"Expand/Offense" and "Deepen/Defense" Strategy of Patent Acquisition for Leader and Follower: Evidence from Drug-Eluting Stent

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Abstract--**This article tries to explore the strategic intension of patent acquisition for drug-eluting stent manufactures by the approach of patent citation network. From the view of supplementary and complementary, we could understand the change of patent employments and patent portfolios of the leader, Johnson & Johnson/Cordis, and the follower, Boston Scientific/BSS, before/after patent acquisition. Four patent indicators, Technological Knowledge Status, Technological Knowledge Reliability, Common Internal Knowledge, and Common External Knowledge, provide the movement of position and role and change of supplementary and complementary of manufactures. The result shows that the leader acquires patents of complementary technology and the follower acquires patents of supplementary technology. The leader employs "expand/offense" and the follow adopts "deepen/defense" strategy of patent acquisition.**

I. INTRODUCTION

Global demand of treatment for cardiovascular disease increases continuously. The severe competition of stent along with huge investment of R&D triggers acquisition activities among those large manufactures. Thus, how to response the dynamic competition of growing market and how to offense and defense of patent portfolio is an important problem for the biotechnological and pharmaceutical manufactures.

For this recent decade, Drug-Eluting Stents (DES) has been the main technological direction of manufactures including Cordis and Boston Scientific, subsidiary companies of Johnson & Johnson. Guidant, the leader of Bare Metal Stent (BMS), also joined the field through Vision of DES in 2006. From 2010, DES became the battle of Johnson & Johnson/Cordis and Boston Scietific. Johnson & Johnson/Cordis was leader temporarily. Both adopt patent acquisition to response pressure of technology and market [1-3].

There are different intentions of patent acquisition for leaders and follows in this industry based on different thought of patent portfolio. This study tries to figure out what kinds of patents they buy and how they evaluate patents to buy by patent citation network which is constructed by nodes of patents and relation ties of citations based on the concept of social network [4, 5]. Patent citation network is a useful approach to analyze the technological ability of manufactures [6-9].

The coopetitive relations within an industrial organization include two different concepts of supplementary and complementary [10-12]. According to these two concepts, companies have different activities including knowledge, technology and product management [3, 13, 14]. This study explores the patent acquisition strategies of leaders and follows based on supplementary and complementary of knowledge and technology[14-16] and furthermore understands how to strength patent portfolios of both under the coopetitive relationship.

Based on the point above, this study first adopts patent co-citation approach (PCA)[17] to classify the technologis of the leader and follower in the industry of Drug-Eluting Stents in order to distingwish the important technological classication and distribution of both. Secondly, the two indicators of technological knowledge status (TKS) and technological knowledge reliability (TKR) brought up by Chen(2013) could measure the changes of technological position and role of manufactures in the patent citation network. In addition, this study also adopts common internal knowledge (CIK) and common external knowledge (CEK) in order to understand the change of supplementary and complementary. These two indicators could detecte the relative change of the patent portfolio of a pair of manufactures to help the rivals evaluate the coopetive strategy between both.

Thus, this study adopt those indicators above, TKS, TKR, CIK, CEK to explore the leader, Johnson & Johnson/Cordis, and follower, Boston Scietific.

i. The technology they acquire is whether supplementary or complementary?
ii. Does the change happen in technologies of both companies in the patent citation network before/after acquirsition?
iii. The management implication for the chcnge of both companies' technological position.

II. METHODOLOGY

The study process contains data collection and data analysis which includes patent co-citation approach and knowledge redundancy analysis of technological knowledge status (TKS), technological knowledge reliability (TKR), common internal knowledge (CIK) and common external knowledge (CEK), Fig. 1.

