technological centers	0.050	0.404	1.051	0.240***	6.013	1.271	0.181	4.626	1.199
Industrial associations	0.004	0.001	1.004	-0.233*	3.593	0.792	-0.035	0.091	0.965
Research associations	-0.034	0.068	0.967	-0.017	0.014	0.983	-0.123	0.818	0.885
Private institutes	0.197*	3.390	1.218	0.142	1.267	1.152	-0.309***	9.380	0.734
Sample number	1,124			1,124			1,124		
-2 Log likelihood	1453.615			1308.941			1412.128		
Chi-square	90.426***			99.235***			127.049***		

Note: *** significant at the 1% level. ** significant at the 5% level. * significant at the 10% level.

5. SUMMARY AND CONCLUSION

This paper analyzes the potential determinants of firm's innovative activity, using Korean Innovation Survey (KIS) dataset. Especially, we focused on the role of external networks in performing innovative activities. Product innovation, product improvement, and process innovation are used as proxies for innovative activity. The explanatory variables such as market concentration ratio, lagged profitability, foreign ownership, export ratio, firm's age, formal R&D activity, and industrial R&D intensity are also considered. With data from 1,124 Korean manufacturing firms for two years (2000-2001), we estimated the logistic regression model. The main findings are summarized as follows.

First, the overall network effects exist regardless of type of innovation. The result confirms that cooperation or networks among firms or research institutions in promoting innovation became more important in the Korean manufacturing sector.

Second, the network effects by partners vary across type of innovation. However, user-supplier linkage plays an important role in all kind of innovations.

Third, the determinants of firm' s innovative activities differ according to type of innovation. For example, while the inverse U-shaped hypothesis is accepted in process innovation, there is no any relationship between firm size and innovation in product innovation.

These findings in the Korean Manufacturing firms provide an important policy lesson. The innovation policy should be designed to foster networking among firms or institutions, especially the partnership with user firms and part suppliers in product innovation and with machine suppliers and consulting firms in process innovation. Presently the Korean government is trying to promote geographically balanced national development through subsidizing considerable amount of money to local universities and inducing industry-university cooperation (Choi, 2004). Since the role of universities seems to be weak in promoting innovation, the government must lead industry-university cooperation for efficient implementation.

However, some limitations of the paper should be noted. There is no distinction between the quantity and quality (or value) of innovative activity. For example, a firm which reported a cluster of highly valuable new products will be labeled innovative, as would a firm that introduced only a new product. There is also the problem about the concept of innovation. The surveyed companies may interpret differently or subjectively what is 'new', 'technologically', or 'substantially' changed.

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