The Innovation Process of Huawei and ZTE: Patent data analysis

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Abstract: This study compares the innovation process of Huawei and ZTE in China using their patent data. By using patent statistics and raw data, this study provides more detailed findings than what statistics alone can provide. Huawei and ZTE were selected for this study mainly because they were the only Chinese firms that ranked among the top 100 PCT applicants in 2011. This study investigates the difference in the innovation process in R&D between Huawei and ZTE by analyzing (1) domestic and international patent application pattern, (2) granted patents, (3) co-applicants and inventors, (4) knowledge accumulation inside Huawei and ZTE, and (5) knowledge spillover to domestic and foreign firms.

Keywords: China, Huawei, Patent data, Patent statistics, ZTE
JEL classification: L25, L96, O31

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1. Introduction

Innovation is a key for economic growth. Although the primary actor for innovation is the firm, the policy maker is also an important actor. The policy maker's role is to choose and install based on evidence the best practice among "let the market rule", "let the government rule", or a mixture of the two. However, the policy maker's understanding of the innovation process was very difficult because there were no standardized data. Even if there existed, some were country-specific. There was the need for guidelines for standardized data and indicators that can tell the innovation process.

One type of data that provide information about the innovation are the surveys. The Organisation for Economic Co-operation and Development (OECD) has been publishing the Oslo Manual (OECD & Eurostat, 2005) since 1992. The Oslo Manual is a guideline for data and standardized indicators necessary to understand the innovation process. However, surveys have limitations for two reasons. First, it is sometimes difficult for respondents in surveys to objectively answer their behaviors. Second, doing additional surveys is not an easy work in terms of time and cost.

Patent data do not have such limitations. First, patent documents contain real information about the innovation process. If we look at any patent document, we can obtain not only information about the inventions but also about the patent office to which the patent is applied, the title, the inventors and their addresses, the assignee and their address, the application number, the publication number, the publication date, other related patent applications, the foreign application priority data, the patent classification, the abstract, and the best mode figure. Second, the patent office is a government organization, hence the applicants must follow all its rules. Third, once registered, information in patent documents does not change over time. For those reasons, patent data are a very important data source that lets us understand the innovation process in national (Kang, Huo, & Motohashi, 2014), sectoral (Kang & Motohashi, 2014a;), corporate, business-departmental, and personal (inventor) levels (Kang & Motohashi, 2014b).

Patent filing is sometimes regarded as innovativeness. Recent years have witnessed an explosion of domestic and international patent filing by Chinese firms. According to a report by the World Intellectual Property Organization (WIPO) in 2011, ZTE Corporation and Huawei Technologies Co, Ltd, both Chinese telecommunication equipment manufacturers, ranked 1 and 3 respectively as PCT applicants (Table 1). Since patents correlate positively with research and development (R&D) (Pakes & Griliches, 1980) and are regarded as an indicator of innovation (Griliches, 1990;

Nagaoka, Motohashi & Goto, 2010), one may assume that Huawei and ZTE have become highly innovative.

Table 1. Published PCT International Applications by Top Ten Applicants

2011 Ranking	Applicant	Country of Origin	PCT applications published in 2011
1	ZTE Corporation	China	2826
2	Panasonic Corporation	Japan	2463
3	Huawei Technologies Co. Ltd	China	1831
4	Sharp Kabushiki Kaisha	Japan	1755
5	Robert Bosch Corporation	Germany	1518
6	Qualcomm Incorporated	U.S.	1494
7	Toyota Jidosha Kabushiki Kaisha	Japan	1417
8	LG Electronics Inc.	Korea	1336
9	Koninklijke Philips Electronics N.V.	The Netherlands	1148
10	Telefonaktiebolaget LM Ericsson	Sweden	1116

Source: WIPO (2011).

The burst of Chinese patent filings has raised the question of whether this increase in patent applications in China reflects a growth in Chinese R&D capability. To answer this question, two studies sought to explain the recent surge of Chinese patent applications. Hu & Jefferson (2009) found that China's patent explosion can be attributed to the increase in foreign direct investment (FDI) and patent system reform while the intensification of R&D has had little effect. Then a recent study by Li (2012) found that a more significant reason has been the patent subsidy program by local governments. Whether or not patent statistics truly reflect the innovativeness of Chinese firms is still under discussion, and this forms the research question of the present study.

To answer the research question, this study analyzes detailed information beyond the PCT patent applications of Huawei and ZTE. Statistical information retrieved from a large number of patent applications, known as patent statistics (Basberg, 1982; Griliches, 1990; Nagaoka, Motohashi, & Goto, 2010), has been widely used in innovation studies. However, this study uses raw information in addition to patent statistics. By doing so, this study provides a clue as to how reliable patent statistics are in better analyzing the innovation performance of Chinese firms compared to using statistics alone. I believe the findings of this study have several implications in

understanding the applicability of patent statistics to the patent data of Chinese firms.

I present an in-depth investigation of Huawei and ZTE. The selection of Huawei and ZTE is viable for two reasons. First, Huawei and ZTE were the only Chinese firms that ranked among the top 100 PCT applicants in 2011. Accordingly, their patent applications provide large samples, and various patent statistics can be applied to these samples. Second, concerns have been raised in prior studies regarding how innovation patterns can be explained as the outcome of different technological regimes (Breschi, Malerba & Orsenigo, 2000; Lee & Lim, 2001). However, such concerns are not applicable for Huawei and ZTE, because they have almost the same history and operate in almost the same field of business in the same industry (as will be discussed later in Section 3). I assume that the differences in their innovation patterns are largely affected not by external factors but by internal factors.

The structure of this paper is as follows. The next section discusses previous literature about patent statistics. Section 3 gives a brief overview of Huawei and ZTE. Section 4 presents the research data and shows the findings of this study. Section 5 discusses the findings. Section 6 concludes with remarks on the implications and the limitations of this study.

2. Literature Review: Empirical study using patent data for innovation studies

The data analysis for this study is based on the information retrieved from a large volume of patent data, called patent statistics. Patent data provide useful information that helps us to understand the technological innovation process (Jaffe & Trajtenberg, 2002). Thanks to the rapid developments in the computer industry in recent decades, information can be obtained in simple, digitalized form. Using suitable software, the digitalized data in patent documents can be transformed into information, which is then used in quantitative analyses. In addition, high-performing databases that enhance the processing of big data such as patent documents have been developed in line with the developments in the computer industry.

Since patents are often regarded as an output of R&D and are considered an indicator of innovation, the analysis of the information acquired from patent documents allows us to see how R&D is conducted and how technological innovation is derived from inventions. Various scholars have proposed dozens of patent statistics for the effective analysis of patent data. Patent statistics are used in various fields such as science and technology, social sciences, and economics. The number of empirical studies using patent statistics has increased significantly in recent years.

In the following subsections, I introduce the patent information that is used in this study.

2.1 International patent application

Patents are territorial. If an applicant wants exclusive rights in other countries, he/she must file for patents in all the countries of interest. There are two routes to file international patents. One route is the Paris Route. An applicant directly files patent applications simultaneously in the countries where he/she wants to protect his/her invention. The other route is the Patent Cooperation Treaty (PCT) route. A major advantage of PCT applications is that the applicant can postpone the decision to enter each patent office up to 30 months (Schmoch, 1999). However, patent applications are subject to a tradeoff between dominance and cost. Companies doing business in global markets apply for patents in all the countries of interest, which involves the risk of high cost. Thus, analyzing the countries where an applicant files patents would help to understand where the applicant already has markets or to which countries he/she is planning to expand his/her markets.

A study by Schmoch & Schnöring (1994) empirically showed how international patent filing discloses marketing strategies of the patent applicants. They analyzed patents of European and Japanese telecommunications equipment manufacturers and found which company conducted R&D internationally and which company aimed at foreign markets.

2.2 Grant ratio

A patent application needs to satisfy certain requirements for the patent to be granted. The requirements differ over time and across patent offices. Among the various requirements, novelty and inventiveness are the most common ones. Novelty requires that an invention must not be known to the public before the date of the patent application. Inventiveness requires that a person having ordinary skills in the art of invention must not be able to make the invention easily at the time the invention was made. Inventiveness is also known as non-obviousness. Patents that are granted can be assumed to have good value because they satisfy the requirements. A high grant ratio of an applicant implies that the applicant has high capability to apply for (and obtain) valuable patents.

