The Effect of Initial Public Offering (IPO) on Open Innovation: Findings from Seoul Digital Complex (SDC)

JinHyo Joseph Yun* · EuiSeob Jeong** · YoungGi Kim*** · JeongHo Yang****

I. Introduction

This study is based on the literature reviews on open innovation and patents. (Nelson and Winter, 1982) We made quantitative analyses through statistics, and performed qualitative analyses through in-depth interviews with corporate core members (mainly, with CEOs). Open innovation is gradually being established as an innovation paradigm that represents the era of the knowledge-based economy. Open Innovation stresses that companies could and should use external and internal knowledge as well as internal and external paths to markets as companies look forward to advancing their technologies (Chesbrough, 2003). The knowledge-based economy, which is referred to as large amounts of knowledge outside of companies, has been developed so much that even enterprises with the greatest R&D investments could obtain more valuable ideas for their product or service developments from exterior knowledge (Bianchi et al., 2010; Di Benedetto et al., 2008; Hughes and Wareham, 2010; Yun and Choi, 2008; Yun et al., 2011; Yun and Mohan, 2012b; Yun and Ryu, 2012). Open innovation is emerging as an important subject in more areas of business and in other socioeconomic activities such as car assembly, publishing, media, governmental activities, education, and forecasts of natural disasters. The provision of new products and public services based on knowledge and technologies from the outside as well as the external utilisation of internal knowledge and technologies, which were previously scarce, is occurring in diverse areas (Sloane et al., 2011; Tapscott and Williams, 2009). Meanwhile, precedent studies had investigated open innovation levels mainly through either qualitative research or being heavily dependent on survey data. (Chiaroni et al., 2010; Gassmann et al., 2010).

Since open innovation is emerging as a subject of new innovation and new product developments in almost all economic areas, it is becoming more important to measure companies' levels of open innovation in a more accurate way and to realize the implications for which companies pursue for better performances.

While the number of business model patents by companies, open innovation platforms, and open innovation strategies increases, open innovation levels of companies should be measured more objectively in the era of the open innovation paradigm. Several studies on open innovation measurements have been

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carried out since Laursen and Salter (2006) was released, which handles the level measurements of open innovation through a questionnaire survey. However, little progress has been made thereafter, regarding developing the means to quantitatively measure the open innovation levels of companies, except for the research tools such as survey studies or case studies (Yun et al., 2010).

This study performed quantitative measurements of open innovation with the database from the Korea Institute of Science and Technology Information (KISTI) and analysed the implications the differences in the open innovation levels before and after their IPOs do mean. The width and depth of open innovation are, respectively measured by the concepts of the ROI and IOI with the data on companies' patent applications. This study also examined the applicability of the method through the comparative analysis of open innovation patents among industries and companies and through the analysis of the relationship between patent-based open innovation activities of companies and companies' performance.

Companies were selected within the Seoul Digital Complex (SDC) area such that they could represent the korean industrial complex (Vrande et al., 2009). Table 1 shows of companies in the SDC area, the data of which come from the KISTI patent database.

Table 1. Companies in the SDC area

	Total	*IT*	*Electronics*	*Machinery*	*Clothing*	*Service*	*Others*
Companies	11,191	3,791	2,548	659	655	3,392	866
Ratio	100%	31.8%	21.4%	5.5%	5.5%	28.5%	7.3%
IPO Companies	*61*	*32*	*7*	*9*	*1*	*5*	*7*
Ratio	100%	52.5%	11.5%	14.8%	1.6%	8.2%	11.5%

We selected 61 IPO companies among a total of 11,911 ones and categorised those into five sectors such as IT, Electronics, Machinery, Clothing, Service, and others. There are 3,791 (31.8%) and 2,548 (21.4%) companies in the IT and Electronics sector, respectively, and 655 (5.5%) companies in the traditional clothing sector. Among the KOSDAQ companies (IPOs), there are 32 (52.5%) and 7 (11.5%) companies in the IT and Electronics sector, respectively, and only one (1.6%) company in the traditional clothing sector, reflecting that it is in the new industry areas that KOSDAQ companies are more concentrated than in traditional areas.

The time span this study considers is from the January in 1984 to the January 2014, but from 2013, patent data have not been thoroughly added into the KISTI database in the same form as in the other years, because of the issues around patent application disclosure. Instead, the financial statements in 2013 were included in the temporal scope of our analysis.

Table 2 shows the numbers of patents applied by general and IPO companies during the time span considered. A total of 11,911 companies applied for 20,955 patents, averagely two patent applications per company. The IPO 61 (0.51%) companies, however, have 3,300 (15.72%) patent applications, and thus, on average, 54 patents were applied for per IPO company.

