Competition in Core-Periphery Technology?: Investigation of Overseas Companies on Their Integration of Mainstream Technologies and Surrounding Technologies in China

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Abstract--**This paper aims to investigate the evolution of technology strategies of international companies operating in China in typical manufacturing sectors. Technology strategies are measured by a CP-system, in which two kinds of technologies, core technologies and periphery technologies, and three layers of technologies, Mainstream Technology (MT), Scope Technology (ST), Service based technology (SBT) are involved. Based on the patent data of 70 manufacturing MNEs selected from Fortune 500 companies, this research tries to shed light on typical questions over technical competitive performance, especially on nature in concentration and diversification, and relevant technical services in those sample F500 companies.**

Major findings in this paper are: sample F500 companies do possess important technology backed competitive power than other non-F500 companies and local Chinese companies; all sample F500 companies widened their technical areas or technology scope; fields in IPC classification of IT and telecommunication technologies are the most competitive areas for sample F500 companies. On the other hand, other non-F500 sample companies, especially local Chinese companies also increasingly develop their own technology strength in technical areas differentiated with those more competitive fields owned by sample F500 companies. Meanwhile, a strategic positioning of the five clustered sample company group is found on MT and ST in particular for concentrated and scoped technology trend. Through three measures over SBT by using information on subsidiaries, R&D centers in different regions, this paper further provides more overall picture of the sample F500 companies on their technology backed MT-ST-SBT system operations in China.

I. INTRODUCTION AND RESEARCH BACKGROUND:

It has been long discussed topic on competition of core competence in manufacturing companies, together with their increasingly added value on service part, generated from their solid production values. Scholars from Hong Kong used to explore such relationship on overseas companies operating in southern China, based on agglomeration effect by a so called core-periphery relationship [1]. Krugman [2] initiated an investigation framework on regional agglomeration of core-periphery system (or CP-system), in which regional agglomeration is increasingly formed by such actions of core – periphery relationship among member companies in the region, especially under across boarder FDI (Foreign Direct Investment) based manufacturing company cases. Clearly, nature of regional embedded agglomeration of either manufacturing or service technologies could be influencing factors, however, on the other hand, along with rapid globalization, both regional and sector based characters of involved companies can be important impact factors, this may be especially true for those larger multinational enterprises.

Meanwhile, as technology resource is often used for local market development, foreign direct investment (FDI) firms may develop more significantly versatile ways of combination of core and surrounding technology, than local companies in host developing countries. So called periphery technology, as well as "service" based technology, can thus be defined and studied together with the core "hard" technologies, especially for those manufacturing companies. Such Core-Periphery relationship or CP-System formation and its degree may be used to measure competitiveness of certain group of international companies.

As analyzed in larger numbers of international literature, patented technology resources are usually considered as one of the most important market controlling and expending power for multinational companies, when their investment in host countries gradually entering into higher value added sectors and product lines. In order to find typical larger companies' technology resource backed behavior in Chinese market, in depth study over typical MNE's is necessary. In this paper, special concern will be focus upon Fortune 500 companies, especially those sample F500 companies particularly active in their patenting movement in China. The Core-Periphery relationship among those companies can be further studied based on patent information. Since service based technologies is difficult to be located in patent information, expansion of their business lines and penetration of regional market by those sample F500 companies will be studied as second kind of important information based on conceptual C-P system framework.

Major questions to be answered by this study in Chinese market case will be three folds:

- Do larger overseas companies (especially Fortune 500 companies in manufacturing sectors) outperform local companies in patent technologies in typical competing technology fields, or otherwise, as an important competitive position?
- Do larger overseas companies (especially Fortune 500 companies in manufacturing sectors) extend typically their technology scope for larger Core-Periphery circle or otherwise, as an important competitive advantage?
- Which kinds of technical fields would be considered as mainstream technologies (MT) for those representative F500 companies involved, in terms of patent

technologies, according to their technical competition in China?

II. TYPICAL FORTUNE 500 COMPANIES' PATENTING DEVELOPMENT IN CHINA.

Fortune 500 companies, as a special group of direct investment operators in the world, was named in 1955, reflecting related developing trend among largest industrial companies in the US. As time goes by, the group of Fortune 500 includes not only companies in the US, but also other companies worldwide, however still within industrial scope before 1990. In 1995, the Fortune 500 list included at the first time companies from service industries. Today, it is highly visible that structure of country origins of those Fortune 500 companies has already been changed dramatically. In terms of average size of the F500 companies, there used to be interesting change during mid 1990's when average size of those Asian and Pacific region based F500 companies (24.1 billion USD turnover as an average measure for company size) outperformed European and North American companies (18 billion USD and 19.1 billion USD, respectively, as average size), however, in recent years (e.g.2007), European and Northern American composition of F500 have been raised to 33.2 billion and 28.8 billion USD respectively, much higher than F500 from Asian and Pacific regions (24.71 billion USD in average).