A study by Li (2012) investigated that patent subsidy programs in China did not lower patent application quality. He used the grant ratio of patent applications as an indicator of patent application quality. By showing that the grant ratio of patent

applications in China did not decrease, he concluded that patent subsidy programs in China did not lower patent application quality.

2.3 Co-applicants and co-inventors

Collaboration is a requisite for successful technological innovation because resources and competence are dispersed organizationally and geographically (Teece, 1992). Recent environmental changes such as shortened product life cycles, increasing technological complexities, and the increasing cost of R&D have made it necessary to utilize external knowledge sources. Collaboration with others is one channel for making use of external knowledge sources. Collaboration between competitors and university-industry collaboration (UIC) have been increasing over the last decades (Hagedoorn, 2002; Gnyawali & Park, 2011). Collaboration with others appears in the patent data in the form of co-applications and co-inventors. Analyzing the co-applicants and co-inventors in patent documents would help to understand from where a firm obtained external knowledge.

A paper by Guellec et al. (2001) showed the extent of internationalization of R&D activities. One of the indicators that they proposed focused on co-inventions by inventors from different countries. Using the number of co-inventions, they compared the extent of co-inventions in one country with that in other countries and analyzed national trends of internationalization of R&D activities.

2.4 Knowledge accumulation and knowledge spillover

Patent citation analysis is widely used to measure knowledge flow (Fung & Chow, 2002; Jaffe & Trajtenberg, 2002; Nelson, 2009). References are used to examine patent applications. The addition of references is the patent examiner’s responsibility. Patent examiners add references that narrow the scope of the patent documents and block the claims in the patent documents. However, applicants often add references although there is no incentive for them to do so. The applicants disclose references that would help to explain the information in the patent documents and to support their claims (Hedge & Sampat, 2008). The references added by both parties form the invention chain. Accordingly, the patent citation analysis provides useful information about the knowledge that has influenced an invention. By analyzing the sequences of patent citations, one can follow the trajectories of knowledge flow (Verspagen, 2007; Fontana, Nuvolari, & Verspagen, 2009; Martinelli, 2011).

The interpretation of patent citations is such that if patent A cites patent B, knowledge flows from B to A. Knowledge accumulation can be measured by the

proportion of citations of the patents filed by the same applicant (self-citation). A study by Kang, Huo, and Motohashi (2014) used self-citation in the patents of Chinese and Korean firms to show how they accrued knowledge in the mobile communications industry. Knowledge spillover can be measured by the proportion of citations of the patents filed by any other applicant.

3. Huawei and ZTE[1]

Using Huawei and ZTE for this case study has three advantages. First, they file a large number of patents; thus, their patent data provide large samples that would help in better understanding their innovation process. They were the only Chinese firms that ranked among the top 100 PCT applicants in 2011 (WIPO, 2011). Second, they are in the China's telecommunications industry. China has played "catch-up" in this industry, and it is generally accepted that it has been successful. In addition, China has built up a basis for long-term innovation in the industry (Lee, Cho, & Jin, 2009). Third, prior studies (Harwit, 2007; Gao, 2011) have showed that Huawei and ZTE stand out among the players in China's effort to catch up. Other representative companies in China's telecommunications industry have been Eastcom, Datang and Great Dragon. Eastcom's strategy of merely buying foreign advanced technology without accumulating technological capability did not increase its revenue (Gao, 2011). Datang had technological capability and was the main developer of Time Division Synchronous Code Division Multiple Access (TD-SCDMA), but the company failed to achieve commercial success (Gao, 2011). Great Dragon, which became a conglomerate when the Chinese government decided to amalgamate domestic manufacturers into one in 1995, could not survive a price war initiated by domestic competitors (Harwit, 2007). Meanwhile, despite their short histories, Huawei and ZTE have achieved rapid growth in global markets (Figure 1).

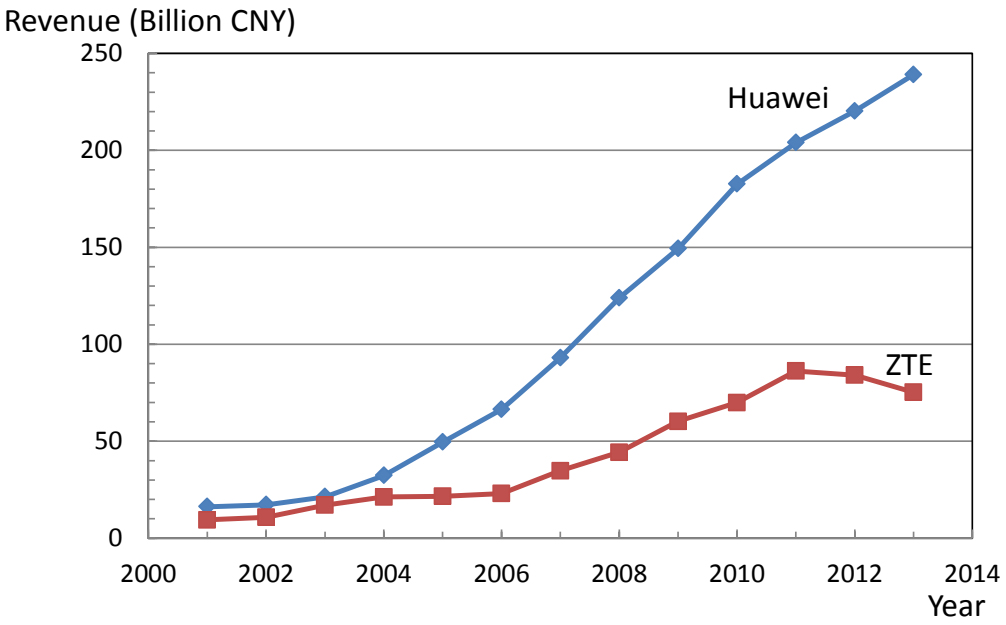
Huawei is a global telecommunications equipment manufacturer. It was founded by Ren Zhengfei in 1987 in Shenzhen. After working for the army and a state-owned enterprise, Ren started his business as a sales agent for a Hong Kong company producing private branch exchange (PBX) switches. The company achieved rapid growth, and today Huawei has become one of the top telecommunications equipment suppliers. The company is famous for its active R&D. Nearly 50 per cent of all the employees are R&D staff. The shareholders of Huawei are the Union of Huawei

[1]Most of the information profiling Huawei and ZTE comes from their web pages and fromhttp://www.chinese-champions.com (Last access: 10/06/2014).

Investment & Holdings Co., Ltd. and Ren; the former is wholly owned by Huawei's employees, meaning that Huawei is owned by its employees.

ZTE also is a global telecommunications equipment manufacturer. ZTE was founded in 1985 in Shenzhen by a group of state-owned enterprises associated with China's Ministry of Aerospace. With the government seeing the need for more domestic companies to produce telecommunications switches, ZTE expanded its business into the telecommunications industry (Harwit, 2007). The largest shareholder is Shenzhen Zhongxingxin Telecommunications Equipment Company Limited (Zhongxingxin), a state-owned shareholder (ZTE, 2013). ZTE claims its business model is a "state-owned and privately-managed (guo you si ying)" one (Harwit, 2007). Nevertheless, since the largest shareholder is a state-owned entity, it is natural to assume that ZTE's management to some extent is influenced by Zhongxingxin for governmental purposes.

Figure 1. Huawei's and ZTE's Growth in the 2000s



(Source: GTA Data and Huawei's and ZTE's annual reports)

Information about Huawei and ZTE is summarized in Table 2. As can be seen, the two companies have almost the same history and operate in almost the same field of business with one critical difference: their type of ownership. Huawei is privately-owned while ZTE is state-owned.