Table 2. Patents Applied by Companies

	Number of Companies	*Average Founded Year*	*Average IPO Year*	*Number of Patents Applied*
Companies	11,911	-	-	20,955
KOSDAQ Companies (IPOs)	61	1993	2005	3,300
Ratio	0.51%	-	-	15.72%

This study measures the levels of open innovation of the 61 IPO companies and compares the values between before and after the IPOs of the 61 companies. In addition, this study explores over the effects of open innovation on corporate performance.

II. Literature Review and Research Framework

1. Literature Review

When the concept of open innovation was proposed by Chesbrough (2003), it was not conceptualised in a measurable way, but was based on various case studies. He considered companies with trade patents open innovation companies and conducted an in-depth analysis of these companies. In the process of analysing various open innovation business models, Chesbrough (2006) specifically extended the concept of open innovation of companies to business model concepts beyond open innovation strategies.

Meanwhile, Laursen and Salter (2006) first suggested the concept of comparable measurement of open innovation of companies beyond case studies. In order to measure the open innovation levels of companies, Laursen and Salter (2006) developed the concepts of “width” and “depth” in open innovation. They analysed the relationship between open innovation and corporate performance by studying manufacturing enterprises in the U.K. Their analysis was based on the data collected through a technical innovation survey of companies considered to be advanced enterprises, and it was based on concepts from the Oslo Manual. They measured the width of open innovation based on the answers from companies that had open innovation levels of more than two points on a five-point scale. They measured “depth of open innovation” based on the answers from companies that had open innovation levels of more than three points on a five-point scale. Although these measures set up a foundation for the measurements of open innovation levels of companies, they have inherent limits. They measured open innovation levels based on a survey in which the responses were obtained only from the companies. Moreover, the correlation between the width and the depth of open innovation had a very high value of 0.417, which implies the existence of mixed concepts between the open innovation width and the open innovation depth.

Many studies on open innovation have been conducted using case study methods and interviews, while others have adopted survey-based research methods following the framework introduced by Laursen and Salter (2006) as shown in Table 3. (Li, 2010a; Li et al., 2010b; Yun et al, 2013; West, 2006)) In other papers, financial data have been utilised to measure corporate performances (Yun et at., 2009; Yun et al.,

2010). Nevertheless, the means with which levels of open innovation could be estimated have not been sufficiently developed, and thus quantitative data-based research has not been built well.

Table 3. Dimensions of Open Innovation Patent Analysis Framework

Analysis Elements	*Contents*
Ratio of open innovation based on collaborative patents (ROI)	This is the ratio of open innovation patents jointly applied for with external agencies to the total number of patent applications by a specific company, through which the width of open innovation of the company can be measured.
Intensity of open innovation based on collaborative patents (IOI)	It is the average number of applicants per one patent application applied by a specific company through which the depth of open innovation of the company can be measured.
Total level of open innovation based on collaborative patents (TOI)	This is the value of multiplying the standardised ROI by the standardised IOI. This implies the total effects of open innovation of a specific company. That is, TOI means the combined effect of ROI and IOI.

However, Yun and Mohan (2012a) slightly improved the open innovation measuring method of Laursen and Salter (2006) in some aspects. Above all, they conceptualised open innovation levels on a single measurement basis by multiplying the open innovation “width” and “depth”. Second, they improved upon the concept of open innovation depth to provide a more systematic definition by arithmetically calculating the mean value of five-scale answers obtained from surveys on open innovation levels. However, this approach does not overcome the inherent problems of the subjectivity of survey-based research and the fact that it depends on the questions developed from the Oslo Manual.

Yun et al. (2011) conducted a patent-based analysis in developing more quantitative indices to measure the open innovation levels of companies. When companies independently apply for patents, they are said to perform closed innovation because the devised results are from the independent R&D activities. On the other hand, when companies apply for patents through partnerships with external companies, universities, research institutes, or other individuals, they are considered to develop open innovation outside their boundaries. Based on the ideas, they defined the patents jointly applied for with external agents as open innovation patents, and they defined the ratio of open innovation patents to the total number of patent applications as the ratio of open innovation (ROI), an estimate of the open innovation width of a company. In the research, they showed that the open innovation level of Hyundai Motors (approximately, 9%) was far lower than that of Toyota Motors (approximately, 30%), and the open innovation level of Samsung (approximately, 13%) was also much lower than that of Nokia (approximately, 65%).

However, the previous study was not able to explain the levels of open innovation dimensionally in the process of patent application of companies. For example, as a patent application filed jointly with external agencies is considered an open innovation patent, measurement of the level of open innovation activities by the number of external agencies making the joint patent application, i.e., measurement of the intensity of open innovation, was not considered. In summary, numerous topics surrounding open innovation have

been largely established with case studies and surveys, so naturally, the challenge has been to develop objective measures.

