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Chinese Huawei Catching up with Swedish Ericsson

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Abstract
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Does a Latecomer Firm Catch up with an Incumbent Firm using ‘Similar or Different’ Technologies?:
Analysing the Case of Huawei vs. Ericsson with Patent Data

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Abstract

The telecommunication equipment industry has long been dominated by the Swedish giant, Ericsson. Recently Huawei, a private Chinese firm, entered the industry to grow rapidly, and finally overtook Ericsson in terms of sales in 2012. Given its rarity, this paper seeks to explain how this has been possible. We first verified that Huawei’s market catch-up was based on technology, and not merely on cost advantages. Then, our analysis of the European patents shows that Huawei grew fast by developing ‘different’ technologies from that of Ericsson, and that the former relies more on ‘recent and scientific’ knowledge in its innovation strategies. This study suggests that creating one’s own ‘technological path’ rather keeping the earlier path of imitation could be a viable strategy for successful technological catch-up.

KEYWORDS: Market shares; Technologies, Catch-up; Huawei; Ericsson; Patents; Patent citations

JEL Classification: O32, L63, O14
1. Introduction

Telecommunication equipment industry has long been dominated by several Western firms. In particular, since the 1990s, the industry has been led by Swedish telecommunications giant, Ericsson, followed by Siemens, Nokia, Motorola, Alcatel, Nortel, and Lucent. In the early 2000s, the industry faced a drastic decline in market demand as a result of the IT bubble burst. While many incumbents suffered, Huawei, a private Chinese firm founded in 1987, successfully entered the global market and achieved rapid growth. Huawei accelerated its market shares since the mid-2000s, and finally overtook the long-time industry leader, Ericsson, in terms of annual revenue in 2012, surpassed.

Huawei’s catch-up is distinct from typical Chinese firms’ catch-ups in that it is not state-owned but private. Moreover, its success has more to do with technological competitiveness than low-cost labor; Huawei was ranked first globally for the number of international patent filings through PCT (Patent Cooperation Treaty) in 2008. Huawei’s portable wireless access device, “Femtocell 2.0”, won an iF Design award and a Red Dot design award in 2009, and its optical distribution network access terminal box, PIVOT, won a Red Dot design award in 2010. Fast Company ranked Huawei 5th among the world’s 50 most innovative companies in 2010.

The Chinese government did play some part in Huawei’s accumulation of technological capability, in that the former’s “trading market for technology” policy allowed China to gain access to telephone switching technologies via foreign direct investment in the 1980s (Mu and Lee 2005). In the 2000s, the Chinese government’s support for TD-SCDMA as a third generation mobile telecommunication standard helped Chinese telecommunication equipment firms to establish indigenous innovation capabilities (Liu and Dalum 2009; Yu 2011).
However, not all Chinese firms were as successful as Huawei; ZTE, the second-largest telecommunication equipment firm, is still far behind the major incumbents. This indicates that the role of the Chinese government’s policy was an important but not a primary factor in terms of Huawei’s catch-up.

Hence, to explain Huawei’s successful catch-up, one needs to into Huawei’s innovation strategies. Previous research has emphasized Huawei’s intensive internal R&D, strategic R&D alliances and R&D globalization (Yeung 2005; Huang 2006; Zhu 2008; Sun 2009; Zhang 2009; Zhu et al. 2009; Athreye and Chen 2010; Zhang and Duysters 2010; Gao 2011; Fan 2010). Since the 1990s, Huawei has invested more than 10% of its revenue on R&D, and globalized its R&D into India, Sweden, and the United States and others. Starting in 2000, Huawei established strategic R&D alliances with Texas Instruments, IBM, Motorola, Lucent, Intel, and Sun Microsystems, and joint ventures with NEC, 3COM, Siemens, and Nortel. Intensive internal R&D, R&D globalization and strategic R&D alliances have undeniably contributed tremendously to Huawei’s technological competitiveness. Given the heavy investment into R&D, an emerging question is what happened with this enormous amount of R&D, and what exactly Huawei did in terms of innovation strategy.

This study focuses on the technological details of Huawei’s catch-up strategy, raising a key research question of whether Huawei has caught up and finally forged ahead by using ‘similar or different’ technologies, from those of the forerunning incumbent. The ‘similar’ technologies imply that the latecomer simply attempts to imitate the incumbents, whereas the ‘different’ technologies refer to the latecomer seeking to create new technologies and take a different technological path or trajectory from the incumbents. This contrast of the ‘similar versus different’ technologies is interesting in terms of the literature on technological catch-
up. The traditional or early literature, such as Lall (2000), Kim (1980), Westphal, Kim, and Dahlman (1985), and Hobday (1995), tends to observe that the latecomers tried to catch up with advanced countries by assimilating and adapting the latter’s more-or-less obsolete technology. In contrast, a more recent and emerging view, expressed by Lee and Lim (2001) and Lee (2013), is that the latecomer does not simply follow the advanced countries’ path of technological development; rather they sometimes skip certain stages or even create their own path that is different from the forerunners.

However, we have found no studies that have quantitatively analyzed whether a latecomer firm catch up with forerunners in market share relying on the same or different technologies, and there has been suggested no method for such analysis. This paper suggests an assessment method using patent citation data, and applies the method to the case of Huawei vs. Ericsson. Our choice of these two companies has not been made arbitrary. Our objective is to compare a leading company in the field and a latecomer firm which eventually overtook the former leading company. There may be other latecomer firms that are also increasing market shares in diverse speed but they are not our target of comparison. We want to pick up a case that catch-up in market share is ‘completed,’ and thereby aims at finding out the ‘necessary’ condition of a successfully completed catch-up.