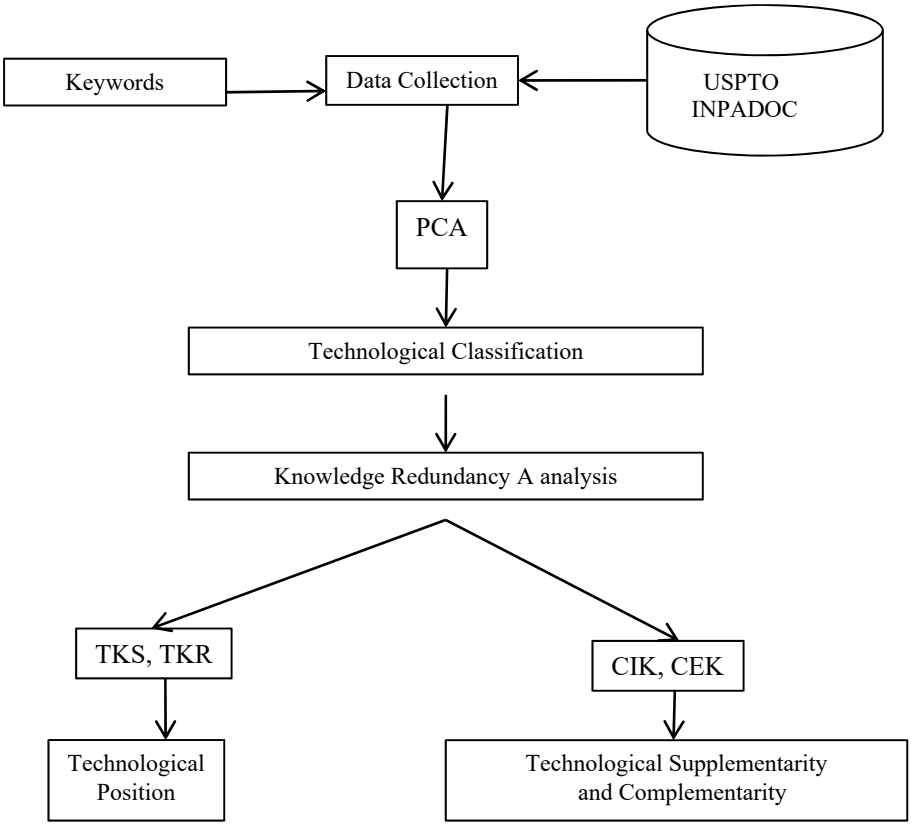

Fig. 1

A. Data Collection

Patents approved in the period of time from Jan 1st 1976 to Nov. 26th 2013 is collected from USPTO with seven keywords, stent, intravascular, cardiac, Cardiovascular, coronary, angioplasty, blood vessel from literature reviews and secondly data. Patent data contains 8809 patents and 125 companies of 15 group of stent industry.

B. Data Analysis

This study first adopts the concept of patent co-citation approach, PCA[17] combining Taboo Search and cluster Analysis [18, 19] to classify the technologies of stent in order to recognize the main technological classification. The optimum cluster counts are scree plot of R-square[19, 20]. Then, technological knowledge redundancy detects technological position change with TKS, TKR and analyzes technological supplementary and complementary with CIK and CEK. The concept and algorithm of TKS, TKR, CIK and CEK[21].

Knowledge Status, TKS, and Technological Knowledge Reliability, TKR, could figure out the position and role of companies and the movement of position within the network because of acquisition.

Common Internal Knowledge, CIK and Common External Knowledge, CEK could measure the supplementary and complementary of patent and technology.

CIK: Patent citation represents not only the direct dependency for technology but also common knowledge between patent. A patent citing a prior patent shares the supplementary knowledge with the prior art[15]. More patents two companies cite each other, more common knowledge they share. Chen (2013) call this overlap of common knowledge as 'common internal knowledge', CIK, to measure the supplementary knowledge between two companies.

CEK: The dual indirect ties from the third actor could create innovative activity for the couple of actors[22]. Therefore, these indirect ties from the third actor shows that this couple of actors have more common knowledge confirmed by outsider but less similarity of knowledge shared by each other. Chen (2013) call this overlap from outsiders as 'Common External Knowledge', CEK, to measure the complementary knowledge between two companies[23].