2. Research Framework

In general, the analysis was conducted using patents that were collaboratively applied for and publicised, because patent applications as well as registered patents, are conceptually the result of various innovation activities. (Jeong et al., 2014; Yang and Anderson, 2011; Yoo et al., 2013) This study defines a patent issued by more than two individuals, corporations, or institution applicants, as an open innovation patent. This can therefore be considered as evidence that the patent technology was not developed from inside bodies but from collaboration with external entities or acquired from outside the organisation. Furthermore, there may be cases in which companies apply for patents jointly with external organisations as a way of releasing their own technologies outside their organisation, which could be considered, open innovation.

Meanwhile, a question may be raised as to whether a patent application made jointly by members inside a company can be considered an open innovation patent. Because a joint patent application by a company with inside members is illegal given that it is an infringement of company interest, such patents are not considered open innovation patents.

However, there may be cases of joint patent applications by companies and their internal members in the process of introducing idea developers from the outside to the inside by companies or in the process of carrying out relevant patent-related business outside a company by internal idea developers. These cases represent typical open innovation activities of companies and should be considered open innovation patents.

Here, as noted in Table 3, there are three indexes measuring open innovation levels of companies; the Ratio of Open Innovation (ROI), the Intensity of Open Innovation (IOI), and the Total level of Open Innovation (TOI)

The ROI, defined as the ratio of open innovation patents over the total number of patent applications, shows the width of open innovation of a specific company by measuring a proportion of the company's innovation activities. The IOI, defined as the average number of applicants for the total patents applied by a specific company, reflects the number of external agencies with which the company carried out innovation activities. (Serenko et al., 2010) It appraises the open innovation depth, showing the differences among companies in the number of applicants in the total patents of individual companies.

The TOI, defined to be obtained from multiplying the standardised ROI by the standardized IOI, is described as in Fig 1. Based on collaborative patents, it is a unique concept to represent the open innovation level of a company. While the IOI and the ROI express different open innovation aspects, the TOI shows the standardisation of different measures. TOI should be based on statistical methods used in determining IOI and ROI. If we use a statistical method, we easily obtain the TOI from IOI and ROI. The TOI concept is not separate from the concepts of IOI and ROI. When we, however, require a unique level of Open Innovation for a company, TOI can be the overriding concept.

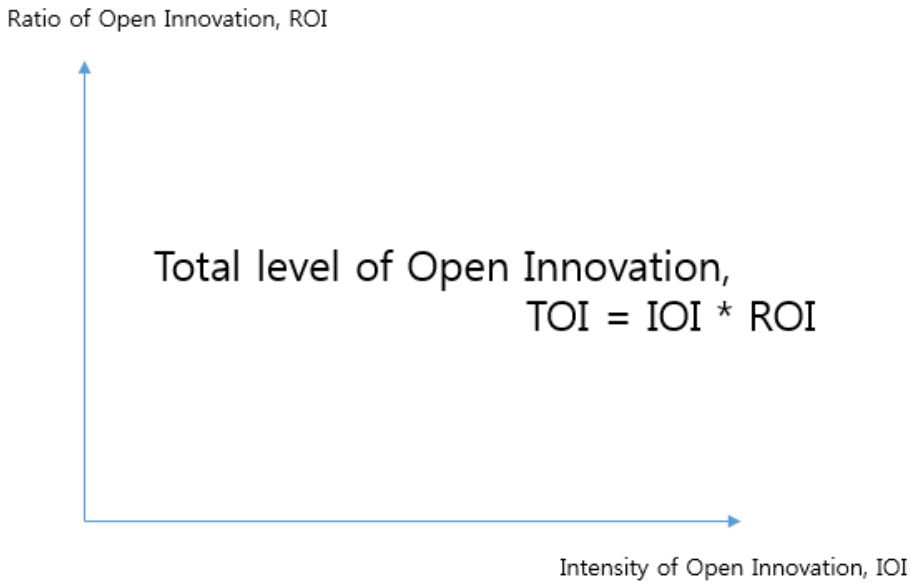

Figure 1. Total level of Open Innovation from ROI & IOI

This study examines the applicability and possibility of measuring, analysing, and comparing open innovation levels of companies by adopting the research framework described as in Fig. 2.