This paper uses the patent and related citation data of Huawei and Ericsson filed in the European patents office between 2000 and 2010. Our analysis will show that Huawei’s untiring accumulation of technological capability, rather than its cost advantage, has been the crucial factor in its successful catch-up. Furthermore, we show that Huawei’s catch-up is thanks to its eventual success in creating its own technological advantages although it did attempt to imitate the forerunner by integrating the same or similar technologies in its early
The diverse aspects of technological catch-up are also examined using patent citation data in the case of Samsung vs. Sony (Joo and Lee 2010). Similarly to Joo and Lee (2010), this study also define and measure various patent-based variables, including the way in which they validate the ‘comparability’ of the two rival firms in terms of the firms’ patent portfolio. However, their study did not have an explicit research question as to whether the latecomer (Samsung) had been catching-up with the forerunner (Sony) by developing the ‘same or different technologies’ as the forerunner.

The rest of the paper is structured as follows. In section 2, we first provide a brief overview of Huawei and Ericsson, and then describe Huawei’s catch-up in the global telecommunication equipment market. Section 3 discusses the data, methodology, and the hypotheses of this research. Section 4 analyzes Huawei’s technological catch-up with Ericsson in terms of three criteria to verify our key hypothesis, such as quality of their patents, mutual-citations, and self-citations. Section 5 deals with two additional aspects of comparison, such as citation lags and citations to non-patent literature. Lastly, section 6 summarizes the findings and makes concluding remarks.

2. Huawei vs. Ericsson

2.1 Basic Profiles of the Two Firms Compared

2.1.1. Ericsson

Ericsson has been the undisputed world leader of the telecommunication equipment industry since the 1990s. It is no exaggeration to say that the history of Ericsson is also the history of
Ericsson introduced several significant innovations, such as the 500-point rotating switch in the 1920s, the 500-point crossbar switch in the 1950s, and the AKE 13 SPC switch in the 1960s. The 500-point rotating switches, which accommodated about 100 telephone systems (350,000 lines), were produced by the 1930s. Sales continued to rise during the 1940s, and they were sustained until the 1970s (Ericsson 2014). Production of the 500-point crossbar switch started to exceed that of the 500-point rotating switch from the early 1960s, with cumulative production of the crossbar switch reaching one million by 1971. With the success of the 500-point crossbar switch, Ericsson became one of the major international telecommunication equipment manufacturers; in 1970, it had 50,000 employees in 26 different companies in 15 countries (Fridlund 1999). The AKE 13 was the world’s first multi-processor SPC switch with modular software architecture. AKE switches were not commercially successful as they were expensive and their technological capacity was limited; however, it laid the foundation for Ericsson’s technological breakthrough in the 1970s – the AXE switch.
In 1970, Ericsson formed a research joint venture with Televerket, and started to develop digital switches. In 1977, Ericsson launched the AXE switch, which elevated Ericsson to one of the global leaders of telecommunication equipment industry. The AXE switches are easily adjustable to different regional landline telecommunication systems, and at lower costs thanks to its innovative modular architecture. In 1989, Ericsson was ranked the 4th largest supplier of landline telephone switches with a 13 percent global market share (Ericsson 1989). AT&T (U.S.), Northern Telecom (Canada), and Alcatel (France) held larger market shares than Ericsson at that time; however, most of their sales were from the well-established domestic market rather than the competitive international market.

In addition, Ericsson had been deeply involved in mobile cellular technology since the 1970s. During the commercial development of mobile cellular technologies in the 1980s, the flexible architecture of the AXE switch enabled Ericsson to successfully cope with various first generation cellular mobile telecommunication technical standards, such as Nordic Mobile Telephony (NMT), Advanced Mobile Phone System (AMPS) and Total Access Communication System (TACS). In 1989, Ericsson became the unrivaled leader in mobile telephony systems occupying 40 percent of the world market (Ericsson 1989).

In the 1990s, Ericsson led the advance of telecommunication technologies, and expanded its business, maintaining its dominant position in the rapidly expanding mobile infrastructure market. In 1999, Ericsson held the lion’s share (27.6%) of the global mobile infrastructure market (Gartner 2001). In 2000, Ericsson was ranked the 2nd largest telecommunication equipment provider with revenue of USD 29.26 billion, closely following Nortel (formerly Northern Telecom), which posted USD 29.80 billion of revenue.
2.1.2. Huawei

Huawei was established in 1987 by Ren Zhengfei, a former People’s Liberation Army (PLA) communications officer, and five fellow PLA members with starting capital of RMB 20,000 ($3,000). Huawei started from scratch with $3,000 of capital in the city of Shenzhen (Xu and Girling 2004). The firm used to be a telecommunications equipment distributor in a barn on a Shenzhen farm, from which the founders sold telephone switches imported from Hong Kong.