Table 2. Information about Huawei and ZTE

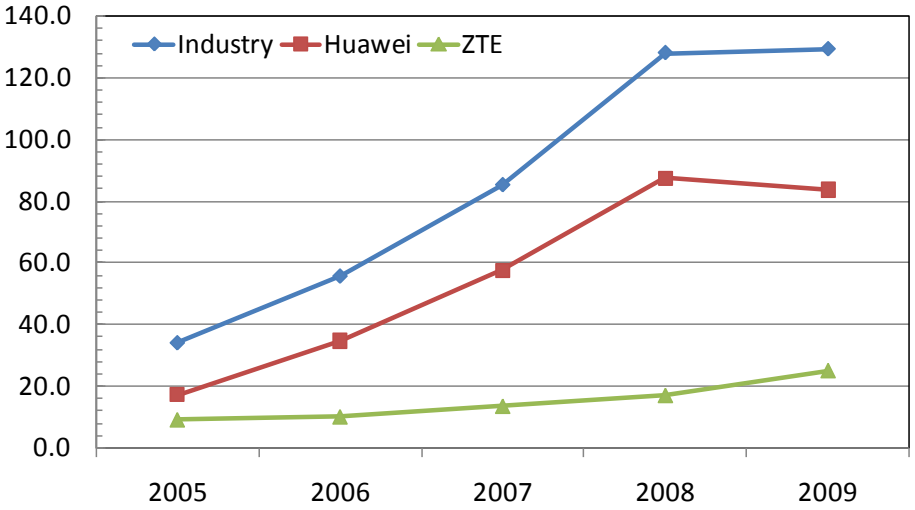
	Huawei	ZTE
Name	Huawei Technologies Co. Ltd. (华为技术有限公司)	Zhongxing Telecommunication Equipment Corporation (中兴通讯股份有限公司)
Founded	1987	1985
Headquarters	Shenzhen, Guangdong, China	Shenzhen, Guangdong, China
Industry	- Telecommunications equipment - Networking equipment	- Telecommunications equipment
Shareholders (as of 2013)	- Huawei Investment & Holding Co., Ltd. (98.6%) - Ren Zhengfei (1.4%)	- Zhongxingxin (30.1%) - HKSCC Nominees (18.3%) - CITIC Trust (1.7%) - Hunan Nantian (1.1%) - etc
Owner type	Private	State

(Source: Huawei's and ZTE's annual reports and websites)

Many indicators show that Huawei and ZTE are the two leading firms in the telecommunications industry[2] in China. I introduce three representing indicators. First, the delivery value of the exports between 2005 and 2009 is shown in Figure 3. The share of the two companies' delivery value of the exports in the industry in 2005 was about 77.6 per cent. Their share continuously increased and reached 84.2 per cent in 2009. Second, the gross industrial output value between 2005 and 2009 is shown in Figure 4. The share of the two companies' gross industrial output value in 2005 was about 62.3 per cent. Their share continuously increased and reached 74.2 per cent in 2009. Third, the employment between 2005 and 2009 is shown in Figure 5. The share of the two companies' employment in 2005 was about 52.5 per cent. Their share continuously increased and reached 71.7 per cent in 2009. All these indicators show that Huawei and ZTE are the two leading firms in the telecommunications industry in China.

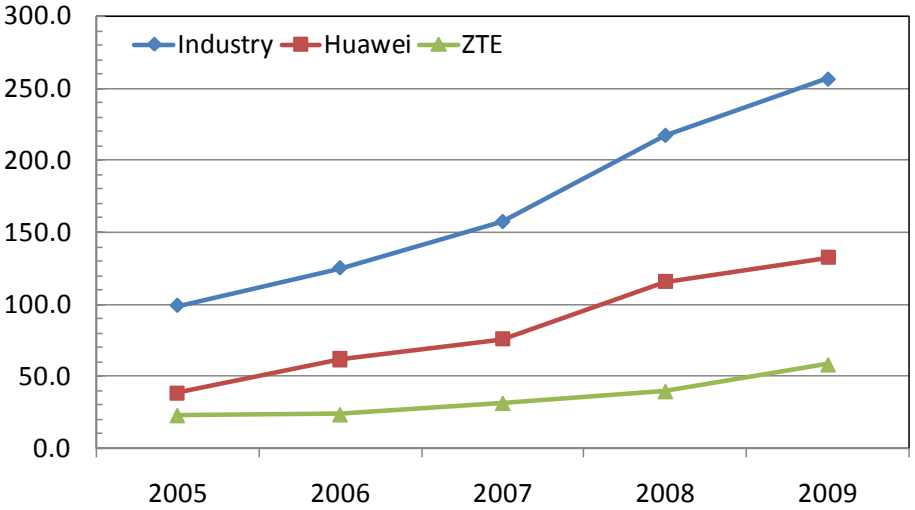
Figure 3. Delivery value of exports (billion CNY)

[2]The industry was named as 'manufacturing of communication switching equipment' in the database.



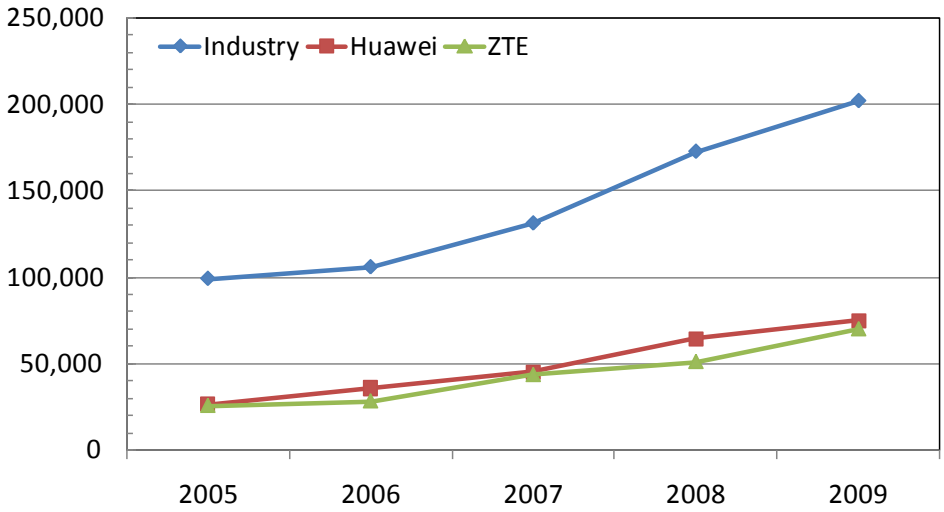
(Source: GTA Data)

Figure 4. Gross industrial output value (billion CNY)



(Source: GTA Data)

Figure 5. Employment (No. of people)



(Source: GTA Data)

4. Data and Findings

4.1. Patent applications

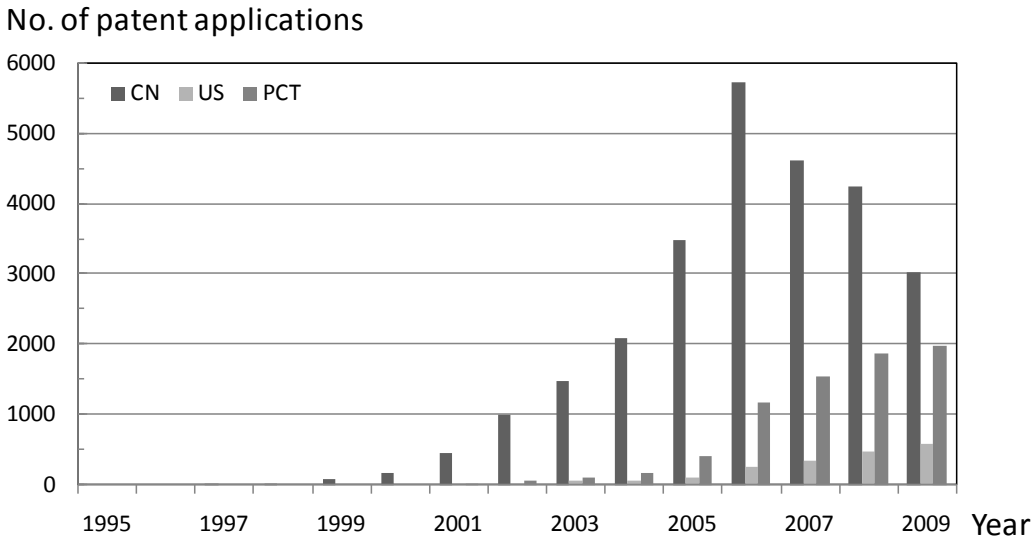
I examined the patent data that Huawei and ZTE submitted to the State Intellectual Property Office (SIPO) of the People's Republic of China and to the US Patent and Trademark Office (US PTO) from the time of each company's founding until 2012. I also examined PCT applications filed with SIPO during the same period. The PCT is administered by the International Bureau of WIPO. Since the PCT enables a patent application filed with one patent authority to be effective with other patent authorities of PCT contracting states, companies doing business in global markets file many PCT applications.