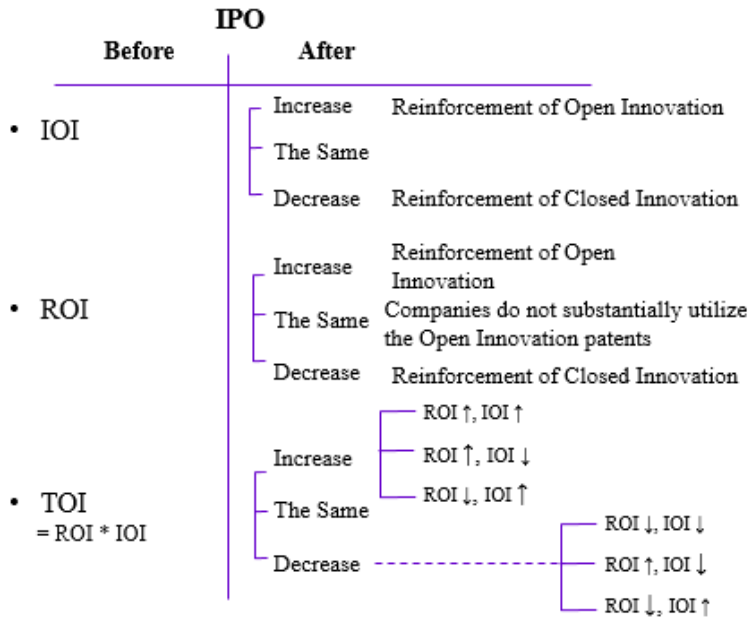

Figure 2. Research Framework for analysing the effect of IPO on Open Innovation

The Fig. 2 shows various possibilities of scenarios. That is, comparing the values of IOI, ROI, and TOI before initial public offerings (IPO) of companies, the values could vary, after companies go public, so much that the changes in the values could imply the relationships between the levels of open innovation and corporate performances. For example, if there are, after IPOs of companies, increases in IOI or ROI, we could consider there has been reinforcement of open innovation activities, because, by the definitions

of the indexes, it means that a specific company has attracted more diverse participants in applying for patents or applied for more patents collaboratively devised with exterior agencies. However, the increase in one of the indexes does not guarantee the increase in the other index, that is, even if the value of IOI increases, the value of ROI could decrease. Therefore we need to track the variations in the values of the indexes to understand well of what has happened before & after IPOs of companies.

For the case of TOI, even if the value increased (or decreased) after IPOs, we need to investigate how it has been so. Since it is composed of IOI and ROI, larger variation in one could lead the whole change. Nevertheless, we could know the whole levels of open innovation of companies at a glance only by tracking the values of TOI.

Summing up the research framework, it, above all, should make it possible to measure and analyse the open innovation levels of companies objectively. Second the framework should establish an analysis concept that considers both the width and depth of open innovation of companies. Third, these measurement concepts should be able to measure other aspects of the open innovation of companies in such a way that does not allow the existence of a high correlation between the width and the depth of open innovation.

Ⅲ. Analysis

1. Descriptive Analysis

Patent output is related to the composition of a company's alliance portfolio, including the diversity, depth, and scope of technologies, extent of alliance partner co-specialisation, entry stage of technology development, and extent of prior alliance partner experience (McGill and Santoro, 2009). This study attempts to measure the differences in open innovation before and after corporate IPOs, focusing on the 61 IPO companies in the SDC area since 1984.

Table 4 shows the Annual Trend of Patent Application and IPO from 1984 to 2014. Before 2004 a total of 60 companies were established, but after 2005, only one company was established. Until 2004, a total of 29 companies held IPOs, and after 2005 a total of 32 companies held IPOs. A total of 841 applications were made until 2004, but a total of 2,459 patent applications were made since 2005. That is, an average of 46.7 patent applications per year was made before the average year of IPO, but an average of 245.9 patent applications per year was made, 5.6 times more than the pre-IPO year.

Table 4. Annual Trend of Patentbn Application and IPO

Year	Foundation Number	IPO Number	Patent Number	Year	Foundation Number	IPO Number	Patent Number
1984 - 1995	25*	1	31	2005	1	3	207
1996	2	0	30	2006	0	2	276
1997	5	1	31	2007	0	5	311
1998	7	1	66	2008	0	4	379
1999	6	3	58	2009	0	4	299
2000	8	7	89	2010	0	6	292
2001	1	5	80	2011	0	5	345
2002	4	9	121	2012	0	2	275
2003	1	2	147	2013	0	1	71
2004	1	0	188	2014	0	0	4
Subtotal	60	29	841	Subtotal	1	32	2,459
Subaverage	2.9	2.9	46.7	Subaverage	0.1	3.2	245.9
Total					2.0	3.1	3,300

*25 can be normalised as 2.1 for 12 years.

Figure 3 shows the Annual Trend of Patent Application and IPO on KOSDAQ from 1984 to 2014. We find that most KOSDAQ companies were established around 2000 when Korean ventures were booming. The number of patent applications continuously increased until 2007 and was saturated thereafter.

Table 5 and Figure 3 show the Patent Application Trend before and after IPO. We divided the entire time frame into four periods of three years each except for the last one. We found that patent applications remarkably increased just after IPO and especially rose during the three years after IPOs of companies.