On the other hand, due to limited measure for the ranking (only on annual business turnover), some scholars argue that this special group of firms may not be typical companies for technology power, as market turnover can be determined by various kinds of different economic factors, technology strength might be just one of them. However, if more strategic movement by MNEs is taken into account, not to say wider understanding of technology terms, which usually implies systematic combination of different resources, including hard and soft (for example service) technologies, then this group of F500 companies can still be used as idealistic samples to investigate technology backed investment, especially when they are technology intensive companies.

At the same time, although energy and power sector usually hosts the biggest numbers of member companies in F500 group, it can also be seen as important sign that technology intensive industries as special sector, increasingly raises emerging technology backed stars into F500 group. In fact, today, composition of F500 group has been kept widening into technology intensive sectors, along with traditional sectors, such as, electronic and electrical equipment, pharmaceutical, medical service, retail, telecommunication, forest and paper manufacturing, portfolio finance, mining and petroleum, financial securities, entertainment, network communication, public services and power generation, and aircraft manufacturing vs. air transportation. Meanwhile, composition share for some more traditional technology based sectors fall, e.g., chemical industries, commercial banking, industrial and agricultural equipment, as well as other sectors, including crowed oil refinery, metal and metallurgical manufacturing, trading, automobile, tobacco, railway, and industrial construction. In this regard, investigation over technology contents in typical F500 should be meaningful.

In terms of Chinese market case, it is reported in 2010 that more than 480 companies out of F500 list have been already operating in Chinese market, along with the faster pace in regional and industrial economic development in China in developing important regional as well as industrial operation. In the meantime, investment by overseas companies for their local R&D centers in China has been booming ever since late 1990's, among them, typical companies in F500 are highly active. It is reported that in recent years, overseas companies' invested R&D centers amounted already to some 1400 in China. Even in early 2000's there is already more systematic study over F500 companies in China[3]. Due to faster pace of globalization in Chinese market, larger MNEs, typically strong technology backed F500 companies, need to be studied during this faster pace of technology backed competition, especially through patent records.

In fact, foreign companies' patenting movement is closely connected with regional economic development in host countries, and such kind of relationships are frequently studied by international scholars, commonly over relationship between patent system development and regional economic performance, as shown by H. Grupp and Schmoch [4] over legislative framework of patent system. Meanwhile, increasingly booming patenting and linkages between patenting movement and regional productivity in OECD countries are studied by numbers of international scholars, such as Kortum and Lernerr [5] and Eaton and Kortum [6]. More direct investigation over overseas patenting, particularly by larger MNEs patenting can be found later in China, such as typical study over the largest Fortune 500 companies on their patenting distributions in China (Liu, Xia, and Wu,[7]. This is because that beginning from mid 1990s, patenting volume in invention type by overseas MNEs in China raised dramatically, dominating over important technical areas including mobile telecommunication (accounting for 91%), computer (93% in information storage technology), medical and pharmaceutical, electronic, and home appliances (76% in basic electronic circuits) during those years until early 2000s. However, it should be noted that in recent years, when technology based competition in Chinese market is increasingly keen, technology resources and technical backed competitiveness become a major issue. Stimulate also by innovation policy, local Chinese companies have been improving their technically competitive position in a rather faster pace, especially in some typical high tech sectors such as telecommunication, electronic, pharmaceutical, new type of energy, advanced materials, etc.. The key issue here is that international MNEs' patenting is usually develop in a more strategic way than local companies, in order to leverage their technology resources, therefore, to study differences on technology resource pattern (C-P system) in typical F500 is meaningful.

TABLE 1. DISTRIBUTION OF FORTUNE 500 COMPANIES ON THEIR PATENTING VOLUME BEFORE 2003

Patenting	>10000	1001-10000	101-1000	11-100	1-10	0
Number of F500	4	30	63	58	71	269
% of the total patenting	30.25%	55.35%	13.05%	1.18%	0.16%	0
Average Patenting Volume	13168	3109.0	355.09	36.76	3.9	0
Std of Patenting by Groups	2094.70	2059.24	233.02	21.94	3.05	0
% of the Std over Average	15.9%	66.2%	65.6%	59.6%	78.2%	--