The numbers of annual patent applications by Huawei and ZTE are shown in Figures 6 and 7, respectively. I eliminated the most years between 2010 and 2012 to ensure that the patents used in this analysis had sufficient time to be filed in foreign patent offices. The patent application data held by SIPO indicates that Huawei started to apply for patents from 1995 and ZTE 1999. It took 8 years and 14 years respectively from their foundings for Huawei and ZTE to file their first patent applications. Although ZTE was established earlier than Huawei, it filed its first patent application later than Huawei.

The first bars in Figures 6 and 7 show the number of patent applications to SIPO. From 1999 Huawei's and ZTE's patent applications to SIPO increased rapidly and continuously until the late 2000s. This increase implies that their R&D activities increased, which in the case of ZTE is also supported by the increase in the number of

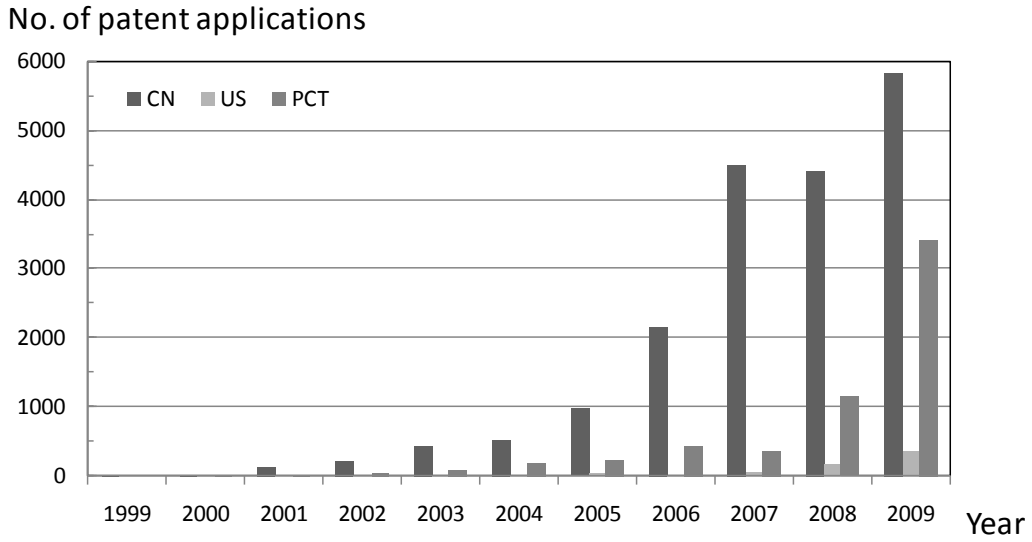
its R&D employees in the 2000s. Considering that ZTE's R&D staff accounts for about half of its employees (Figure 8), ZTE is being more aggressive in applying for patents than is Huawei.

Figure 6. Huawei's Patent Applications



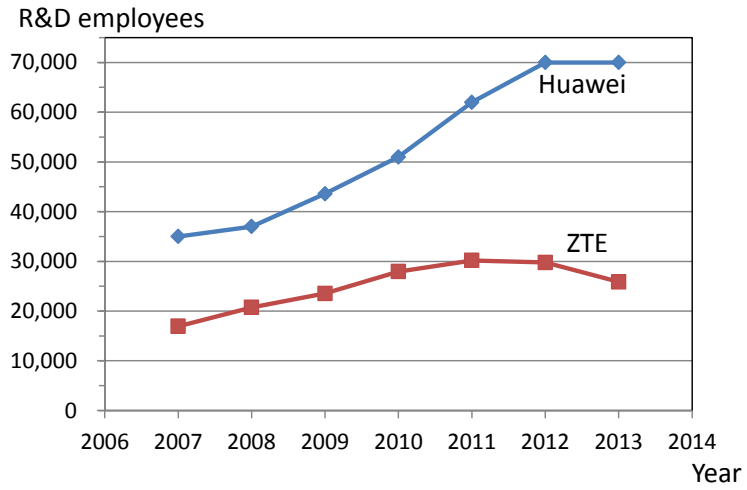
(Source: Author's calculation using PATSTAT)

Figure 7. ZTE's Patent Applications



(Source: Author's calculation using PATSTAT)

Figure 8. Size of R&D Staff in Huawei and ZTE

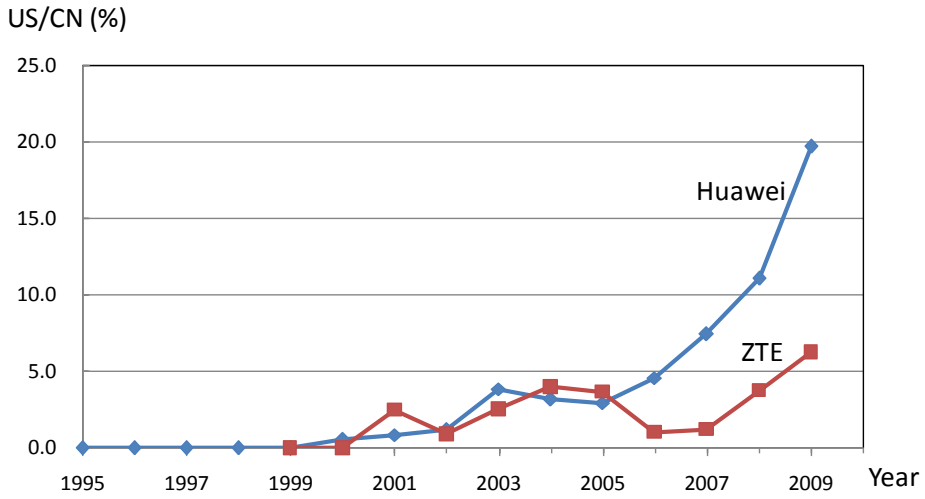


(Source: Huawei's and ZTE's annual reports 2007-2013)

The second and the third bars in Figures 6 and 7 show respectively the number of patent applications to the US PTO and the number of PCT applications. Interestingly, US applications and PCT applications by both Huawei and ZTE started from 2000. China's accession to the World Trade Organization (WTO) in December 2001 probably made the Chinese firms consider to expand their business into the global market and accordingly, as a first step, file international patent applications. Applications to the US PTO and PCT applications by both companies continued to increase until recently. For both firms, the ratio of PCT applications to applications to SIPO has been much higher than that of the US PTO applications to applications to SIPO. This is because the PCT application allows an applicant to delay up to 30 months after the first patent filing the making of any strategic decision, and hence the PCT applicant has a longer time to consider a strategic patent filing.

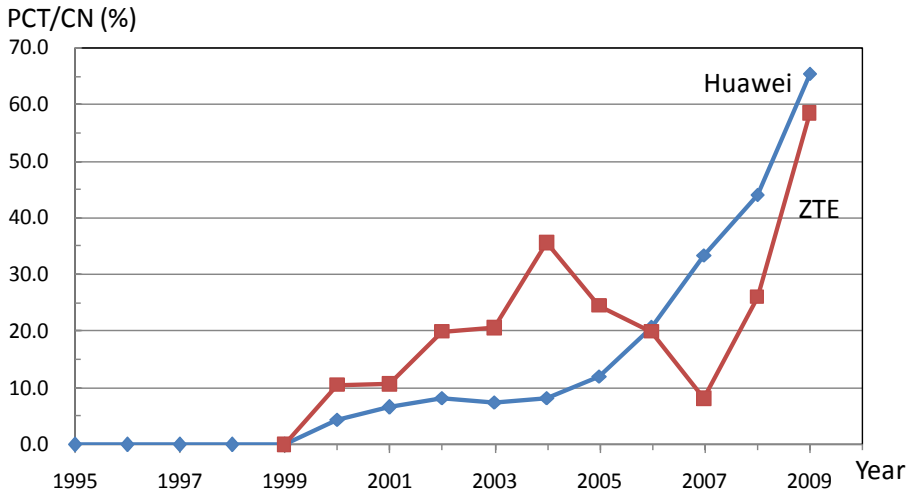
The ratios of US and PCT patent applications to China patent applications by Huawei and ZTE are shown in Figures 9 and 10.Figure 9 shows that in recent years, Huawei tended to file more patent applications with the US PTO compared to ZTE. On the other hand, Figure 10 shows that ZTE began to file many PCT patent applications from 2007.Figures 9 and 10 show that ZTE's curves dropped in 2006 and 2007. Presumably, this sharp drop is due to the sharp increase in the number of patent applications filed with SIPO.