Table 5. Patent Application Trend Before and After IPO

Year	1	2	3	4	5	6	7	8	9	10
Before IPO	167	134	116	65	77	41	28	16	40	51
After IPO	164	167	169	126	143	114	91	132	70	505
Year Period		I			II			III		IV

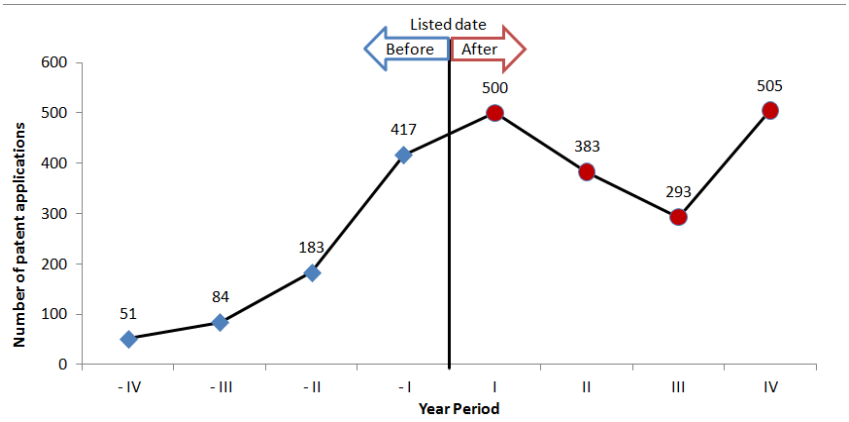

Figure 3. Patent Application Trend Before and After the average year of IPOs

Table 6 shows the Ratio and Intensity of Open Innovation of 61 Companies from 1984 to 2014. As shown in Table 5, while the number of average patent application per company is comparably high at 54.1, the number of average open innovation patents is 4.3. The average number of applicants per company for the whole period is 59.3. The ROI is averagely 8.2% and the differences in ROI among companies are rather large. The IOI is averagely 1.06 and the differences in IOI among companies are rather small.

Table 6. Ratio and Intensity of Open Innovation of 61 Companies

Applicants	*Total Patents (A)*	*OI Patents (B)*	*Total Applicants (C)*	*IOI (=C/A)*	*ROI (B/A)%*
Kohyoung	172	37	209	1.22	21.5
Nanoentek	43	5	48	1.12	11.6
Neofidelity	17	4	29	1.71	23.5
Green Cross Cell	60	4	64	1.07	6.7
Daesung Eltec	43	0	43	1.00	0.0
DongYang P&F	3	0	3	1.00	0.0
Diotek	34	1	35	1.03	2.9
Ringnet	0	0	0	0	0
Macrogen	63	28	103	1.63	44.4
SaraminHR	1	0	1	1.00	0.0
3S Korea	21	2	23	1.10	9.5
Samji Electronics	56	4	61	1.09	7.1
Seoul Semiconductor	1,086	22	1,114	1.03	2.0
Seoul Credit Rating & Information	18	0	18	1.00	0.0
Seohwa	33	4	37	1.12	12.1
Sungho Electronics	12	1	13	1.08	8.3
Sejin Electron	105	13	120	1.14	12.4
Cellumed	30	5	35	1.17	16.7
Sonokong	29	3	32	1.10	10.3
Solacia	57	1	58	1.02	1.8
Soulbrain Eng	242	50	297	1.23	20.7
Secuve	19	2	21	1.11	10.5
CNB Technology	20	1	21	1.05	5.0
Anapass	30	0	30	1.00	0.0
Anam Information Tech	0	0	0	0	0
Aromasoft	0	0	0	0	0
ITX Security	31	3	34	1.10	9.7
Energy Solution	0	0	0	0	0
SG&G	4	1	5	1.25	25.0
ST cube	3	0	3	1.00	0.0
Able C&C	7	2	9	1.29	28.6
EXA E&C	51	3	55	1.08	5.9
Mgame	5	0	5	1.00	0.0
Mcnex	36	0	36	1.00	0.0
YoungIn Frontier	45	2	47	1.04	4.4
Orbitech	54	11	65	1.20	20.4
Osstem Implant	160	4	164	1.03	2.5
Ommitel	32	2	34	1.06	6.3
Welcron	30	2	33	1.10	6.7

Ubivelox	5	0	5	1.00	0.0
UBcare	54	3	58	1.07	5.6
Yujin Robot	98	1	99	1.01	1.0
Initeck	35	1	36	1.03	2.9
Esang Networks	4	0	4	1.00	0.0
Emnet	4	0	4	1.00	0.0
Ezwelfare	10	0	10	1.00	0.0
Ecredible	2	0	2	1.00	0.0
Infinitt Healthcare	47	1	48	1.02	2.1
Zalman Tech	99	9	108	1.09	9.1
JNK Heaters	7	4	23	3.29	57.1
Com2us	11	0	11	1.00	0.0
KT Music	32	1	33	1.03	3.1
Core Cross	22	1	23	1.05	4.5
Cubes	9	3	13	1.44	33.3
Texcell Netcom	3	0	3	1.00	0.0
TVLogic	21	2	23	1.10	9.5
Puloon Tech	63	11	74	1.17	17.5
KCP	29	2	32	1.10	6.9
Hanbit Soft	5	0	5	1.00	0.0
Hanil Networks	2	0	2	1.00	0.0
Hanjin P&C	85	8	96	1.13	9.4
Average	54.1	4.3	59.3	1.06	8.2