Algorithm of TKS, TKR, CIK and CEK

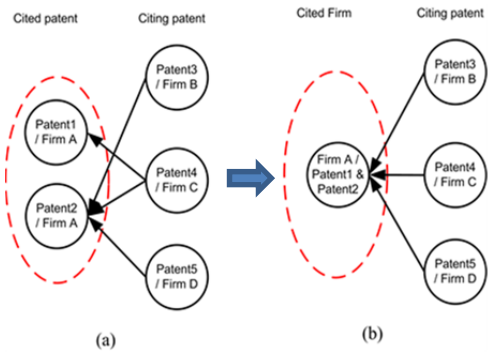

Fig. 2: Technological Knowledge Status, TKS Source: Chen & Lai

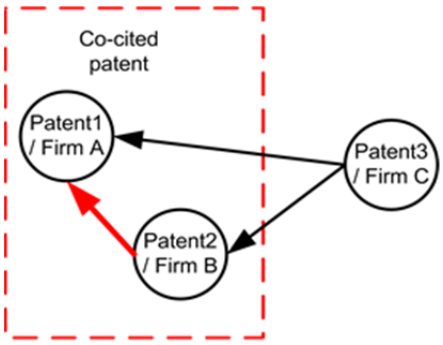

Fig. 3: Technological Knowledge Reliability, TKR Source: Chen & Lai

Step 1: construct the affiliate network of firms and patents

$M = [\alpha_{kr}]_{g\times h}$,

$$\alpha_{kr} = \begin{cases} 1 \text{ if } P_k \text{ affiliatd to } A_r \\ 0 \text{ else} \end{cases} \quad g \geq h \quad \begin{matrix} k = 1,2,\dots,g \\ r = 1,2,\dots,h \end{matrix} \qquad (1)$$

k : k^{th} patent, r : r^{th} firm, g : patent counts, h : firm counts

Step 2: Technological Knowledge Status, TKS

$[TKS_{ii}]_{h\times h} = M^T M$,

$TKS_{ii} = \sum_{k=1}^{g} \alpha_{ik}\alpha_{ki} \quad i = 1,2,\dots,h \qquad (2)$

α_{ik} : k^{th} patent affiliated to i^{th} firm, g: patent counts, h: firm counts

Step 3: Technological Knowledge Reliability, TKR

$[TKR_{ij}]_{h\times h} = M^T M$,

$$TKR_{ij} = \sum_{k=1}^{g} \alpha_{ik}\alpha_{kj} \quad \begin{matrix} i=1,2,\dots,h \\ j=1,2,\dots,h \end{matrix} \; i \neq j \qquad (3)$$

TKR_{ij} : overlap of knowledge between i^{th} firm and j^{th} firm

$$TKR_{ii} = \frac{\sum_{j=1}^{h} TKR_{ij}}{TKS_{ii}} \quad i = 1,2,\dots,h \text{ and } j = 1,2,\dots,h,\ i \neq j \qquad (4)$$

TKR_{ii} : overlap of knowledge of i^{th} firm with others

Step 4: Common Internal Knowledge, CIK

$$CIK_{ij} = \frac{\sum \alpha_{ik_o}\alpha_{jk_e}}{\sum \alpha_{ik_o}} \quad \begin{matrix} i=1,2,\dots,h \text{ and } j=1,2,\dots,h,\ i\neq j \\ o=1,2,\dots,n \text{ and } e=1,2,\dots,n,\ n<g \end{matrix} \qquad (5)$$

Approval date of patent k_o of i^{th} firm must be earlier than Approval date of patent k_e of j^{th} firm

Step 5: Common External Knowledge, CEK

$$CEK_{ij} = \frac{TKR_{ij} - \sum \alpha_{ik_o}\alpha_{jk_e}}{TKS_{ii} - \sum \alpha_{ik_o}} \quad \begin{matrix} i=1,2,\dots,h \text{ and } j=1,2,\dots,h,\ i\neq j \\ o=1,2,\dots,n \text{ and } e=1,2,\dots,n,\ n<g \end{matrix} \qquad (6)$$

III. RESULTS

A. Technological Classification by PCA

This research builds up a patent citation network matrix of $[\alpha_{ij}]_{\text{stent},8809\times8809}$ for all cardiovascular medicine technologies. Four hundreds and ninety patents left forms a matrix of $[\varepsilon_{ij}]_{\text{stent},490\times490}$ because patents with 62 citations or less are cut off. The row matrix is citing patents and the column matrix is cited patents. Due to the point of analysis is citations, patents of column matrix with two forward citations or less and patents of row matrix with zero backward citation cut off forms a new matrix of $[\varepsilon_{ij}]_{\text{stent},383\times222}$.

The co-citation matrix of $[\omega_{ij}]_{\text{stent},222\times222}$ is built after calculating co-citation counts between every two patents based on PCA. Then, the relation matrix of $[\gamma_{ij}]_{\text{stent},89\times89}$ is built by correlation coefficient. Six cluster counts decided by the scree plot of R-square. According to description of patents, these six clusters are labeled as table 1. TF3, Drug-Eluting Stent, is the field of research.