Figure 9. Ratio of US patent applications to China patent applications



(Source: Author's calculation using PATSTAT)

Figure 10. Ratio of PCT patent applications to China patent applications



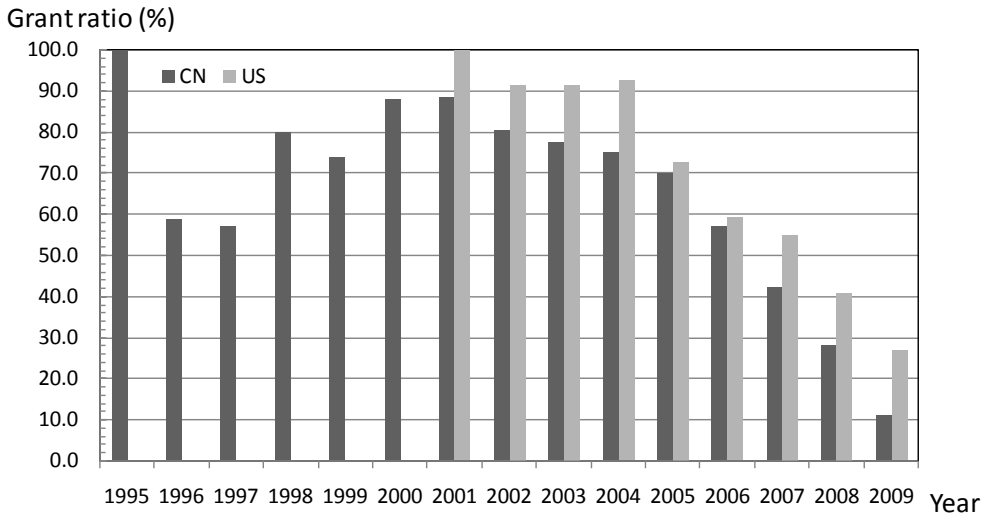
(Source: Author's calculation using PATSTAT)

4.2. Granted patents

The rates of patents granted annually to Huawei and ZTE per application year are shown in Figures 11 and 12, respectively. The grant rate in domestic and international patent applications has decreased as the 2000s have progressed. Assuming that there has been no change in the norm needed to examine patentability despite the boost in global patent applications, the rise in Huawei and ZTE patent applications should affect the quality of their invention. Huawei and ZTE might have applied for patents without owning by disclosing knowledge before the knowledge is owned by competitors. This strategic behavior gives a degree of freedom for future R&D (Baker

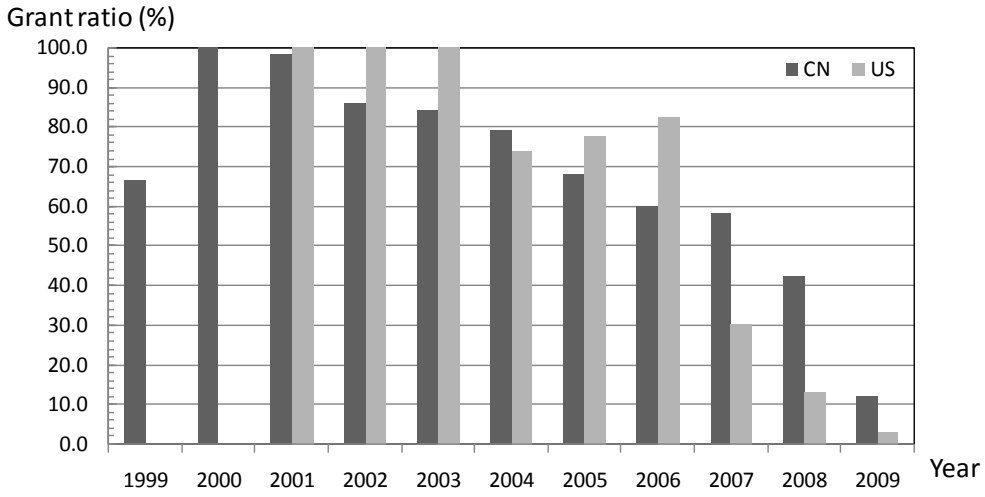
& Mezzetti, 2005; Ponce, 2011). The sharp drop in the grant rate of both firms in recent years presumably can be explained by the time lag for patent examination. The statistics are similar for both Huawei and ZTE showing no clear difference between the two in the rate of patents granted.

Figure 11. Huawei's Granted Patents Rates



(Source: Author's calculation using PATSTAT)

Figure 12. ZTE's Granted Patents Rates



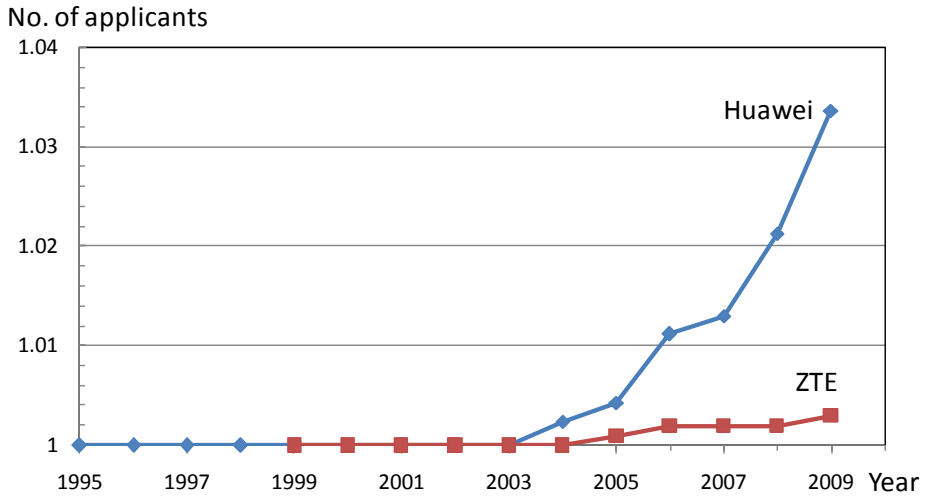
(Source: Author's calculation using PATSTAT)

4.3. Co-applicants and inventors

Figures 13 and 14 show the number of applicants and inventors in Huawei's

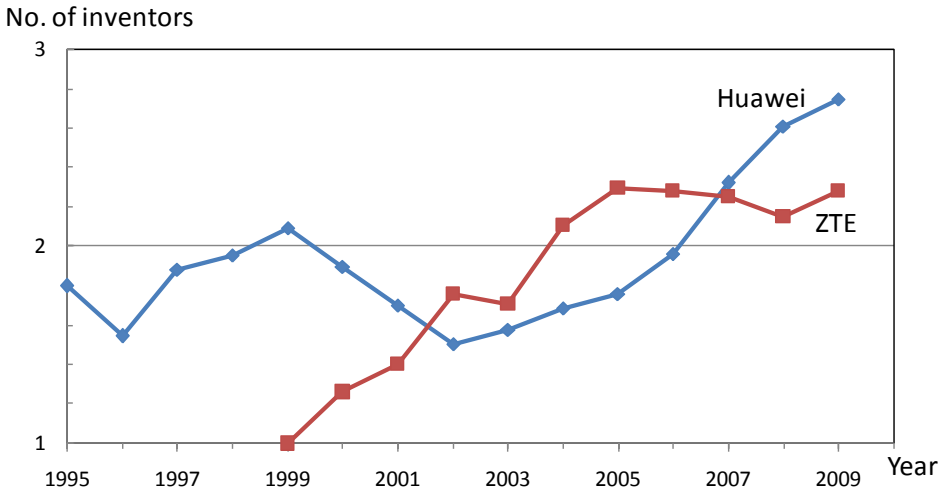
and ZTE's patent applications to SIPO. For both firms, the number of applicants has slightly increased since their first patent applications. Until the mid 2000s, their patent applications were filed only by themselves. Since 2004 and 2005, their co-applications have increased although the increase is slight. When the two companies are compared, Huawei has more co-applicants than ZTE has, implying that Huawei is more active in utilizing external knowledge sources. The number of inventors in both firms' patent applications has also increased slightly with Huawei showing slightly more inventors than ZTE after 2006.