2. Analysis for Applying to Research Framework

We start with the patents of KOSDAQ companies in the Korea SDC area, which is regarded as a representative Korean company sector. The patents are analysed to view the differences in open innovation. Table 7 shows the Ratio and Intensity of Open Innovation of 61 Companies before and after 2004. As shown in Table 8, before 2005 the average number of patent applications per company is comparably high at 13.8, and the number of innovation patents is comparably low at 1.7. The average patent number is comparably low at 15.8 per company. The Ratio of Open Innovation (ROI) is comparably high at 9.1%. In contrast, the difference of ROI is large among companies. The Intensity of Open Innovation (IOI) is comparably low at 0.86%. After 2005, the number of average patent applications per company is comparably high at 40.3, and the number of innovation patents is 2.6. The average patent number is comparably high at 43.5 per company. The Ratio of Open Innovation (ROI) is comparably low at 7.6%. In contrast, the difference of ROI is large among companies.

After IPO, the number of average patent application per company remarkably increased by as much as 26.51, the number of average innovation patents slightly increased by 0.95, and the number of average total patents remarkably increased by as much as 27.75. In contrast, the Intensity of Open Innovation (ROI) slightly increased by as much as 0.12, and the Ratio of Open Innovation (IOI) remarkably decreased by -1.6. These results demonstrate that the total level of open innovation slightly decreased after IPO by 0.38 because of relatively large decrease in ROI, and the innovation status was maintained after the IPO, although a small fluctuation exists.

Table 7. ROI and IOI of 61 Companies Before & After their IPOs for the whole time span

Applicants	Before IPO					After IPO					Difference	
Applicant Name	Total Patents	OI Patents	Total Applicants	IOI	ROI	Total Patents	OI Patents	Total Applicants	IOI	ROI	IOI	ROI
Kohyoung	24	0	24	1.00	0.00	138	35	173	1.25	0.25	0.25	0.25
Nanoentek	7	0	7	1.00	0.00	6	3	9	1.50	0.50	0.50	0.50
Neofidelity	4	0	4	1.00	0.00	9	0	9	1.00	0.00	0.00	0.00
Green Cross Cell	46	3	49	1.07	0.07	13	1	14	1.08	0.08	0.01	0.01
Daesung Eltec	1	0	1	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
DongYang P&F	2	0	2	1.00	0.00	1	0	1	1.00	0.00	0.00	0.00
Diotek	9	0	9	1.00	0.00	16	0	16	1.00	0.00	0.00	0.00
Ringnet	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
Macrogen	3	2	5	1.67	0.67	11	3	14	1.27	0.27	-0.39	-0.39
SaraminHR	1	0	1	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
3S Korea	4	0	4	1.00	0.00	4	1	5	1.25	0.25	0.25	0.25
Samji Electronics	5	1	6	1.20	0.20	11	0	11	1.00	0.00	-0.20	-0.20
Seoul Semiconductor	2	0	2	1.00	0.00	371	13	387	1.04	0.04	0.04	0.04
Seoul Credit Rating & Information	0	0	0	0	0	3	0	3	1.00	0.00	1.00	0.00
Seohwa	13	0	13	1.00	0.00	8	3	11	1.38	0.38	0.38	0.38
Sungho Electronics	0	0	0	0	0	1	0	1	1.00	0.00	1.00	0.00
Sejin Electron	33	5	38	1.15	0.15	23	3	28	1.22	0.13	0.07	-0.02
Cellumed	6	0	6	1.00	0.00	6	0	6	1.00	0.00	0.00	0.00
Sonokong	23	2	25	1.09	0.09	5	1	6	1.20	0.20	0.11	0.11
Solacia	43	0	43	1.00	0.00	7	0	7	1.00	0.00	0.00	0.00
Soulbrain Eng	6	0	6	1.00	0.00	81	40	126	1.56	0.49	0.56	0.49
Secuve	4	1	5	1.25	0.25	9	1	10	1.11	0.11	-0.14	-0.14
CNB Technology	7	0	7	1.00	0.00	10	1	11	1.10	0.10	0.10	0.10
Anapass	19	0	19	1.00	0.00	9	0	9	1.00	0.00	0.00	0.00
Anam Information Tech	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
Aromasoft	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
ITX Security	3	0	3	1.00	0.00	21	0	21	1.00	0.00	0.00	0.00
Energy Solution	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
SG&G	0	0	0	0	0	2	1	3	1.50	0.50	1.50	0.50
ST cube	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
Able C&C	3	1	4	1.33	0.33	1	1	2	2.00	1.00	0.67	0.67
EXA E&C	3	0	3	1.00	0.00	10	0	10	1.00	0.00	0.00	0.00
Mgame	1	0	1	1.00	0.00	4	0	4	1.00	0.00	0.00	0.00
Mcnex	16	0	16	1.00	0.00	2	0	2	1.00	0.00	0.00	0.00
YoungIn Frontier	31	1	32	1.03	0.03	10	1	11	1.10	0.10	0.07	0.07
Orbitech	37	8	45	1.22	0.22	7	2	9	1.29	0.29	0.07	0.07
Osstem Implant	42	0	42	1.00	0.00	97	3	100	1.03	0.03	0.03	0.03
Ommitel	10	0	10	1.00	0.00	9	2	11	1.22	0.22	0.22	0.22
Welcron	9	0	9	1.00	0.00	7	0	7	1.00	0.00	0.00	0.00
Ubivelox	0	0	0	0	0	5	0	5	1.00	0.00	1.00	0.00
UBcare	0	0	0	0	0	9	0	9	1.00	0.00	1.00	0.00
Yujin Robot	1	0	1	1.00	0.00	12	1	13	1.08	0.08	0.08	0.08