However, it should be noted that technology backed F500 companies, operating in technology intensive sectors, are rather limited in numbers and usually account limited shares in patenting technologies. According to authors' previous analysis work, during the time period between 1990 and 2003, patenting records for 463 out of the F500 companies, or 92.6% of total member companies in 2003, own maximum less than 1000 records in China. 68% companies were actually patenting less than 10 pieces or even zero (53.8%) during these 14 years. Larger volume of patented technologies was under control of highly limited member companies (for example, 4 companies own more than 10000 pieces of patents per firm in average, refer to Table 1). This reflects the fact that there are highly diverse ways for larger MNEs to operate in international market, or in particular in emerging market such as in China, with technology backed investment. It worth to note that in recent years, typical groups of patentees, including domestic, overseas in total, and even member companies in F500 group increased their patenting volume in Chinese market. In general, since 2006 and 2007, domestic patenting has been increasingly outperformed overseas firms in patenting quantities, but not necessarily in qualities (Refer to authors' paper in 2012[8]). In this case, in order to capture characters of patenting by overseas companies, especially those F500 companies in particular, the research window in this paper is located in the period between 1990 and 2006, when overseas companies' patenting is most active and significant in volume. While after 2006, it would be more meaningful for studying patents in quality measures, rather than quantity terms. However, the methodology used in this study can be also of reference to those studies on patent volume and qualities over core-periphery natures.

III. NATURE OF 70 SAMPLE FIRMS AS REPRESENTATIVE FORTUNE 500 COMPANIES

Patent records are approved by numbers of international studies for their effectiveness of innovation index (refer to [4], [6], and [9]). In this paper, patenting records are investigated based on data from SIPO (State Intellectual Property Office of China) website, between 1990 and 2005, for typical technical fields. 34 fields are eventually selected, under IPC code, according to the principles of patenting frequency and patenting volume. The statistical results show that patenting volume from these 34 fields account for 80.7% of patenting in overall 120 different IPC defined technical fields. Therefore, patenting movement in these fields can be representative to those F500 companies operating in Chinese market, in terms of their competitive strength. It should be noted that these technical fields can reflect both core technology areas and important surrounding technologies by those sample F500 companies, therefore, these fields can be defined as combination of Mainstream Technologies (MT) and Scope Technologies (ST). Since larger numbers of the Fortune 500 companies have not yet any patenting record (about 53.8%), and among those companies that did have patenting records (in total 231 companies in Fortune 500 list), 56.7% companies' patenting records are less than 100, between 1990 and 2005, this study only selected sample companies with 200 patenting records and above.

Based on above mentioned rules, the final selection of the sample 70 companies from F500 list approve to be highly representative in the following nature,

- Each sample company' patenting records in these 34 technical fields account for at least 60% of its total patenting volume, except only two companies with minor gap, namely Honda Motor (57.9%) and Mitsubishi Heavy Industries (58.8%).
- Patenting volume by all sample companies account for 95.8% of overall patenting records in China by total Fortune 500 companies in the 34 sample technical fields, 96.7% of all patenting volume by total F500 companies.

Detailed information on selected 70 sample companies can be found in Appendix of this paper, with their patenting ranking (measured by their shares of each companies' patenting volume against overall numbers of patenting by all sample companies) and Fortune 500 ranking (2007 Version).

IV. DETAILED INVESTIGATION OVER TYPICAL GROUP AND TECHNOLOGY FIELDS

A. Cluster Analysis:

Cluster analysis was introduced to psychology by Robert Tryon in 1939[10] and developed and applied further by Cattell in 1943[11] for trait theory classification in personality psychology. Cluster analysis or clustering is aimed at task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (in particular sense or character) to each other than to those in other groups (clusters). By this method, a task of exploratory data mining may be achieved, and therefore can be used as common technique for statistical data analysis.

Based on the selected sample F500 and corresponding 34 IPC fields, such a Cluster Analysis is conducted in order to