Figure 13. Number of applicants in Huawei's and ZTE's patents



(Source: Author's calculation using PATSTAT)

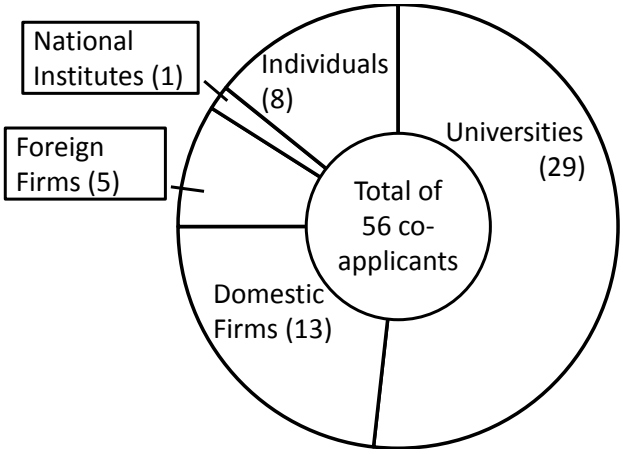
Figure 14. Number of inventors in Huawei's and ZTE's patents



(Source: Author's calculation using PATSTAT)

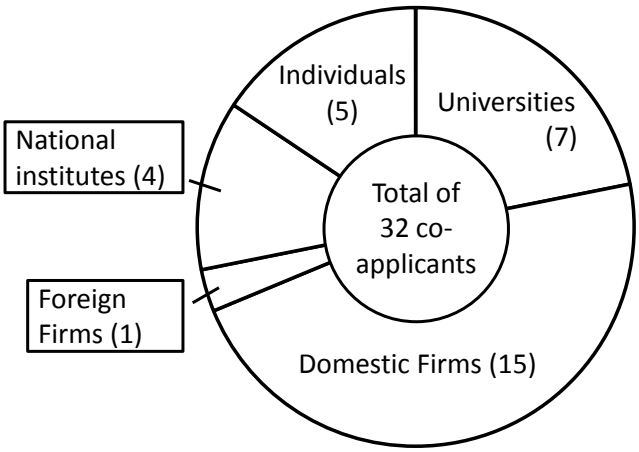
Figures 15 and 16 show the share of Huawei and ZTE co-applicants by type. Huawei (Figure 15) has had 56 co-applicants in total. Universities account for slightly over 50 per cent of all the co-applicants. This indicates that Huawei is active in UIC. Meanwhile ZTE (Figure16) has had 32 co-applicants in total. The domestic firms among ZTE's co-applicants account for nearly 50 per cent of all the co-applicants. Further analysis of whether collaboration with ZTE has helped these domestic firms innovate beyond the knowledge they received from ZTE will be presented in subsection 4.5.The figures show that ZTE has more collaboration with national institutes. While Huawei has collaborated with only one such institute, ZTE has collaborated with four. This greater collaboration with national institutes implies that ZTE is an important partner for these institutes.

Figure 15. Huawei's Co-applicants in Patent Applications to US PTO



(Source: Author's calculation using PATSTAT)

Figure 16. ZTE's Co-applicants in Patent Applications to US PTO

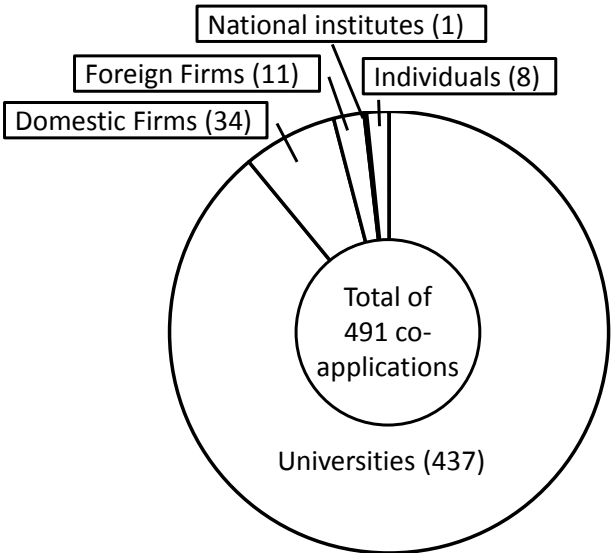


(Source: Author's calculation using PATSTAT)

Figures 17 and 18 show the share of the co-applications per each co-applicant type shown in Figures 15 and 16. Huawei co-applied for 491 patents. Universities accounted for 89.0 per cent of all co-applications. Although co-applicants other than universities made up nearly 50 per cent of Huawei's co-applicants, its collaborations with these co-applicants accounted for only 11.0 per cent of Huawei's co-applications. Thus, Huawei's collaboration is concentrated in universities. This may be because Huawei is the leading domestic firm in the telecommunications industry, and it is difficult for Huawei to find domestic firms qualified for collaboration.

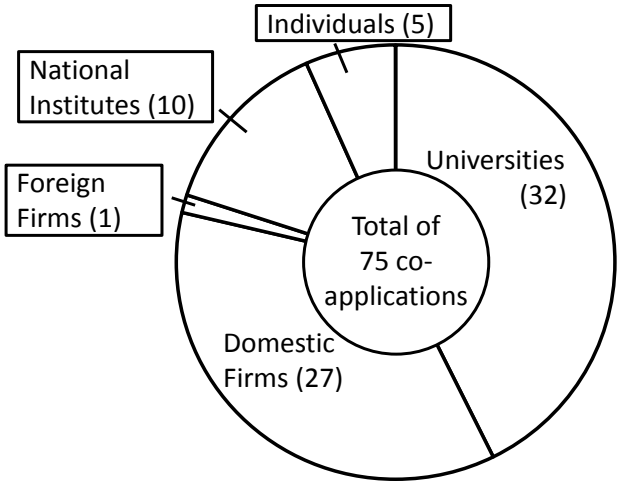
In the case of ZTE, its rate of co-applications has been far less, numbering 75 compared to Huawei's 491. The distribution of ZTE's collaboration has been more than Huawei's. Universities and domestic firms have been ZTE's largest collaborators. Figure 18 again confirms that ZTE's collaboration with the national institutes is not insignificant. While Huawei filed one patent application with one national institute, ZTE's co-applications with four national institutes accounted for 13.3 per cent of its co-applications, further confirming that ZTE is an important partner for the national institutes in China.