Initeck	3	0	3	1.00	0.00	9	1	10	1.11	0.11	0.11	0.11
Esang Networks	2	0	2	1.00	0.00	1	0	1	1.00	0.00	0.00	0.00
Emnet	4	0	4	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
Ezwelfare	6	0	6	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
Ecredible	2	0	2	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
Infinitt Healthcare	5	0	5	1.00	0.00	32	1	33	1.03	0.03	0.03	0.03
Zalman Tech	36	0	36	1.00	0.00	44	8	52	1.18	0.18	0.18	0.18
JNK Heaters	5	4	21	4.20	0.80	2	0	2	1.00	0.00	-3.20	-0.80
Com2us	6	0	6	1.00	0.00	3	0	3	1.00	0.00	0.00	0.00
KT Music	13	0	13	1.00	0.00	10	1	11	1.10	0.10	0.10	0.10
Core Cross	3	0	3	1.00	0.00	17	1	18	1.06	0.06	0.06	0.06
Cubes	3	1	4	1.33	0.33	5	1	6	1.20	0.20	-0.13	-0.13
Texcell Netcom	1	0	1	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
TVLogic	9	0	9	1.00	0.00	10	1	11	1.10	0.10	0.10	0.10
Puloon Tech	19	2	21	1.11	0.11	30	9	39	1.30	0.30	0.19	0.19
KCP	0	0	0	0	0	3	1	5	1.67	0.33	1.67	0.33
Hanbit Soft	1	0	1	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
Hanil Networks	1	0	1	1.00	0.00	0	0	0	0.00	0.00	-1.00	0.00
Hanjin P&C	23	2	27	1.17	0.09	34	5	40	1.18	0.15	0.00	0.06
Average	9.2	0.5	10.0	**1.08**	**0.06**	18.7	2.4	21.2	**0.90**	**0.11**	**-0.18**	**0.05**

Categorizing all the 61 IPO companies into groups according to variations in the values of IOI and ROI, the companies that showed rises in both IOI and ROI amount to 31, whereas 7 companies have been decreased in both IOI and ROI. As a result of analysing 3,300 patent applications by the 61 IPO companies to the research framework as in Figure 2, we could arrange as in Table 8.

Table 8. Number of Companies for Each Case after IPOs

IOI \ ROI	Increased	Unvaried	Decreased
Increased	31	4	0
Unvaried	0	11	0
Decreased	1	7	7

From Table 7, we could find out the changing of patents after IPO at firm level. According to Table 8, there are diverse changes in open innovation between firms after IPO.

Ⅳ. Discussion

Through Figure 4, we can see the average changes in IOI and ROI before & after IPOs of companies. Before IPOs of the 61 companies, the average IOI and ROI are 1.09, 0.06, respectively. However after the IPOs, IOI and ROI increased up to 1.1, 0.08, respectively. In other words, after IPOs, more amount of open innovation patents has been applied by companies and, on average, more applicants have been involved in applying for patents. Consequently, the total level of open innovation (TOI), which is obtained

by multiplying the IOI by the ROI, is increased. The increase in TOI implies that, after their IPOs, companies develop their corporate strategies that reinforce open innovation paradigm, comparing to before IPOs.