TABLE 1: MAIN TECHNOLOGICAL CLUSTERS OF STENT

TF1	Rhythm Detecting and Automatic Pacemaker	TF2	Rhythm Signal Generator
TF3	Drug-Eluting Stent	TF4	Bare Metal Stents
TF5	Stent Form	TF6	Bifurcation Stent

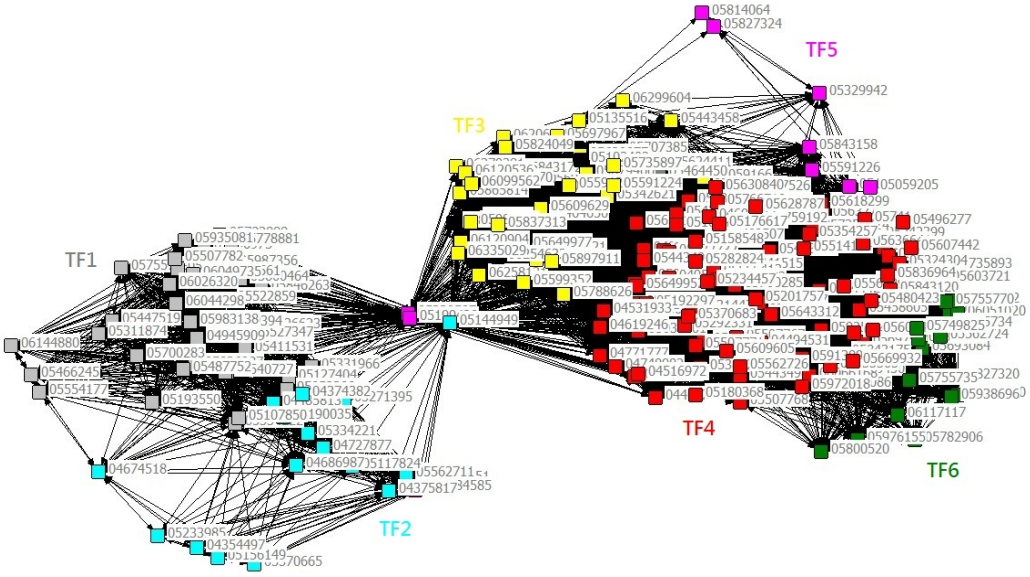

Fig. 2: patent clusters and their connection

B. Database Construction of DES

TF3, Drug-Eluting Stent, DES, has 48 patents. We collect the patent family of these 48 patents from INPADOC and searches patents related to this family. The new database of DES has 5652 patents forming the network matrix$[\alpha_{ij}]_{\mathrm{DES},5652\times5652}$. We delete those patents with 104 citations or less. There are 493 patents left in the matrix. The citing patents have 493 ones and cited patents have 244 ones of $[\varepsilon_{ij}]_{\mathrm{DES},493\times244}$.

C. Technological Knowledge Redundancy Matrix

After calculating the patent co-citation counts of $[\varepsilon_{ij}]_{\mathrm{DES},493\times244}$, We have a co-citation matrix of $[\omega_{ij}]_{\mathrm{DES},399\times399}$. Setting the diagonal is zero because we are not interested in the relation by itself and then calculate the technological knowledge redundancy matrix of $[\gamma_{ij}]_{\mathrm{DES},399\times399}$. Four indicators of TKS, TKR, CIK, CEK are calculated based on $[\gamma_{ij}]_{\mathrm{DES},399\times399}$.

D. Technological Position of TKS and TKR

The changes of technological position of companies before/after patent transfer in Fig. 5 and Fig. 6 are holistic changes within the structure i.e. any companies' positions change along with others' positions change. When the important and complemental patents are transferred, companies' TKSs change a lot. If the patent is also fundamental which attract a lot following technological developments, the company gains this patent will increase its TKR a lot. Before patent transfer, the 399 patents belong to 168 companies. Only 152 companies left after patent transfer. The leader of DES is Medtronic with very high TKS(205) before patent transfer. However, after patent transfer, Cordis jumps on the leading position by increase its TKS(245).