TABLE 2 COMPANY COMPOSITION OF EACH CLUSTER WITH THEIR PATENTING SHARES

No.	Business Areas	Numb. firms	Companies in the group / clusters
I	Electronics, Electrical Equipment/Network and Other Telecommunication Equipment **(ET cluster)** **Patenting share: 76.5%**	31 firms: Average Patenting per firm: 3675	Matsushita Electric Industrial, Samsung Electronics, Royal Philips Electronics, Sony, Hitachi, Siemens, Toshiba, IBM, NEC, Mitsubishi Electric, Fujitsu, Nokia. Sharp, Motorola. Hon Hai Precision Industry, Intel, General Electric, Microsoft, ABB, Alcatel, Sumitomo Electric Industries, BT, Cisco Systems, L.M. Ericsson, Quanta Computer, Schneider Electric, Tyco Electronics, LG Electronics Inc., Sanyo Electric, Mitsubishi Heavy Industries, Deere.
II	Scientific Instruments, Photographic and Office Equipment **(OP Cluster)** **Patenting share: 6.02%**	6 firms: Average Patenting per firm:1627	Canon, Fuji Photo Film, Ricoh, Eastman Kodak, Xerox, Hewlett-Packard
III	Chemicals and Petroleum Refining **(CP Cluster)** **Patenting share 7.44%**	12 firms: Average Patenting per firm: 851	3M, DuPont, Sumitomo Chemical, Royal Dutch Shell, Sinopec, China National Petroleum, Mitsubishi Chemical Holdings, Dow Chemical, Exxon Mobil, Idemitsu Kosan, Asahi Glass, BP
IV	Motor Vehicles and Transportation **(MT Cluster)** **Patenting share 5.88%**	12 firms: Average Patenting per firm: 597	Honda Motor, Toyota Motor, Nissan Motor, Denso, Robert Bosch, Hyundai Motor, Honeywell Intl., Michelin, General Motors, Bridgestone, Goodyear Tire & Rubber, Lear
V	Food, Pharmacy and Household Products **(FP Cluster)** **Patenting share 3.68%**	8 firms: Average Patenting per firm: 648	Procter& Gamble, Pfizer, Nestle, Unilever, Wyeth, GlaxoSmithKline, AstraZeneca, Merck

Notice: Nippon Steel from Japan is the only sample company in the 6th cluster, therefore the company is deleted from the 5 grouped clusters of companies.

classify patenting volume and patenting growth in different groups. In more detail, 70 sample companies are examined on their business nature through cluster analysis over field closeness of the patenting. Five clusters are extracted through cluster analysis, with specific nature and corresponding name defined by common nature of the sample companies in the clusters (refer to Table 2). Clearly, the first cluster I host the highest volume (76.5%) of patenting by the largest numbers of member companies in the group. Other clusters are similar in patenting shares (between 3.68% and 7.44%) with specific names according to technology nature in the clusters.

B. Competitive advantage analysis

Further, RTA[1] technique is applied in this study for detailed investigation over the competitive advantage of those 70 sample companies in China. The so called Revealed Technological Advantage (RTA) index, built from information on the International Patent Classification (IPC) of inventions, provides an indication of a given firm's relative specialization in various technology domains. The revealed technological advantage index is defined as the share of a firm's patents in a particular technology field relative to the share of total patents of that firm to the given sample group. The index is equal to zero when the firm has no patents in a given field, or equal to 1 when the firm's share in the sector equals its share in all fields (no specialization). RTA would be larger than 1 if the relevant company possesses a positive specialization.

Value of RTA can be achieved according to following formula:

$$\mathrm{RTA}ijT = \left\{ \frac{Kij}{\sum_{j=1}^{m} Kij} \Big/ \frac{\sum_{i=1}^{n} Kij}{\sum_{i=1}^{n}\sum_{j=1}^{m} Kij} \right\}_{T}$$

Where *Kij* indicates the i^{th} company's patenting in technical field *j* during time T period, and correspondingly, *RTAijiT* indicates ratio of share of the patenting number in field *j* against all patenting in totally ***m*** fields in that particular company, to share of all sample companies' patenting in field *j* against all patenting volume by all sample companies. Since this study only investigate 70 companies from F500 list over the top 34 technical fields, m is consequently 34 and n is 70. Through such kind of investigation, it can correspondingly find out the competitive position of each sample company in particular technical fields.

In order to contrast RTA based competitiveness change, two time periods are divided between 1990 and 2005. It is commonly defined that when value of RTA is larger than 1, then corresponding companies in related technical field are more competitive than others, otherwise, they are rather weak in competitiveness than other groups. These RTA based value is compared among sample F500 companies, non-F500 overseas companies, domestic companies, and foreign capital companies in total. It can be seen that foreign firms in general is highly competitive in most of the technical fields, however, Chinese local firms are competitive in recent time periods on 14 technical fields, according to the second time span between 1998 and 2005.

[1] This can refer to "OECD Science, Technology and Industry Scoreboard 2013: Innovation for Growth", OECD Publishing, 2013

TABLE 3 COMPARISON OF RTA VALUE AMONG THE F500 SAMPLE COMPANIES AND OTHER PATENTING GROUPS IN 34 TYPICAL TECHNICAL FIELDS.