Figure 17. Huawei's co-applications to US PTO



(Source: Author's calculation using PATSTAT)

Figure 18. ZTE's co-applications to US PTO



(Source: Author's calculation using PATSTAT)

4.4. Knowledge accumulation

This section analyzes knowledge accumulation by Huawei and ZTE. I conducted a patent citation analysis to measure Huawei's and ZTE's knowledge accumulation. To conduct the citation analysis, I relied on patent applications to the US PTO. This is because of the unavailability until recently of patent citations in patent applications to SIPO.[3] When applying to the US PTO, patent applicants must disclose

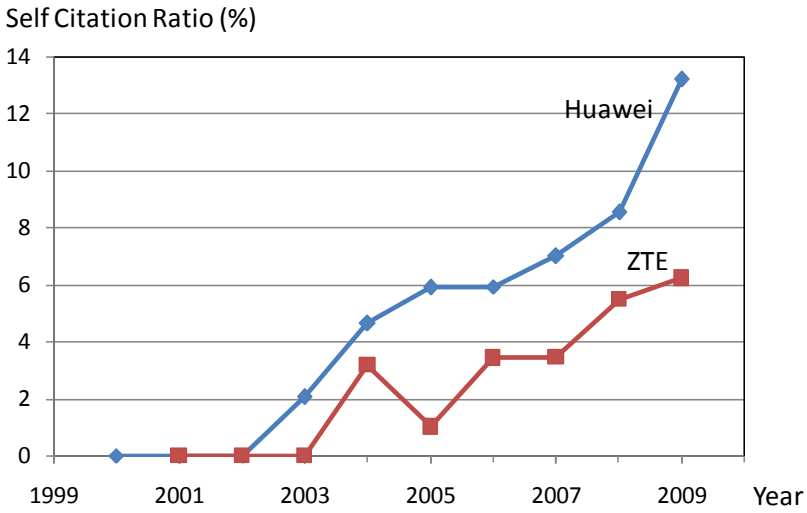
[3]At the 6th Meeting of the Standing Committee of the Eleventh National People's Congress on December 27, 2008, Article 36 of the Patent Law of the People's Republic of

the prior art behind an invention. Failure to disclose all prior art results in no patent being granted. Consequently, patent applications to US tend to have more patent citations than those to other patent authorities. However, there is a limitation in using patent citations. A significant proportion of citations in a patent application to a patent authority come from domestic references of the patent authority (Michel & Bettels, 2001). Accordingly, readers need to be aware that in this study a significant number of citations in a patent may come from US references.

The results of the citation analysis are shown in Figure 19. The figure shows that Huawei and ZTE have grown increasingly reliant on internal knowledge (internal knowledge source) for patents. Until 2002 Huawei relied entirely on the knowledge received from external sources for its patents. Thereafter accumulated internal knowledge began to become a source, and in 2009, 13 per cent of Huawei's patents relied on knowledge obtained within itself. Although the knowledge flow from external sources still predominates, knowledge has accumulated within Huawei and this accumulated knowledge has assisted Huawei's growth. The company's knowledge dependence has fluctuated in recent years, but the trend of Huawei's knowledge reliance has been increasing on its own internal source. Meanwhile, ZTE's patents until 2003 also relied entirely on the knowledge received from external sources. Thereafter reliance on internal knowledge for patents gradually increased. In 2009, 6 per cent of ZTE's patents relied on knowledge obtained within. However, ZTE's reliance on internal knowledge for patents has increased less than it has for Huawei.

Figure 19. Self-citation Ratio

China was amended to mandate the submission prior art: "When an applicant for an invention patent requests substantive examination, he shall submit the reference materials relating to the invention existing prior to the date of application."



(Source: Author's calculation using PATSTAT)

4.5. Knowledge spillover to domestic and foreign firms

The previous subsection measured knowledge accumulation by counting Huawei's and ZTE's self-citations. This subsection measures knowledge spillover from Huawei and ZTE to others by focusing on applicants whose patent applications cite Huawei's and ZTE's patent applications; i.e., self-citations are excluded for the analysis in this subsection. I used applications to the US patent office for the same reason as cited in the last subsection. Thus, this analysis also contains a US bias.

The results are shown in Table 3. The left side of the table shows those for Huawei, the right side for ZTE. A total of 1106 patent applications to the US PTO cited Huawei's patent applications, and they were filed from 25 different regions. The most applicants, more than 40 per cent of them, were from the US, followed by applicants from Japan then Korea. Applicants from China accounted for only 7.4 per cent. For ZTE a total of 332 patent applications to the US PTO cited ZTE's patent applications, and they were filed from 17 different regions. Interestingly, the most applicants were from China; those from the US were next. In absolute patent count, ZTE is higher with 126 compared to Huawei's 83. This indicates that there is a significant knowledge flow from ZTE to domestic firms (a point that will be further analyzed in this subsection). The results in Table 3 imply that Huawei's technology is highly and globally valued by others when focusing on the number of Huawei's forward citations compared to that of ZTE's,[4] but as a knowledge input, ZTE's patents seem to be contributing more to

[4]More precisely speaking, the technological value of a patent can be better measured by dividing the number of forward citations by the average number of forward citations

Chinese domestic firms' future R&D.

Table 3: Top Five Regions of Origin for Applicants Seeking US patents That Cited Huawei's and ZTE's Patent Applications

Huawei			ZTE's		
Regional Origin	Patent count	Ratio	Regional Origin	Patent count	Ratio
US	485	43.5 %	China	126	38.0 %
Japan	136	12.2 %	US	89	26.8 %
Korea	122	10.9 %	Korea	33	9.9 %
China	83	7.4 %	Japan	30	9.0 %
Taiwan	57	5.1 %	Taiwan	20	6.0 %
Other* (20 countries)	233	20.9 %	Other** (12 countries)	34	10.2 %

* Other included Canada (46), Sweden (41), France (36), Finland (26), Germany (26), Israel (9), and Spain (9).

** Other included Canada (14), Sweden (7), Finland (3), and the Netherlands (2).

(Source: Author's calculation using PATSTAT)

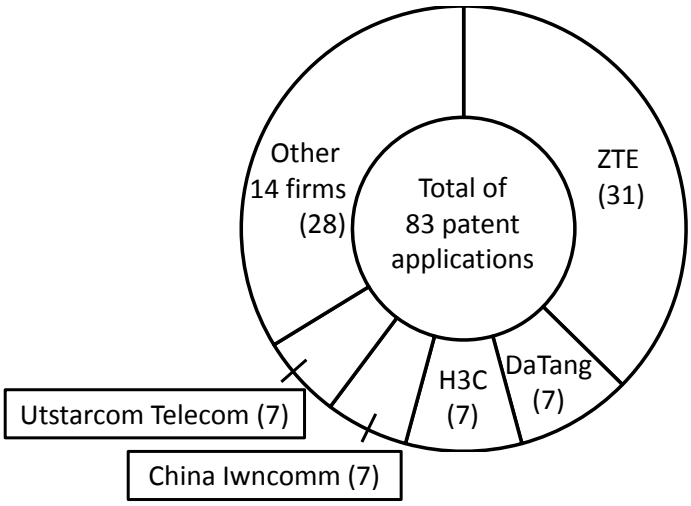
Analyzing more closely who in China are using Huawei's and ZTE's patents for their future R&D, Figures 20 and 21 show the results for Huawei and ZTE, respectively. Eighty-three of the US patents shown in Table 6 cited Huawei patents and were filed by 19 firms. The largest share, accounting for 37.3 per cent of the filings, was by ZTE. The next share was by DaTang, H3C, China Iwncomm, and Utstarcom Telecom. On the other hand, 126 of the US patents in Table 6 that cited ZTE were filed by 9 firms. The largest share, 89.7 per cent, was filed by Huawei. The remaining patents were filed by the other firms. The results presented here show that ZTE's patent output as a knowledge source for China's domestic R&D is by and large being absorbed by one company, Huawei. On the other hand, although Huawei's patent output as a knowledge source for domestic R&D has been less than ZTE's, its effect has spread to a wider distribution of firms (although ZTE has been the largest absorber). Figures 20 and 21 confirm that Huawei and ZTE are the most significant citers of each other's patents, that

from the same application year and technological category (Jaffe & Trajtenberg, 2002; Nagaoka, Motohashi, & Goto, 2010). But since Huawei and ZTE have a similar patent application history in the same industry, I assume that normalization will not change the findings.

they are the two leading firms in China's telecommunications sector, as indicated by other studies (Harwit, 2007; Gao, 2011), and that their knowledge has become interdependent.

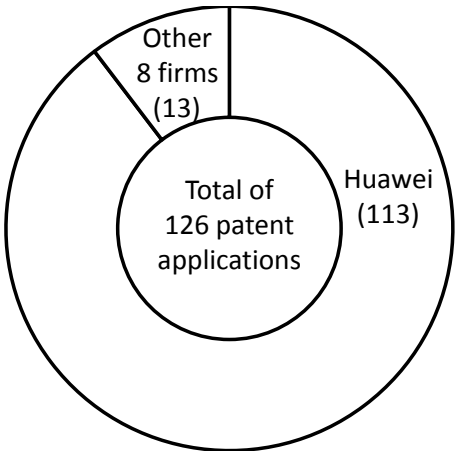
A comparison between Huawei's and ZTE's R&D collaborators and the absorption of knowledge from Huawei's and ZTE's R&D output by these collaborators reveals that the co-applicants of both companies (shown in subsection 4.4.) scarcely cited Huawei's or ZTE's patent applications. This implies that collaboration with Huawei and ZTE does not promote knowledge spillover from them to their collaborators.