Table 2 shows the main companies' TKS and TKR. After Expandable transfers its all patents to Cordis, Cordis's TKS increases to 245 leaving the former leader, Medtronic, far behind to sit on the leading place securely. BBS takes over 11 patents from BBC, a subsidiary of Boston group, 13 patent from Schneiderd, 19 patents from Scimed and some scattered patents increasing TKS to 226 to be the second place. CMT gains 15 patents from CI and MED being the sixth. Only 15 patents increasing lots of TKS means these patents cited a lot. They are the important patents in DES field.

CI differing greatly from Cordis and BSS of TKS shows that CI has different direction of technological development but its status is low. However, CI having a small gap with Cordis and BSS of TKR shows that these three companies have similar amount of knowledge redundancy with others. Because its technological status is low, CI may be a follower citing others a lot. Cordis and BSS with high TKS may be cited a lot by others.

Secondary data showed that Johnson & Johnson spent ten millions to gain licensing from Expandable in 1988 and then acquired Cordis in 1996. In 1998, Johnson & Johnson spent five hundred millions to acquire Expandable and then transferred all patents of Expandable to Cordis made Cordis be the technological leader leaving other competitors far behind.

TABLE 2: TKS, TKR AND COUNTS BEFORE/AFTER PATENT TRANSFERENCE

items / companies	TKS		TKR		counts	
	before	after	before	after	before	after
Medtronic	205	189	13.23	13.17	29	28
Expandable	183	X	13.39	X	5	X
ACS	179	175	13.49	13.81	79	78
Cordis	158	245	14.07	12.33	18	26
CI	155	159	13.38	12.49	16	8
BSC	116	24	16.13	21.37	13	3
Scimed	108	54	13.68	15.29	26	5
Schneider	95	24	15.87	18.20	17	3
MED	78	X	14.53	X	10	X
BSS	X	226	X	12.77	X	62
CMT	X	115	X	15.98	X	15

BSS became a follower at the second place after patent transfer. In 1995, BSC acquired Scimed and changed its name as Boston Scientific Scimed(BSS) and then transferred 19 important patents belonging to Scimed originally to BBS. Then, BSC spent two hundred and twenty millions to acquire Schneider whose product offerings include stents, angioplasty catheters and accessories for coronary and peripheral operations under Pfizer Medical Technology Group originally. BSC transferred 13 patents from Schneider and 11 patents from itself to BSS. BSC enhances its patent portfolios by strategic acquisitions.