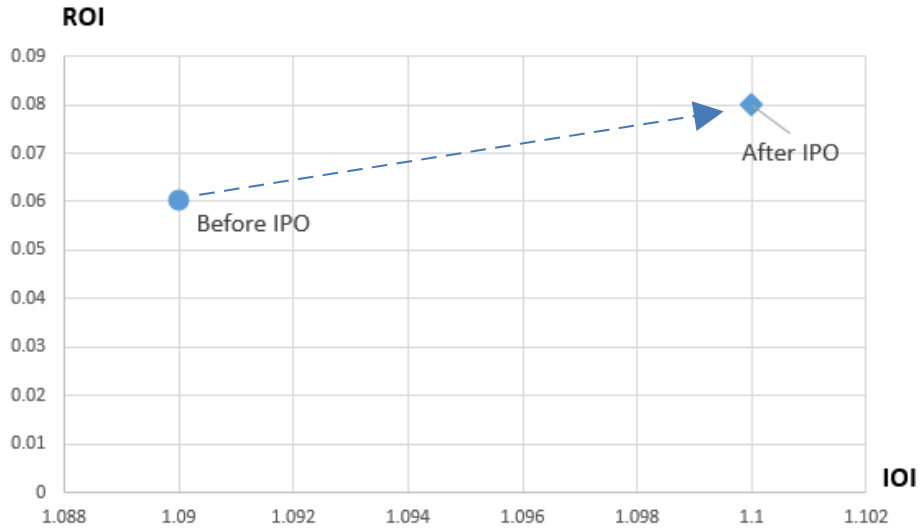

Figure 4. Average Variations of IOI and ROI before & after IPOs for the entire period

We could find out two discussion points from here. First, firms choose a large portion of research project with partners who do not belong to the firm.

First, firms should not hesitate to make networks with outside identities to introduce new idea, new technology, and new business models in research steps. Increase in ROI means this. A lots of research projects which have partners outside, can give new chances to find out creative technology, new business model, and new market. In addition, a lots of research projects which have partners outside, can give chances to increase modern market, transfer non-used technology, and increase the usefulness of technologies which firms have.

Second, firms should not hesitate to include additional partners in research projects. Normally, lots of firms increased the number of partners in research projects. Increase in IOI means this. Additional partners in research projects will give firms more chance to meet creative technologies, and business models. Most of all, new market creation will be possible from diverse new combination between new and modern technologies and new and modern markets from a lots of ideas from increased partners at research projects.

V. Conclusions

1. Summary and Implication

In this study, the concepts of IOI, ROI and TOI are verified by analysing patents among Korea Securities Dealers Automated Quot(KOSDAQ) companies in the SDC. This is the first study to investigate differences

in open innovation levels before and after companies' IPOs through a quantitative patent analysis. We found that patent applications remarkably increased after IPO, especially during the three years before and after IPO. The standardised IOI slightly increased from 1.09 to 1.10. The standardised ROI also increased from 0.06 to 0.08. As a result, the standardised TOI increased from 0.07 to 0.09. This means that after the IPO, companies cooperate with more external partners in technology development and patent application activities to improve the technological and market accessibility.

In this study, we considered the strategic values of patents in the knowledge-based economy in relation to corporate IPO. IPO companies require joint developments of patents with various external partners for their sustainable capabilities. After IPOs, companies may have to cooperate with more exterior partners to develop a variety of profitable technologies.

We could find out 3 implications from this research.

First, Firms choose different open innovation strategies between before and after of IPI. Even though firms' patent application during 3 years after IPO decreased, the level of open innovation during this period increased. Maybe firms choose different open innovation strategy after IPO normally.

Second, Firms' open innovation increase from just before 3 years of IPO. This means that firms increase open innovation to make successful situation for IPO. So, Open Innovation is one of key factors for the success of open innovation. If any firm wants to succeed in IPO, it hast to increase open innovation.

Third, according to the table 8, after IPO half firms increased in ROI, and IOI together, and 7 firms decreased in ROI, and IOI. In addition, a large portion of firms did not move in IOI and ROI after IPO. This means that open innovation strategy chosen by firms are very different according to situations such as belonging industries, firm's volume, and firms' state at the belonging market. These factors we could find out by additional interviews.

2. Limitations and Additional Research Goals

This study performed an in-depth quantitative analysis with the data of patent applications, whereas a qualitative analysis was not covered enough. The company's actual performance variables such as sales and profit margins were not considered. Accordingly, through in-depth interviews with major companies, supplementary studies are needed to evaluate the differences in qualitative characteristics of open innovation and performance before and after IPO.

This research is first step for analysing the change of open innovation after IPO. We have to a lot of additional researches to find out diverse factors which give effects to open innovation of firms before and after IPO. First, we should analyse the difference of open innovation according to different industries. Second, we should analyse the difference of open innovation according to the year and volume of firms. Third, we should analyse the difference of open innovation according to clusters or regional innovation systems which firms belong to. Forth, we should analyse the difference of open innovation according to life cycle of belonging industry. Fifth, we have to choose additionally big volume of qualitative interview methods and quantitate patent database analysis approach altogether to generalize our findings.

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