In 1990, Huawei decided to risk transforming itself into a telecommunication equipment manufacturer by using in-house research and development, rather than a joint venture with multi-national firms as was the case with most Chinese manufacturers. However, Huawei had neither telecommunications equipment knowledge, nor sufficient money for such development. Huawei’s five researchers experienced repeated failures and the company was forced to reinvest all its profits. However, by reverse engineering an imported switching device and networking equipment, Huawei developed the HJD48 (a 512-line analog telephone switch) in 1991. Huawei’s cost advantage allowed it to gain access to the rural Chinese market, which is neglected by multi-national firms.
Huawei expanded its efforts to developing a large capacity digital switch. It recruited many engineers who had experience and knowledge of developing the HJD-04 system (the local Chinese digital switch) at Great Dragon. In 1993, Huawei achieved its breakthrough by launching C&C08, a program-controlled public digital switch system (PDSS) with a switching capacity of 2,000 lines. Huawei started to deploy the C&C08 from the small cities and rural areas in which Huawei had built close customer relationships. In 1995, Huawei upgraded the C&C08 to accommodate 10,000 lines, and thereafter penetrated the major city market, at that stage dominated by multi-national firms and joint ventures. Huawei multiplied its market share rapidly by rolling out an aggressive marketing campaign and taking advantage of the Chinese government’s support including its “buy local” policy and preferential loans. In 1998, Huawei became the largest digital switch supplier in China (Mu and Lee 2005).

From mid-1990, by establishing domestic R&D centers in Beijing and Shanghai, Huawei extended its R&D into access equipment, optical transmission, data network, and wireless networks thereby transforming itself into an end-to-end solution provider. It expanded its product line into High-Capacity Optical Networking and Enabling Technologies (HONET), integrated access network and Synchronous Digital Hierarchy (SDH) optical transmission equipment in 1996, data communication equipment (routers) in 1997, and GSM mobile communications systems in 1998. However, the Chinese mobile communication market was still dominated by multinational firms, and local Chinese firms, including Huawei, held less than 5 percent market share until 1999.

In parallel, Huawei started to reach out to the international market, stretching from Hong Kong.

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1 The Chinese government started to impose tariffs on imported telecommunications equipment, and extended Huawei RMB 3.9 billion in buyer’s credit from China Construction Bank, and RMB 3.5 billion of revolving credit from the Bank of China and ICBC (Industrial and Commercial Bank of China).
in 1996 to the emerging and developing countries – such as Russia, India, South Africa, and Latin America. Huawei’s international market revenues were sluggish during the first few years, but surged from the late 1990s, reaching USD 120 million in 2000. Despite this, respective sales comprised less than 5 percent of its total.

To cope with the challenge of increasing complexity and inefficiency, the result of the rapid growth of the business and organization (see Figure 2), Huawei set up Huawei Basic Law and conducted business and R&D process reengineering from the mid-1990s. To achieve long-term sustainable growth, with IBM’s assistance Huawei prepared itself with an advanced management system, incorporating Integrated Product Development (IPD) and Integrated Supply Chain (ISC) (Fan 2010).


Figure 2. Huawei’s Growth in 1990s²

2.2 Huawei’s Sales getting Bigger than Ericsson

Telecommunication sector investment experienced a sharp decline with the bursting of the IT

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² Source: Yu et al.(2004)
bubble in the early 2000s. OECD member countries cut their investment in telecommunication infrastructure by almost 40 percent over two years from USD 241 billion in 2000 to USD 150 billion in 2002 (See Figure 3).

Figure 3. Telecommunication Infrastructure Investment of OECD Countries

Figure 4 clearly shows the ripple effects of the severe downturn in the telecommunication equipment industry. The downstream industry’s drastic slowdown meant that total sales of telecommunication equipment by major firms dropped by over 30 percent from 2000 to 2002 (see Figure 4 (a)). Nortel, Ericsson and Lucent (formerly AT&T’s telecommunication equipment branch), whose main business area was landline/mobile telecommunication equipment

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3 Source: OECD(2013), OECD Communications Outlook

4 Telecommunication equipment includes landline/mobile telecommunication infrastructure (e.g., switching systems and base transceiver stations), user equipment (e.g., mobile phones) and enterprise network infrastructure (e.g., routers, hubs, and modems), and the sales of these telecommunication equipment are analyzed. Because firms in the telecommunication equipment industry sometimes have large sales from other industries, such as consumer electronics, computers, and electronic components, it is more relevant to analyze firms’ telecommunication equipment sales rather than their total sales to see the effects of the slowdown in the downstream industry.

5 “Major firms” refers to the telecommunication equipment manufacturers that posted at least USD 10 billion sales in telecommunication equipment as of 2000. They are Nortel, Ericsson, Nokia, Lucent, Cisco, Motorola, Alcatel, Siemens, and NEC.

6 The figure fell further to 40 percent, if we exclude Nokia, whose mobile phone sales represent a high percentage of its total sales.
infrastructure, lost more than half their telecommunication equipment sales in the same period.⁷

Figure 4. Telecommunication Equipment Sales of Major Firms in Early 2000s⁸

To tackle this slowdown and survive, most major firms in the market embarked on mergers and acquisitions from the mid-2000s in order to achieve economies of scale. Alcatel, a French firm with a 108-year history, and Lucent Technologies, a 137-year-old US firm, officially announced their merger in April 2006, with the combined Alcatel-Lucent established in December 2006. In June 2006, Nokia and Siemens agreed to launch a new joint venture by merging their telecom equipment arms and founding Nokia Siemens Networks (NSN) in April 2007. Moreover, Nortel, which had posted USD 29.80 billion in sales in 2000, the world’s highest, filed for bankruptcy protection in January 2009, and sold its LTE and CDMA business divisions to NSN in June 2009. In 2011, Motorola was split into Motorola Solutions (the telecommunication infrastructure branch) and Motorola Mobility Holdings (mobile phones), with Motorola Mobility taken over by Google. Excluding Cisco, the main business

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⁷ Nokia showed a sales increase, however, it reflects Nokia’s sales increase from the mobile phone market, not from the infrastructure market.

of which is data communication equipment, and NEC, which had a large established domestic market, Ericsson was essentially the only survivor of the industry turmoil in 2000s.