IPC field	RTA Sample F500 Patenting In China			RTA Non F500 overseas Patenting in China			RTA Domestic Patenting in China			RTA Total Overseas Patenting in China		
	Time I	Time II		Time I	Time II		Time I	Time II		Time I	Time II	
G11	4.97	**3.05**	+	0	0	-	0.18	0.35	-	1.99	**1.74**	+
G03	3.7	**2.25**	+	0.02	0.23	-	0.49	0.36	-	1.39	**1.38**	+
H04	2.95	**2.22**	+	0.46	0.04	-	0.43	0.62	-	1.54	**1.28**	+
F24	1.76	**2.0**	+	0.13	0.05	-	1.27	**1.48**	+	0.86	**1.18**	++
F04	1.56	**1.8**	+	0.55	0.35	-	0.96	0.9	-	0.95	**1.2**	++
G06	2.45	**1.72**	+	0.03	0.14	-	1.09	0.95	--	0.98	**1.04**	++
H03	1.85	**1.66**	+	0.67	0.88	-	0.66	0.46	-	1.19	**1.32**	+
H01	1.87	**1.63**	+	0.85	0.75	-	0.63	0.58	-	1.29	**1.24**	+
G09	0.77	**1.46**	++	0.65	0.65	-	1.28	0.82	--	0.71	**1.11**	+
H02	1.47	**1.39**	+	0.58	0.54	-	0.97	0.91	-	0.96	**1.03**	++
G02	1.44	**1.37**	+	1.39	**1.14**	+	0.47	0.53	-	1.44	**1.27**	+
B41	3.13	**1.35**	+	0.28	**1.33**	++	0.59	0.43	-	1.32	**1.35**	+
F02	0.88	**1.32**	++	0.88	**1**	+	1.05	0.71	--	0.88	**1.19**	++
H05	1.18	**1.26**	+	0.92	**1.23**	++	0.81	0.56	-	1.07	**1.25**	+
A47	0.42	0.92	-	0.79	0.88	-	1.36	**1.13**	+	0.63	0.92	-
B60	0.61	0.91	-	1.09	**1.31**	+	1.04	0.86	--	0.89	**1.08**	++
C08	1.5	0.64	--	1.35	**1.79**	+	0.58	0.75	-	1.37	**1.13**	+
B23	0.38	0.61	-	1.23	**1.61**	+	1.06	0.92	--	0.87	1.03	++
C10	0.72	0.6	-	0.64	0.5	-	1.45	**1.69**	+	0.68	0.56	-
C09	0.5	0.51	-	0.91	**1.46**	++	1.29	**1.12**	+	0.73	0.91	-
G01	0.52	0.51	-	1.14	**1.26**	+	1.06	**1.17**	+	0.88	0.83	-
B29	0.47	0.42	-	1.65	**1.93**	+	0.75	0.88	-	1.17	**1.06**	+
C07	1.23	0.4	--	1.79	**1.73**	+	0.47	0.96	-	1.51	0.96	--
F16	0.31	0.39	-	1.51	**2.08**	+	0.93	0.82	-	1.02	**1.11**	+
B65	0.37	0.39	-	2.09	**2.36**	+	0.59	0.62	-	1.38	**1.22**	+
B01	0.58	0.32	-	1.38	**1.63**	+	0.98	**1.16**	++	1.03	0.88	--
C22	0.48	0.31	-	0.66	**1.31**	++	1.5	**1.41**	+	0.57	0.74	-
C01	0.31	0.3	-	0.87	**1.14**	++	1.43	**1.53**	+	0.64	0.66	-
A61	0.11	0.21	-	1.23	**1.45**	+	1.32	**1.38**	+	0.77	0.74	-
A23	0.16	0.16	-	0.35	0.65	-	1.97	**2.03**	+	0.28	0.36	-
C04	0.2	0.14	-	0.62	**1.02**	++	1.71	**1.77**	+	0.43	0.51	-
C12	0.12	0.09	-	1.5	**1.31**	+	1.11	**1.53**	+	0.94	0.61	-
A01	0.22	0.09	-	1.3	**1.38**	+	1.21	**1.53**	+	0.85	0.64	-
E04	0.13	0.07	-	0.85	**1.07**	++	1.57	**1.76**	+	0.54	0.5	-

Notice: numbers of marks are used in this table to indicate dynamic change in RTA value during the two time periods for the sample companies in corresponding groups:

- ++ indicates larger increase in RTA value for the sample companies in the group in related technical fields;
- + indicates modest increase in RTA value for those companies in the group in related technical fields;
- - indicates generally decrease in RTA value for those companies in the group in related technical fields;
- -- indicates larger decrease in RTA value for those companies in the group in related technical fields.