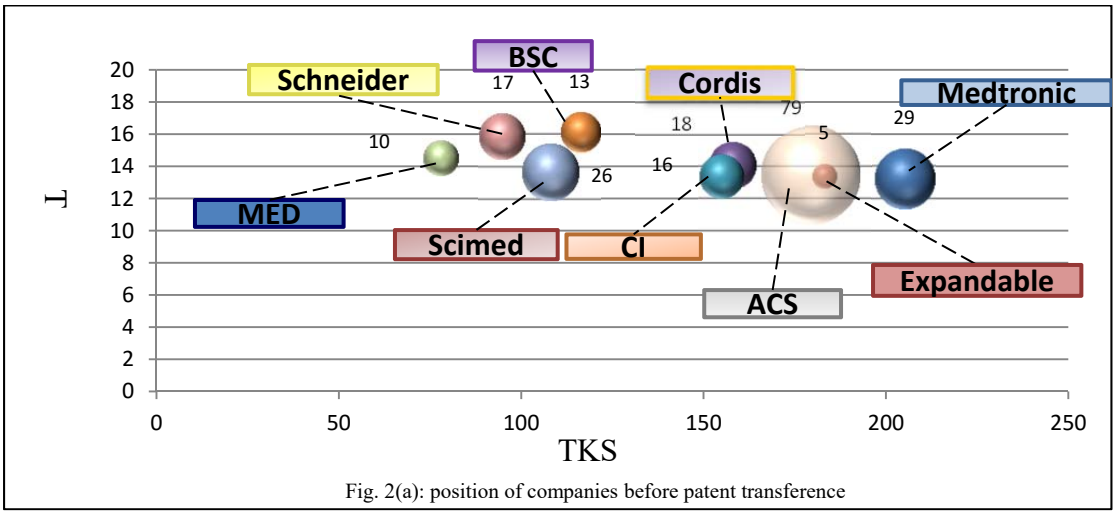

Fig. 2(a): position of companies before patent transference

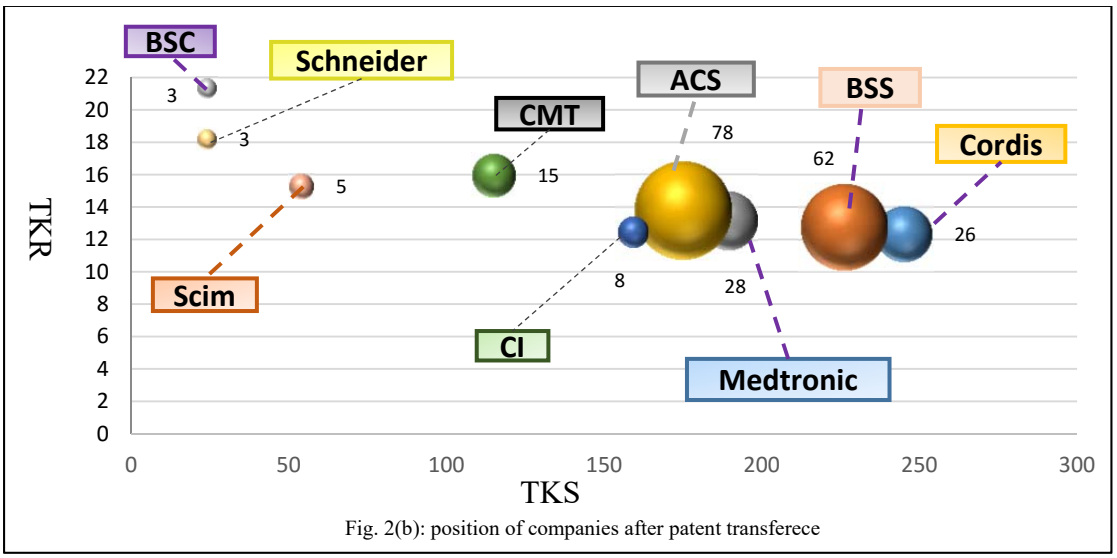

Fig. 2(b): position of companies after patent transferece

E. Supplementary and Complementary Analysis of CIK and CEK

1. Cordis as focal company

Table 3 shows changes of CIK and CEK of main companies before/after patent transfer. CIK represents supplementary for a pair of companies. The highest CIK(1.77) which is between Cordis and ACS represents both companies' technological knowledge depending on communicating with each other highly. Cordis has the second CIK(1) with Scimed. For CEK, Cordis has the highest CEK(0.72) with Medtronic and the second high CEK (0.6) with Expandable. These two companies have complementary technology to Cordis. Cordis acquires complementary technology from Expandable to increase its technological ability.

2. BSC as focal company

BSC has CIK(2.46) with ACS and CIK(1.38) with Scimed. BSC has supplementary technological knowledge with both companies. CEK between BSC and Medtronic is 0.74 and CEK between BSC and Cordis CEK is 0.68. These two companies' technologies are complementary to BSC. BSC acquires Scimed for supplementary technologies to enhance its technological strength. CEK between BSC and Cordis being high shows their technological directions are different and complementary to each other.

TABLE 3: CIK AND CEK BEFORE PATENT TRANSFERENCE

		Medtronic	Expandable	ACS	Cordis	CI	BSC	Scimed	Schneider	MED
Medtronic	CIK		0.58	2.03	0.58	0.89	0.55	0.62	0.55	0.44
	CEK		0.59	0.36	0.57	0.5	0.43	0.32	0.3	0.27
Expandable	CIK	3.4		9.6	2	2	0.8	2.8	0.6	0.2
	CEK	0.58		0.23	0.47	0.6	0.33	0.2	0.25	0.17
ACS	CIK	0.74	0.6		0.4	0.64	0.4	0.65	0.65	0.48
	CEK	0.65	0.41		0.57	0.26	0.42	0.41	0.13	0.29
Cordis	CIK	0.94	0.55	1.77		0.83	0.44	1	0.61	0.5
	CEK	0.72	0.6	0.4		0.44	0.5	0.22	0.2	0.2
CI	CIK	1.62	0.62	3.18	0.93		0.43	0.68	0.37	0.62
	CEK	0.63	0.76	0.18	0.44		0.33	0.29	0.32	0.26
BSC	CIK	1.23	0.3	2.46	0.61	0.53		1.38	0.92	0.76
	CEK	0.74	0.57	0.4	0.68	0.44		0.33	0.3	0.27
Scimed	CIK	0.69	0.53	2	0.69	0.42	0.69		0.42	0.57
	CEK	0.7	0.45	0.5	0.39	0.5	0.41		0.36	0.42
Schneider	CIK	0.94	0.17	3.05	0.64	0.29	0.7	0.64		0.35
	CEK	0.69	0.58	0.16	0.37	0.58	0.39	0.38		0.34
MED	CIK	1.3	0.1	3.8	0.9	1	1	1.5	0.6	
	CEK	0.7	0.47	0.42	0.41	0.54	0.41	0.51	0.39	