Figure 5 compares the annual sales of Huawei and Ericsson. Ericsson witnessed a drastic, 40% drop in sales over three years from 2000 to 2002. From the mid-2000s, Ericsson’s sales improved, it recouped its global telecommunication infrastructure investment, and recently it has showed considerable growth. However, thanks to Huawei’s overwhelming growth, it was able to finally catch up with Ericsson in terms of annual sales in 2012.

In the early 2000s, the Chinese telecommunication industry, and mobile telecommunication in particular, continued to expand despite the global slowdown. Nevertheless, Huawei had limited success in the Chinese mobile telecommunication market. Although Huawei made great strides in the GSM value-added service market (e.g., its short message center and mobile intelligent network), it was nowhere near breaking into the GSM core infrastructure market, which had been dominated by multinational firms, including Ericsson. In addition, Huawei missed the opportunity to participate in the new domestic CDMA market, forcing the Chinese firm to look to the international market.

Fortunately, Huawei’s R&D and its international market efforts in the late 1990s started to pay off from the early 2000s. In 2003, Huawei won the dual-band GSM network contract from MegaFon, the largest wireless operator in Russia, and Etisalat’s UMTS network contract

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9 The main reason for Ericsson’s sales drop in the early 2000s was a downturn in the telecommunication infrastructure industry, but a portion of this sales decrease can be attributed to the spin-off of its mobile phone division. Ericsson spun off its mobile phone division in 2001, and has conducted the business through Sony Ericsson, a joint venture with Sony, since 2001. According to Ericsson’s annual report, mobile phones accounted for 20.5 percent (SEK 56.3 million) of its total sales, and equipment systems (telecommunication infrastructure) accounted for 70.9% (SEK 194.1 million) in 2000. Sales for equipment systems declined by 4 percent to SEK 187.8 million in 2001, and declined 30 percent to SEK 132.0 million in 2002.

10 Unlike Ericsson, Huawei’s mobile phone business is internal. In 2012, mobile phone sales contributed 22% of Huawei’s total sales.
in the UAE, the first UMTS network project in the Middle East and Arab World. Huawei also built the world’s first Automatically Switched Optical Network (ASON) network for Telemar and Oi in Brazil. From the early 2000s, Huawei made inroads into the European market and in 2001 built optical transport networks for PfalzKom in Germany, and Neuf in France.

To push forward with its global expansion, Huawei undertook radical organizational restructuring in the mid-2000s. After failing to obtain British Telecom supplier certification in 2003, Huawei commenced a series of painstaking reform, transforming its hierarchical, functional structure into a multi-dimensional matrix structure (Fan 2010). Huawei became more flexible and able to respond swiftly to global market demand.

To finance its business expansion and to address the increasing cost-consciousness of

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11 Ericsson’s annual sales are obtained from the Compustat Global Database, and Huawei’s annual sales are taken from Huawei’s annual reports (Huawei, 2004, 2006, 2007, 2008, 2011, 2012). Huawei’s annual sales for 2009 and 2010, which are reported in terms of Chinese yuan, are translated into US dollars using the closing exchange rate at December 31 of each year.
customers, Huawei obtained credit lines in 2004 – USD 10 billion from China Development Bank and USD 600 million from Export-Import Bank of China. It was further supported by Sinosure’s export buyer’s credit insurance.

In 2004, Huawei finally entered the first-tier international market – Europe’s third generation mobile network – when the Chinese company beat Ericsson to win the Telfort WCDMA contract in the Netherlands. Huawei products’ cost-saving advantages, rather than their low-cost, stood out for Telfort. Huawei’s unique and innovative solution, a distributed base station system, allowed Telfort to upgrade its existing base stations with WCDMA technologies instead of building new ones (Fan 2010). With Huawei, Telfort could not only save one-third of the total cost of ownership (TCO) for the network but also sidestep the environmental issues that had impeded its rapid deployment.

In 2005, Huawei was selected as one of the priority suppliers to British Telecom for its 21st Century Network program. With its successful entry into the first-tier market, in 2005 Huawei’s overseas revenues exceeded its Chinese market revenue for the first time. In the following year, Huawei was awarded the largest GSM network contract in the Southern Hemisphere by Brazil’s Vivo, and a WCDMA network contract by the world’s largest mobile operator, Vodafone. It also entered the United States and Japanese markets. In 2007, Huawei was on the list of the top-10 telecommunication equipment manufacturers for the first time, ranked 8th.

With ceaseless innovation, Huawei dominated fourth generation mobile technology and delivered one of the world’s first LTE networks for TeliaSonera of Norway in 2009. Huawei emerged as the world’s second-largest provider of telecommunication infrastructure from 2009, rapidly narrowing the gap with the world’s leader, Ericsson. Huawei ultimately topped
Ericsson in terms of annual revenue in 2012, and in 2013 increased its revenue leadership, achieving USD 39.36 billion of revenue vs. Ericsson’s USD 35.39 billion.

3. Data, Methodology and Hypotheses

3.1 Patent Data and Making Sense of Comparison

Indicators based on R&D expenditures, patent statistics, new product introductions, or a combination of these indicators, among others, have been widely used to measure firm’s technological capabilities (Schoenecker and Swanson 2002). Because patents and patent citations provide detailed information on the inventions, and cover a relatively long period of time as well as virtually all fields of technology (Griliches 1990), they have long been accepted as a reliable, though not perfect, source of information to measure firms’ technological capabilities (Narin et al. 1987; Patel and Pavitt 1997). On these grounds, we analyzed the patents and related citations of Huawei and Ericsson (European patents from 2000 to 2010).