This table is arranged by the rank of RTA value in the sample F500 company group, and it is interesting to find that those technical fields with corresponding competitive advantage by different patenting sources are rather complementary to each other. And these competitive advantage revealed by RTA measures indicates that the most significant transfer of competitive position between the two time periods happens in non-F500 company group, while other two, especially domestic companies, significantly upgrade in 7-8 fields. It can be reflected from this table that the sample 70 companies dominates in limited technical fields (significantly in 14 fields), and they are losing ground in some of the technical fields (typically in 2 fields), and it is more likely that other non-F500 foreign companies control more technical fields across the two periods. On the other hand, those technical fields dominated by the sample F500 companies are important and can be considered as core fields, such as G11, G03, H04, F24, F04, G06, H03, H01, G09, H02, G02, B41, F02, and H05, where 43% of total patenting records by all sample companies are located, mostly in IT and telecommunication sectors (G11:information storage; H04: electric communication technique; G06: computing, calculating, counting; H03: basic electronic circuitry; H01: basic electric elements; G09: educating, cryptography, display, etc.; H02: generation, conversion, or distribution of electric power; H05: electric techniques.) in Cluster I, others are scattered typically in the fields by sample companies in Cluster II (G02: optics; G03: photography, cinematography, analogous techniques, optical waves, electrography, etc.), or IV (F02: combustion engines, hot-gas or combustion product; F04: positive-displacement machines for liquids, pumps for liquid or elastic fluid, etc. F24: heating, ranges, ventilating techniques, etc..). Fields related to technical areas by sample companies in Cluster III and V are less significantly competitive in F500 group, while other non-F500 overseas companies and local Chinese owners appear more challenging in those areas. Meanwhile, those technical fields where local Chinese companies possess higher competitive advantage cover some of the technology areas with higher market promising potentiality, including biotechnologies and other telecommunication technologies, such as C01, A61, A23, C04, C12, A01, E04.

In general, these research findings reveal that the F500 sample companies in this study do possess core technologies in typical fields, mostly, in manufacturing technologies, which can be considered as MT, however, other non-F500 overseas companies may own important technologies and more competitive in other technological fields, which may be considered as Scope Technologies to the sample F500 companies. At the same time, local Chinese companies are also improving in patenting positions in differentiated technologies areas if contrasted with fields by sample F500 companies.

C. Technology scope to indicate trend of core- periphery relations among sample companies

Together with measurement in RTA, another variable is applied to this study in order to investigate concentration level of the sample companies. Based on the hypothesis that strategically controlled technology is often wider scope ranged in technology coverage, (wider technology breadth, 2005), the Hefindel Index (HI) is therefore applied to this study to capture technology diversification level in corresponding technical fields by those sample F500 companies.

HI is defined as follows: $HI=\sum_{i=1}^{n}(x_i / \sum_{i=1}^{n} x_i)^2$

where x_i is patenting numbers in technical field i, $x_i / \sum_{i=1}^{n} x_i$ indicate ratio of certain sample companies' patenting in this particular technical area. HI is used to reveal convergence level between 1/n to 1, where patenting movement is more evenly distributed over all sample technical field, then HI will be closely approaching to 1/n, and where patenting is highly concentrated in certain field, and overall distribution is highly uneven, then HI should be close to 1. Since HI is usually heavier weighted for larger sized patenting field, it is more sensitive to changes in those larger volume areas and therefore, it could provide important information on various differences between fields, and reveal those dominating fields as well as clusters. Information on RTA value and degree of HI are given in the following table.

Based on these methods, more detailed investigation is conducted over these patent data to capture technology field concentration. Firstly, investigation window is divided into 2 periods between 1990 and 2005, in order to examine field sensitive nature by all sample companies across the more segmented time spans. Secondly, for each particular technical field defined by IPC standard, participating company numbers are collected for each of the 8 time period, in this way, it can be clearly seen that as time goes by, some technical fields are more increasingly attractive than others for sample companies to file their patent application. Clearly, there is a big difference among technical fields in terms of patenting scope by sample companies, with some technical areas operating by more than 50% (56.1%) of sample companies and some others operating only by 8.7% of sample companies. On the other hand, along the time span, every technical field host more companies than previous time period, which also indicates that technology scope is generally and increasingly wider for each of the sample companies. At the same time, if taking particular technical fields into consideration, those fields with strong background in information, telecommunication, and biotechnologies are attracting the highest numbers of sample companies for potential technology resources (refer to Table 4).