TABLE 4: CIK AND CEK AFTER PATENT TRANSFERENCE

		Cordis	BSS	Medtronic	ACS	CI	CMT	Scimed	BSC	Schneider
Cordis	CIK		1.76	0.96	2.38	0.76	0.65	0.11	0.15	0
	CEK		0.51	0.57	0.29	0.54	0.31	0.15	0.08	0.06
BSS	CIK	0.74		0.61	1.54	0.2	0.48	0.2	0.14	0.08
	CEK	0.68		0.56	0.27	0.5	0.38	0.22	0.09	0.09
Medtronic	CIK	0.89	1.35		2	0.53	0.64	0.17	0.07	0.03
	CEK	0.78	0.57		0.32	0.57	0.38	0.16	0.1	0.09
ACS	CIK	0.79	1.23	0.71		0.43	0.61	0.24	0.1	0.14
	CEK	0.67	0.46	0.54		0.31	0.44	0.28	0.05	0.06
CI	CIK	2.5	1.62	1.87	4.25		0.62	0.37	0.12	0
	CEK	0.78	0.54	0.6	0.2		0.29	0.12	0.11	0.07
CMT	CIK	1.13	2	1.2	3.2	0.33		0.4	0	0.06
	CEK	0.7	0.63	0.62	0.43	0.45		0.31	0.07	0.11
Scimed	CIK	0.8	2.6	1	3.8	0.6	1.2		0	0.2
	CEK	0.69	0.75	0.55	0.57	0.38	0.63		0.04	0.06
BSC	CIK	1.33	3	0.66	2.66	0.33	0	0		0
	CEK	0.85	0.71	0.8	0.23	0.8	0.33	0.09		0.04
Schneider	CIK	0	1.66	0.33	3.66	0	0.33	0.33	0	
	CEK	0.66	0.76	0.71	0.28	0.52	0.52	0.14	0.04	

IV. CONCLUSION

A. Role of Leader and Follower

This study explores that manufactures of cardiovascular stent adopts patent acquisition strategies to response competition through patent information analysis. Patent acquisition considers patent's protection, maintaining and enhancing technological advantage, making up for technological disadvantage, integrating upstream and downstream resources. After patent transfer, Johnson & Johnson/ Cordis increases TKS to raise and protect its technological position, Its TKR also becoming high represents that it cites other patents a lot, likewise it is cited by others lots. Its technologies could be applied in market instantly. Cordis intends raising its unique position and expanding its technological fields. TKR of Boston Scientific Corporation/Boston Scientific Scimed increases more than does after transfer. BSS tries to cooperate with other ambitiously. Its TKS going high but less than Cordis shows that BSS tries to catch up with Cordis.

B. Strategic Intension of Acquisition

Leader intends acquiring complementary and follower intends acquiring supplementary technologies. After transfer, leader as a focal company increasing much CIK with follower shows that leader acquires technologies which are complementary to itself and similar to follower's. Cordis as a leader acquires complementary patents to expand the coverage of technology of DES. It goes the direction of that winner takes all to start offense in every field of technology. Follower as a focal company increasing a little CIK with leader shows that follower who avoids leader expanding influence of market intends deepening and enhancing its own original technological field. BSC as a follower deepening and defense strategy to acquires supplementary patents to enhance its niche technology of DES.

Results show that leader adopts"expand/offense" and follower employs "deepen/defense" strategy of Patent acquisition for manufactures of cardiovascular stent. The leader has stand on a strong position in the technological network and tries to expand its territory. Johnson & Johnson acquires Expandable and transfers its patents to Cordis. These patents are complementary technologies for Cordis. The follower enhance its own technological field to maintain its market share. Boston Scientific Scimed chooses acquiring technologies related to itself and employing supplementary technological knowledge to enhance its own existing technologies and maintain its original advantage. Both of Cordis and BSC have different acquisition strategies.

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