Because the results of patent analysis may vary greatly depending on the data employed, we made an effort to build an appropriate patent data set. Firstly, patents filed by Huawei and Ericsson with various national authorities were obtained from the PATSTAT database, which was created by the European Patent Office (EPO). Looking at the total number of patents from 2000 to 2010, both firms filed the majority of their patents with three common national authorities, EPO, the United States Patent and Trademark Office (USPTO), and the Chinese State Intellectual Property Office (SIPO), all of which report patent statistics to the PATSTAT database (see Table 1). Huawei filed the most patents with SIPO, followed by EPO and
USPTO, while Ericsson filed the greatest number with EPO, followed by USPTO and SIPO.

Table 1. Patent Filings of Huawei and Ericsson to EPO, USPTO, and SIPO

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<tr>
<td>Huawei</td>
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<td>62</td>
<td>85</td>
<td>219</td>
<td>563</td>
<td>647</td>
<td>627</td>
<td>90</td>
<td>3</td>
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<td></td>
<td>USPTO</td>
<td>1</td>
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<td>12</td>
<td>54</td>
<td>56</td>
<td>96</td>
<td>226</td>
<td>314</td>
<td>448</td>
<td>528</td>
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<td></td>
<td>SIPO</td>
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<td>1,004</td>
<td>1,480</td>
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<td>3,484</td>
<td>5,668</td>
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<tr>
<td>Ericsson</td>
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<td>871</td>
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<td>606</td>
<td>431</td>
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<td>658</td>
<td>378</td>
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<td></td>
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<td>SIPO</td>
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Huawei outdid Ericsson in terms of the number of patents filed at all three patent offices — SIPO in 2001, USPTO in 2007, and EPO in 2008. These results provide strong evidence that Huawei’s technological catch-up with Ericsson is real, and not a spurious result from biased patent data. However, Huawei’s technological strength could be over-estimated based on Chinese patents due to its home country advantage, and similarly under-estimated in terms of US patents because of its low business presence in the North American market.\(^\text{12}\) Thus, to ensure objectivity of the analysis of the two firms’ technological strength, we used European patents, rather than Chinese or US patents, for further analysis.

Now, before comparing these two companies, it is necessary to establish that these two companies are similar enough to be compared. In other words, it is vital to confirm that Huawei and Ericsson compete in similar technological areas. If this is not the case, the comparison would not make any sense. This essential and prerequisite process can be conducted by comparing the technological characteristics of the two companies. Because the level of competition between the two firms tends to increase as they rely on increasingly

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12 In 2009, Huawei’s sales in the North American market were USD 408 million, which is less than 2% of Huawei’s total sales (BusinessWeek.com, 2010).
similar sets of technology (Podolny et al. 1996), we analyzed the level of technological similarity of the two firms’ patent portfolio by two measures – technological proximity (Jaffe 1986) and technological overlap (Mowery et al. 1998).

The technological proximity between two firms, i and j, is defined as follows:

\[
\text{Technological Proximity}_{ij} = \frac{\sum_{t=1}^{T} P_{it} P_{jt}}{\sqrt{\sum_{t=1}^{T} P_{it}^2} \sqrt{\sum_{t=1}^{T} P_{jt}^2}}
\]

\( P_{it} \): the share of firm i’s patents in the technological field t among the total patents of firm i

\( T \): total number of technological fields

Technological proximity takes a value between 0 and 1. The more similar the two firms are in their technological specialization, the higher the value it takes, and vice versa. Huawei and Ericsson’s technological proximity at International Patent Classification (IPC) subclass level stands at 0.912. This can be considered to be very high and suggests that the two firms compete fiercely with each other in similar technological fields.\(^{13}\)

The degree of technological overlap between the two firms was measured by the common citation rate suggested by Mowery et al. (1998) as an alternative measure to assess the degree of technological similarity between two firms. While technological proximity measures the similarity of two firms’ technological specialization in a broad sense, the common citation rate measures the similarity of two firms’ knowledge sources (or applications of knowledge) at a more micro level.

\(^{13}\) The average technological proximities among US manufacturing firms within the same sector was 0.75 (Jaffe, 1989), and the technological proximity between Samsung and Sony, two major competitors in the global electronics industry, was 0.98 (Joo and Lee, 2010).
The common citation rate between two firms, i and j, is defined as follows:

\[
Common\ Citation\ Rate_{ij} = \frac{\text{Citation in firm } i\text{'s patents cited in (or citing) firm } j\text{'s patents}}{\text{Total citations in firm } i\text{'s patents}} + \frac{\text{Citation in firm } j\text{'s patents to patents cited in (or citing) firm } i\text{'s patents}}{\text{Total citations in firm } j\text{'s patents}}
\]

The index measures the degree to which two firms’ technologies are based on or applied to the same patents or knowledge sources. Further, it measures the share of citations received by the patents, citing both firms’ patents, among each firm’s total citations received. It takes a value between 0 and 1. The more similar the two firms are in their exact knowledge sources (or applications of knowledge), the higher the value it takes, and vice versa.

The common citation rate measured by citation made is 0.045, and measured by citation received is 0.026. This level of common citation rate cannot be considered to be very high.\(^{15}\)

\(^{14}\) The common citation rate is based on all citations in PASTAT – not only citations from and to EPO patents, but also patents at all the patent authorities.

\(^{15}\) The common citation rate between Samsung and Sony was as high as 0.39 (citation made) and 0.32 (citation received) according to Joo and Lee (2010).
which implies that Huawei and Ericsson may not share the same knowledge sources, and they may have fairly different applications of their knowledge at the micro level.