TABLE 4. COMPARISON OF RTA VALUE AND HI DEGREE AMONG TYPICAL SAMPLE F500 COMPANIES

Clusters / Sample Company Group	Average RTA			Average HI		
	Time I	Time II	Change	Time I	Time II	Change
Cluster I: Electronic and telecommunication (ET31)	1.64	1.39	-15.2%	0.40	0.31	-22.5%
Cluster II: Office photographing (OP6)	2.08	1.40	-32.7%	0.50	0.27	-46.0%
Cluster III: Chemical, Oil & Petroleum (CP12)	0.86	0.65	-24.4%	0.37	0.22	-40.5%
Cluster IV: Motor and Transportation (MT12)	0.99	0.83	-16.2%	0.63	0.29	-54.0%
Cluster V: food, pharmacy (FP8)	0.43	0.38	-12.5%	0.67	0.46	-33.8%
Total Average	1.20	0.93	-20.2%	0.51	0.31	-39.4%

It can be summarized according to above provided information that for all sample F500 companies, both RTA and HI level are decreasing between the two time periods, which reflects the fact that competitive advantage over other groups of companies, especially over other non-F500 companies, as well as over domestic companies, tend to be diminishing, in specified technical fields. Also, lower HI indicates that all groups of sample companies widened their technology scope (as shown by HI value in the table), which implies that ST (Scope Technology) of sample companies in F500 list is developed and MT (Mainstream Technology) is less significant. This is especially true for Cluster II and III (Office Photographing and Chemical, Oil & Petroleum), while at the same time, there are sample companies which increased their ST range and kept similar level of competitiveness in the original MT areas (such as companies in Cluster IV, the Motor and Transportation). There are also sample companies which kept their competitive position in a few specific technical areas and appear less significant in ST (such as sample companies in Cluster I, Electronic and Telecommunication, and in Cluster V, Food & Pharmacy).

Based on these results, competitive advantage by the sample F500 companies against other non-F500 companies, in terms of patenting volume, is decreasing in all technical fields, except "Electronic and Electrical", or in Cluster I. this is clearly increasing trend of technological competition among different groups. On the other hand, it is also important to note that even in the same group (Cluster), difference and technical distance among member firms inside clusters are increasing, e.g., case in Cluster I, which implies that some companies inside cluster is increasingly more competitive than others, and monopolistic advantage in certain technology fields is key for the competition. However, generally speaking, technology based competitive power in original MT areas by the sample companies from F500 list is gradually challenged by diversified sources, including local Chinese companies.

D. Possible service based technology development by sample F500 companies

This study applies other relevant indicators to include dimensions in possible service technologies.

This may particularly related to collaborative relationships of the investigated companies with other local firms (such as research findings over F500 companies by Park and Reber [12] and by Zhu [13]), Numbers of indicators are thus designed in this study for more detailed investigation over nature of collaborations among the sample companies, as follows:

- ***Subsidiary expansion*** is used to indicate scale of the company's investment in China, in terms of numbers of subsidiaries all over China. Clearly, this measures commitment of the company for Chinese market. As larger numbers of subsidiaries would involve higher service technologies in both levels in headquarters and in subsidiary company level, this measure may also be used to indicate service expansion and likelihood of the development of service technology in relevant companies.
- ***Local market collaboration*** is used to indicate whether the company is willing to collaborate with local Chinese companies or rather choose to be more independent (or wholly owned subsidiary form). Clearly, when the corresponding companies choose more joint ventures or other forms of collaborative business practices with local companies, this indicator becomes higher (or collaborative ratio is higher), otherwise, the company would be more independently running its own wholly owned firms and its own market shares.
- ***Provincial Market Access*** measures related company's regional operating scope (numbers of provinces or cities directly under state council in China) in its market development across different regions in China. Higher value of this indicator implies that the company will have wider scope of the geographically bounded regional market in diversified provinces or influential cities in China.
- ***R&D centers*** indicate numbers of R&D facilities of the sample companies and average level of related groups of sample companies.

Based on related information provided by regular publications on F500 operating in China, features of the four indicators as research results from this study can be provided as follows.

TABLE 5. TYPICAL NATURE OF SAMPLE GROUPS IN TERMS OF SERVICE RELATED CHARACTERS.

Cluster and Sample Company Group / Average / Std of Indicators in the group	Subsidiary expansion		Local market collaboration		Provincial Market Access		R&D center	
	Ave.	Std	Ave.	Std	Ave.	Std	Ave.	Std
Cluster I: Electronic and Telecommunication (ET30)	24.8	48.4	72.6%	97.9%	6.10	9.2	1.95	3.6
Cluster II: Office Photographing (OP4)	12.5	16.9	37.6%	49.4%	3.50	4.8	1.70	3.2
Cluster III: Chemical, Oil & Petroleum (CP8)	17.8	31.5	59.5%	89.3%	6.75	10.2	1.70	3.3
Cluster IV: Motor and Transportation (MT11)	21.2	40.7	65.6%	40.7%	5.64	8.6	1.56	2.5
Cluster V: Food, Pharmacy (FP7)	8.9	15.1	50.9%	81.3%	4.25	6.3	1.53	2.7
Total Average	17.0	--	57.2%	--	5.25	--	1.69	

Source: Edited by author based on data from Wang, Zhile, Xu, Li-li, <Multinational Corporation in China Report - 2010> (in Chinese), China Economics Press, 2010.