Figure 20. Chinese Patent Applicants That Cited Huawei's Patent Applications



(Source: Author's calculation using PATSTAT)

Figure 21. Chinese Patent Applicants That Cited ZTE's Patent Applications



(Source: Author's calculation using PATSTAT)

5. Discussion

The findings of this study can be summarized as follows:

(1) Huawei: The study used patent statistics as a proxy indicating innovation (Griliches, 1990), and these supported the argument that Huawei is an innovative actor. The number of its patent applications to domestic and foreign authorities is growing; the company's internal knowledge is accruing; and spillover of this knowledge is going to both domestic and foreign firms. Huawei's R&D output has functioned as a knowledge input for various domestic firms to conduct future R&D. This study also found that Huawei has been very active in UIC. This is attributable to Huawei being a leading domestic firm in its field making it hard to find qualified domestic firms as collaborators.

(2) ZTE: Several patent statistics about ZTE were not consistent enough to show that ZTE is an innovative actor. This finding comes as a surprise given that in recent years, ZTE has filed more domestic and international patent applications compared toHuawei;further, ZTE has only about half as many R&D employees as Huawei. The recent boost in ZTE's patent applications gives the impression that the company is interested merely in patent filing per se. Although the number of its patent applications to domestic and foreign authorities has increasing rapidly, other patent statistics used in this study did not support ZTE as an innovative actor. More specifically, ZTE's knowledge accumulation has not been as great as Huawei's. ZTE has been very active in collaboration with domestic firms, but collaborative R&D output has not functioned as a knowledge input for the collaborators to conduct further R&D. Rather, the knowledge absorption of ZTE's R&D output has been concentrated in Huawei. Nevertheless, this study indicates that ZTE being a state-owned enterprise is an important partner for national institutes. ZTE's collaboration with the national institutes seemed significant compared to that of Huawei. However, lack of data prevented an examination of how ZTE has contributed to collaboration with these institutes.

Based on the preceding discussion and the findings of this study, the answer to the research question posed in this study is that conventional patent statistics may not be able to truly reflect the innovativeness of Chinese firms. The recent increase in patent filings may give ZTE the image of being more "innovatively productive" than Huawei is. However, when the various statistics for ZTE's patent applications are compared with those for Huawei and other companies, the results were consistent only in the case of Huawei.

The results of this study present implications for researchers and policy makers. First, how does one deal with the patent statistics of Chinese firms? Reliance on only a few patent statistics must be avoided. For example, simply counting the number of patent applications filed by Chinese firms is insufficient to understand their innovativeness. Using various indicators together with patent statistics can produce better results. In addition, it would be better not to use old patent data. It took Huawei and ZTE 8 years and 14 years, respectively, from their founding to file their first patent applications (Section 4.1).While there could be various reasons for this, we must consider the social environment in China. As a communist country, private ownership of property has generally been prohibited. Even now, the state makes decisions regarding the usage of patents.[5] Thus, firms in China were not motivated to actively apply for patents prior to China's economic and political reforms.

Second, this study presented evidence that ZTE's R&D output has been absorbed primarily by Huawei. This implies that in this case the knowledge created by ZTE is valuable to some extent, and the privately owned domestic champion in the industry uses this knowledge as an input for future R&D. However, this study also shows that there are not enough innovating actors in the industry that can absorb the knowledge and create economic value based on it. Thus, this study suggests that the government devise policy to nurture innovating actors that can utilize the existing knowledge for innovation.

Lastly, this study provides an implication for developing countries. A report by WIPO (2011) showed that 92% of all international patent applications are from 15 advanced countries, implying that knowledge is monopolized by the advanced countries. Using such knowledge is not free. Thus, policy makers in developing countries, especially those trying to achieve knowledge-based economic growth, will have to find leverage for getting access to monopolized knowledge.

6. Conclusion

This study presented an empirical analysis of Huawei and ZTE, the two major

[5]Article 14 of The Patent Law of the People's Republic of China: "If an invention patent of a State-owned enterprise or institution is of great significance to national or public interests, upon approval by the State Council, the relevant competent department under the State Council or the people's government of the province, autonomous region, or municipality directly under the Central Government may decide to have the patent widely applied within an approved scope and allow the designated units to exploit the patent, and the said units shall pay royalties to the patentee in accordance with the regulations of the State."

enterprises in China's telecommunications industry, using their patent data. The study first reviewed the prior research gone on the patent statistics. After this review, patent data were used to investigate Huawei's and ZTE's innovation process. Five aspects of this process were analyzed: (1) domestic and international patent application pattern, (2) granted patents, (3) co-application and co-applicants, (4) knowledge accumulation inside of Huawei and ZTE, and (5) knowledge spillover to domestic and foreign firms.

This study is not without limitations. One limitation is that this study does not examine the extent to which Huawei and ZTE are given autonomy in decisions related to production, marketing, and investment in China. Studies in the context of China have generally classified enterprises as state-owned or privately-owned enterprises;[6]many of China's state-owned enterprises have been privatized over the course of the country's economic reforms (Young, 1995; Yusuf, Nabeshima, & Perkins, 2005). However, whether enterprises in China, especially state-owned ones, can have full autonomy or whether they still have to submit to government intervention remains to be answered (Child & Yuan, 1996; Kang, Shi, & Brown, 2008). Huawei's and ZTE's cases are no exceptions (Rogers, 2012).

Another possible approach to this problem would be to explain the behaviors of Huawei and ZTE with a game-theoretic approach (Gibbons, 1992). As was previously discussed in Section 3, being the two leading companies in the telecommunications industry in China, Huawei and ZTE have almost the same history and operate in almost the same field of business. Moreover, they cite each other's patents. A game-theoretic approach (such as duopoly) merits further analysis; however, such an approach exceeds the scope of this study.

Acknowledgements

I would like to thank anonymous referees, two guest editors, Professor Michael Zheng Song and Professor Carsten Holz, and the executive editor of *China Economic Review*, Professor Belton M. Fleisher, for their valuable comments and suggestions. This study was conducted as a part of the project "Catch-up industrialization in the 21st century". The earlier version of this paper is available as IDE discussion paper No. 470 (http://www.ide.go.jp/English/Publish/Download/Dp/index.html). All remaining errors are on my own.

[6]The National Bureau of Statistics of China officially classifies Chinese firms into six groups in terms of ownership (Appendix A).

Appendix A

The National Bureau of Statistics of China (NBSC) classifies Chinese firms into six groups in terms of ownership: State-owned enterprises, collectively-owned enterprises, shareholding enterprises, Hong Kong-Macau-Taiwan funded enterprises, foreign funded enterprises, and other. The definitions of these enterprises, as stated by the National Bureau of Statistics of China, are shown in Table A1.

Table A1. Firm classification in terms of ownership

(1) State-owned enterprises	Enterprises where the means of production or income are owned by the state.
(2) Collectively-owned enterprises	Enterprises where the means of production are owned collectively, including urban and rural enterprises invested by collectives and some enterprises.
(3) Shareholding Corporations Ltd.	Economic units registered in accordance with the regulation of the People's Republic of China on the Management of Registration of Corporate Enterprises, with total registered capitals divided into equal shares and raised through issuing stocks.
(4) Hong Kong-Macau-Taiwan funded enterprises	Enterprises registered as the joint-venture, cooperative, sole (exclusive) investment industrial enterprises and limited liability corporations with funds from Hong Kong, Macao, and Taiwan.
(5) Foreign Funded Enterprises	Enterprises registered as the joint-venture, cooperative, sole (exclusive) investment industrial enterprises and limited liability corporations with foreign funds.
(6) Other	Other enterprises (units) including private enterprises, joint-owned enterprises, share-holding economy, foreign-funded enterprises, enterprises funded by the entrepreneurs from Hong Kong, Macao and Taiwan, etc.

(Source: NBSC's website)

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