However, this rate is higher than the average,\(^\text{16}\) and thus we can still infer that it may make a sense to compare these two companies, given the high degree of technological proximity of the two companies.

### 3.2 Main Hypotheses and Measurement

We analyze patents and related citations of Huawei and Ericsson to investigate whether a latecomer catches up with forerunners by developing ‘similar or different’ technologies, compared with those by the forerunners. The ‘similar’ technologies imply that the latecomer simply attempts to imitate the incumbents, whereas the ‘different’ technologies refer to the latecomer seeking to create new technologies and take a different technological path or trajectory from the incumbents. Our main hypotheses is Huawei has caught up with Ericsson in market shares by developing ‘different’ technologies, compared with those by Ericsson.

This contrast of the ‘similar versus different’ technologies can be discussed in terms of the literature on technological catch-up. The traditional or early literature, such as Lall (2000), Kim (1980), Westphal, Kim, and Dahlman (1985), and Hobday (1995), observe that the latecomer tended to catch up with advanced countries by assimilating and adapting the latter’s more-or-less obsolete technology. This is consistent with the so-called product life cycle theory (Vernon 1966). In contrast, a more recent and emerging view, expressed by Lee and Lim (2001) and

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\(^{16}\) The average common citation rate between two firms, which are randomly selected, was between 0.01464 and 0.02413 according to Mowery et al. (1998). The average common citation rate between pharmaceutical and biotechnology firms in in-vivo human therapeutics, which is a very narrow area, was 0.0254 according to Rottaerme and Boeker (2008).
Lee (2013), points out that the latecomer does not simply follow the advanced countries’ path of technological development; rather they sometimes skip certain stages or even create their own path that is different from the forerunners. This observation is consistent with the idea of leapfrogging (Perez and Soete 1988) such that some latecomers may be able to leapfrog older vintages of technology, bypass heavy investments in previous technological systems or stages, and make preemptive investments in emerging technologies to catch up with advanced countries in new markets.

Several studies have confirmed this idea of leapfrogging or path-creating in case studies in East Asia (Lee et al. 2005; Mu and Lee 2005). However, we have found no studies that have quantitatively analyzed whether laggards successfully catching up with forerunners based on the same or different technologies, or that have suggested a method to assess whether the technological path of the laggard is the same or different from the forerunners.

The three criteria we use to assess the ‘same or different technologies’ are as follows: First, we examine the quality of the two firms’ patents (measured by the average number of received citations), to see if the latecomer’s patent quality catches up with or even surpasses that of the forerunner. Second, we examine the mutual citations between the two rival firms’ patents to see to what extent they rely on each other as their source of knowledge. For instance, if Huawei’s patents cite many Ericsson patents, the implication is that Huawei is imitating and relying on Ericsson. Third, we examine the two rival firms’ degree of self-citation, which can be a measure of how self-reliant they on their own knowledge-base (Lee 2013; Ch. 5). Specifically, we focused on the latecomer’s degree of self-citation in order to assess to what extent it becomes independent of external knowledge sources and self-reliant on its own knowledge base.
Given the dynamic nature of the catching-up process, our grand hypothesis is that the latecomer firm would try to imitate the forerunner by incorporating the same or similar technologies in its early stages; however, to be successful eventually, or in the later stages it would try to create new or different technologies from the forerunning firm. The logic behind this idea is simple: if a latecomer continues to follow the same path as its forerunner, it is almost certain that the latecomer would always remain behind the forerunning company, unless it runs much faster than their target which is not easy. Thus, an alternative is for a latecomer to outdo the forerunner is to explore a short-cut or a different path. Lee (2013: xxi) also observes that “just trying to emulate or replicate the practices of the forerunning economies is not enough, and catch-up realizes only if you take a different path.”

In addition to these three aspects of the focus, we also investigate whether Huawei relies more on recent (or old) technologies than the incumbents by examining the latter’s citation lags, as well as the former relies more on scientific knowledge than the latter in terms of their patents’ citation to scientific literature. One may hypothesize that the latecomer would rely more on scientific literature in its catching-up because science literature is not protected by any IPR forms and thus freely available for use. So, the latecomer has a reason to explore fully whatever useful knowledge from scientific commons in their catch-up efforts.

Similarly one may reason that the latecomer would try to rely less on old technologies protected by patents it means continued reliance on the incumbents. Such attitude is also desirable to avoid any possible patent dispute with the incumbents. So, the latecomers have a reason to explore, whenever possible, a technological trajectory which is less connected to existing technologies. In that case, their citation pattern will be more toward recent patents. In other words, the average cycle time of their patent portfolio would be shorter than those of
incumbents. This hypothesis is interesting in view of some literature, such as Park and Lee (2006) or Lee (2013), that find the latecomer countries tend to specialize in short-cycle technology based sectors. While that literature is concerned with across-sector specialization, we explore a twisted question of whether a latecomer firm’s patent portfolio would show the shorter average cycle time than that of incumbents in the same sector.

4. Catching-up with Similar or Different Technologies?

4.1 Is Huawei’s Technology Higher Quality than that of Ericsson?

All patents are not equal. The distribution of patent quality, technological impact, and the economic value is highly skewed – there are a few high quality patents, but most patents have very low quality. Therefore, it is quality and not quantity that counts.

The quality of two firms’ patents can be measured by the average number of citations received, because the more a patent is cited, the more it is considered to be valuable or worthy of use (Albert et al. 1991, Hall et al. 2005). Figure 7 offers a comparison of the average number of citations that the two firms’ patents received. Figure 7 (a) takes into account the citations from all patents in the PATSTAT database – for instance, it includes citations from US patents. On the other hand, the number of citations received by EPO patents is included in Figure 7 (b).