Notice: due to shortage of information in <MNCs in China Report 2010> (in Chinese), some sample companies from original list of F500 sample companies are removed from the list.

From Table 5, it is revealed that sample companies from Cluster I stand at the top level in terms of local market collaboration, with the highest average numbers of subsidiaries, provincial market access, and R&D center facilities, while the sample companies in Cluster II are in the bottom line in terms of local market collaboration, with the smaller scale of subsidiary expansion and provincial market access. On the other hand, from previous sections, it is obvious that the Cluster I also hosts the largest volume of patenting records, indicating the most technology intensive group in terms of patent resources. Thus it can be concluded that the sample companies in the Cluster I may possess both the highest level of core-periphery technologies (clear core technologies with significant surrounding technologies) and the highest level in service based technologies to support those companies' operation. It is worth to note that this situation may be strengthened by technology and market nature in related sectors.

Furthermore, with bench mark of *Local Market Collaboration* measure, which is a closer measure on hard and soft side of technologies involved, numbers of other important indicators can be contrasted (refer to Table 7). The different nature of two grouped samples (higher and lower level of local collaboration) shows that sample companies in highly collaborative group usually focus much further on patenting technologies and correspondingly local technology development through R&D facilities, although these sample companies have almost equal level of average numbers of subsidiaries with the contrasted group – less collaborative samples. This again implies that in depth collaboration with local partners would provide invested companies with higher position not only in service technologies (to develop local relationship and local market share), but also in core-periphery technologies (patenting cases) and in potential opportunities to develop future technologies (R&D facility cases). It should be noted that there other two groups for reference in the following table (total group and group of sample companies with 15 or more subsidiaries).

V. CONCLUSION

Based on thorough study over larger MNEs, and typically sample companies from Fortune 500, following conclusions can be made according to previously designed research questions.

For Question 1: Larger companies, especially F500 companies, developed their business and market in China primarily based on their strength, including technology resources by some typical manufacturing companies, as those sample firms in this study, typically reflected by patenting records. The research shows that those sample F500 companies do possess important technology backed competitive power than other non-F500 companies and local

TABLE 6. CONTRAST BETWEEN THE TWO GROUPS OF COLLABORATIVE LEVEL – SERVICE BASED TECHNOLOGY

Nature of the classified group	Accumulated Patenting Shares (%)	Average numbers of Subsidiaries	Provincial market access	Average R&D centers	Average Collab. Ratio*	Ave. Local Technology Focus Ratio**	Number of the sample companies
Group of less collaborative samples	9.75%	34.22	7	2.33	42.40%	8%	9
Group of highly collaborative samples	30.80%	31.18	8.27	3.00	92.90%	13.10%	11
Subtotal (with 15 or more subsidiaries)	64.67%	33.83	7.97	2.62	69.10%	9.80%	29
Total	93.95%	20.34	5.69	1.77	64.50%	11.00%	62

Notice:

** Collaboration Ratio = (total numbers of subsidiaries – numbers of wholly owned subsidiaries)/total No. of subsidiaries of specific sample company*

*** Local Technology Focus Ratio = Numbers of R&D centers of the company/Numbers of total subsidiaries of the sample company.*

Chinese companies, especially in technology areas G11, G03, H04, F24, F04, G06, H03, H01, G09, H02, G02, B41, F02, and H05. In any case, technology competitive advantage is generally decreasing in the sample F500 company group, compared with other major sources including non-F500 overseas companies and domestic companies. This trend is especially clear if investigated across time periods through member companies in the sample F500 list. The most significant upgrading in RTA terms happen in non-F500 company group, with expended dominated areas.

For Question 2: In terms of industrial technology focus or core-periphery circle, all sample F500 companies widened their technical areas or technology scope, indicated by decreased HI value, while at the same time, their competitive advantage is gradually eroded. Again, it further proves that larger MNEs are more competitive in combined and systematic sources, including technology and others, and patenting based sources along may not be important, demonstrated by decreased competitive advantage in patenting records based RTA measures, however, except a few very large technology intensive companies.

For Question 3: based on this research findings, fields in IPC classification of IT and telecommunication technologies are the most competitive areas for sample F500 companies, which primarily owned by sample companies in Cluster I. On the other hand, those sample owners although decreased in their original competitive position, within this narrowly defined mainstream technologies (MT), their competitive position may be not only dynamically strengthened by their widening technology scope, or wider surrounding areas (ST based technologies), but also dynamically strengthened by their service based technology (SBT) in developing their collaborative platform in the marketplaces and focus on wider range of technologies through heavier R&D facility development.

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