As indicated in Figure 7, Huawei has remained ahead of Ericsson in terms of the average number of citations received since the early 2000s. It is noteworthy that Huawei filed its first European patents in 2000, but it has outclassed Ericsson in terms of patent quality from the
beginning, and remained in the lead ever since.

Figure 7. Average Number of Citations Received by Huawei’s and Ericsson’s Patents

This phenomenon might be partly attributed to differences in Huawei’s and Ericsson’s patent strategies, especially in the early 2000s. Huawei might have filed EPO patents for only a few of its high-quality inventions, because Europe was not its home market, and the cost of an EPO patent application was far greater than the cost of a Chinese patent application. On the other hand, Ericsson may have filed EPO patents for most of its inventions, because the European market was its home market. Ericsson’s patent strategy – filing not only a few good-quality patents but also many low quality patents – may have resulted in low average patent quality for Ericsson.

Notwithstanding the difference in the two firms’ patent strategies, our result provides strong evidence that Huawei caught up with Ericsson in terms of patent quality no later than the mid-2000s. Although Huawei filed a comparable number of EPO patents as Ericsson from the mid-2000s, Huawei stayed ahead of Ericsson with respect to patent quality. This suggests that Huawei filed as many quality EPO patents as Ericsson did.

Table 1 shows that Ericsson filed EPO patents for most of its inventions, while Huawei filed EPO patents for only a few of its inventions in the early 2000s.
It would be much more difficult for a latecomer to catch up with patent quality than patent quantity. When a latecomer focuses on the practical implementation of an intellectual foundation laid down by its forerunners, the latecomer can sometimes be more successful than the forerunners in generating a wide variety of applications. However, it may restrain the latecomer from catching up with the quality of patents, because the latecomer’s developments would reinforce the economic and technological value of the basic principles invented by the forerunners. Thus, the catch-up in patent quality requires a latecomer to produce somewhat radical innovations, and our result shows that Huawei did exactly this.

Catch-up of patent quality can be achieved either by taking a different technological path than one’s forerunners or by taking the same path, but rarely both, because the two paths require a latecomer to adopt different and contradicting strategies and capabilities. If a latecomer takes and tries to climb the same technological ladder after the forerunning incumbents, most of the important and valuable inventions on the current and higher steps are frequently preempted by the forerunners, leaving the latecomer little chance. As an alternative, taking a bypass or a different technological ladder may allow a latecomer to circumvent such difficulties in catching up with patent quality. However, this would be highly challenging and risky. In the former case, a latecomer often takes exploitative innovation strategy – carefully selecting existing state-of-the-art technologies, and focusing on refining and optimizing them to multiply efficiency. In the latter case, the latecomer needs to assume an explorative innovation strategy – deliberately taking the risk of uncertainties, and searching wide sets of knowledge sources to discover a new breed of ideas (March 1991).

It must have been an important decision for Huawei whether to develop similar or different technologies to the forerunning incumbents. Huawei’s patent quality catch-up shows that the
company made a conscious decision at some point, although what exactly this decision was is not clear.

4.2 Does Huawei keeps Imitating Ericsson?: Mutual Citations

Latecomers usually start the technological catch-up by acquiring and assimilating forerunners’ knowledge, and they make improvements or sometimes take innovations afterwards (Kim, 1980). Without their own innovations, latecomers are unlikely to sever their reliance on the forerunners’ knowledge. Hence, the latecomer’s break from the forerunners’ knowledge can be a good signal that the latecomer has its own innovations. The level of technological dependence between the catching-up firm and the leading firm can be analyzed by the degree of mutual citations (Joo and Lee 2010).

The technological dependence of firm i on firm j, is defined as follows:

\[
\text{Technological Dependence}_{ij} = \frac{\text{Firm i's citations directed to Firm j's patents}}{\text{Total citations in Firm i's patents}}
\]

Figure 8 shows that Huawei is becoming less dependent on Ericsson. In contrast, there have been negligible citations by Ericsson toward the patents of Huawei. Given Huawei’s catch-up in patent quality, Ericsson should, in theory, have been increasingly dependent on Huawei’s technology, assuming Huawei had taken the same technological ladder. However, Ericsson’s technological reliance on Huawei has remained unchanged. The results corroborate our argument that Huawei has taken a different path from Ericsson.

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18 Huawei also cited the patents of other forerunners – Nokia, Lucent, Nortel, Alcatel, Siemens, etc. Huawei’s technological dependence on the other forerunners also showed decreasing trends in general.
4.3 Is Huawei getting Independent?: Self-citations

When a latecomer follows a technological path that is accepted industry-wide, it may become less dependent on each major forerunner’s knowledge, while becoming increasingly dependent on external knowledge sources as a whole by diversifying its knowledge sources. Hence, a latecomer’s reduced technological reliance on each major forerunner does not directly imply that the latecomer has taken a bypass or a different technological ladder from the forerunners. Therefore, it needs to be further analyzed whether the latecomer became less dependent on external knowledge sources as a whole, i.e. whether the latecomer came to be more self-reliant on its own knowledge base.

A firm’s ability to create new knowledge from its own knowledge base is an important aspect of its technological capability. Firms endeavor to utilize their internal knowledge base prior to external sources, because establishing in-house proprietary technologies is crucial to their technological competitiveness. The degree to which a firm is capable of drawing innovation

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19 Figure 8 takes account of citations directed to all patents in PATSTAT, not EPO patents only.
from its own knowledge base can be measured by the ratio of self-citations (citations directed to its own patents) of the firm’s patents. The higher a firm’s technological capabilities, the higher a self-citation ratio it shows (Lee 2013: Ch. 5).

Figure 9 shows that Huawei’s self-citation ratio has been steadily increasing, eventually approaching Ericsson’s by the late 2000s. It shows that Huawei became as self-reliant as Ericsson by increasingly developing technologies that are different from those of other firms including Ericsson. Once again, the results support our argument that Huawei has been taking a different path from Ericsson.

Figure 9. Self-Citation Ratio of Huawei and Ericsson

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20 The self-citation ratio also reflects a firm’s technological capabilities (Lee 2013: Ch. 5). The increasing self-citation ratio of Huawei in Figure 9 can also be interpreted as Huawei’s successful accumulation of technological capabilities.

21 Figure 9 takes account of citations directed to all patents in PATSTAT, not EPO patents only.
5. Catching-up with more ‘Recent and Scientific’ knowledge?

5.1 Huawei’s Scientific Explorations (Citations to non-patent literature)

A latecomer has to push the frontier of current technology when it follows the same technological ladder as its forerunners. The latecomer narrows its search space to locate the state-of-the-art technologies on which it can improve. In contrast, when it takes a bypass or a different technological ladder from its forerunners, a latecomer needs to challenge conventional dogma to create a de novo pathway. Because the knowledge within or surrounding conventional dogma does not promote the questioning of conventions, the latecomer expands its search space widely to bring unprecedented ideas, and also searches for a genuine principle. Therefore, a latecomer is more likely to conceive ideas from basic research when it takes a different path from the forerunners.

The extent to which a firm draws ideas from basic research can be investigated by the number of citations directed to non-patent literature (most of them are scientific articles in academic journals). It reflects the proximity to basic research – the more ideas are taken from basic research, the more non-patent literature it cites.

Figure 10 provides the average number of citations directed to non-patent literature by the patents of Huawei and Ericsson. Huawei’s patents had been citing more non-patent literature than Ericsson’s patents until recently. The result suggests that Huawei has been actively exploring basic research, and it confirms our claim that Huawei has been catching up by developing ‘different’ technologies from Ericsson.

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22 Exploring basic research is not an easy task, especially for a latecomer. Huawei may have been reaping the benefits of China’s strong capabilities in basic research.
5.2 Does Huawei relies on More Recent Technologies: Citation Lags

Backward citation lag (BWL) measures how recent the prior patents are that a patent cites, while forward citation lag (FWL) indicates how quickly a patent is cited by subsequent patents. These two indicators show how agile a firm is in terms of assimilating new technologies in order to recreate them, and how rapidly a firm’s technologies are adopted for subsequent developments in the process of a technological catch-up.

BWL and FWL of patent i are defined as follows:

\[ BWL_i = \frac{\sum_{j=1}^{NCITING_i} BLAG_j}{NCITING_i}, \quad FWL_i = \frac{\sum_{k=1}^{NCITED_i} FLAG_k}{NCITED_i} \]

NCITING\(_i\) = Total number of citations made by patent i

\( BLAG_j \) = difference in the filing date between citing patent i and cited patent j

NCITED\(_i\) = Total number of citations received by patent i

\( FLAG_k \) = difference in the filing date between cited patent i and citing patent k
Until recently, Huawei showed shorter backward and forward citation lags compared with Ericsson. The results can be interpreted as Huawei having been focused on developing technologies with a shorter technology cycle. It is in line with the finding of Park and Lee (2006) that the catch-up is more likely to take place in technological sectors with shorter technology cycles. A shorter backward citation lag shows that Huawei has been narrowing the technology gap with Ericsson by accelerating its technological progress with an up-to-date knowledge base. The shorter forward citation lag shows that Huawei’s patents have had more immediate impacts.

Figure 11. Backward and Forward Citation Lag

Summary and Concluding Remarks

This paper has raised the question of whether a latecomer firm catches up with a forerunning firm in market shares by using ‘similar or different’ technologies from those of the forerunners. To answer this, it has investigated the patents by Huawei and Ericsson. It finds that Huawei relied on Ericsson as a knowledge source in its early days, but subsequently

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23 Figure 11 takes account of citations directed to all patents in PATSTAT, not EPO patents only.
reduced this reliance and increased its self-citation ratio. The results of mutual citations and self-citations provide strong evidence that Huawei has caught up with Ericsson by taking a different, rather than the same path from Ericsson. In addition, we found that Huawei, compared with Ericsson, developed its technologies relying on more recent and scientific knowledge, and its technologies are more quickly utilized by other firms in the industry than Ericsson’s. The results of citations to non-patent literature and citation lags showed that Huawei has conducted extensive exploration of basic research and kept its technologies up-to-date in order to accomplish its technological catch-up. Overall, this study suggests that exploring a new and different technological path from that of forerunners is not only a possible but also a viable catch-up strategy for a latecomer.

Besides, Huawei’s case re-confirms the hypothesis that a catch-up in technological capabilities tend to precede a catch-up in market shares, which was verified in the Samsung vs. Sony case in consumer electronics by Joo and Lee (2010). Huawei overtook Ericsson in terms of both quantity and quality of patent before it did in terms of annual sales. It suggests that Huawei’s catch-up with Ericsson in the telecommunication equipment market is not merely based on either Huawei’s sheer cost advantage or the large domestic market with the Chinese government’s support, but that Huawei’s technological catch-up played a pivotal role.

Our study contributes to the literature on innovation and catch-up studies in several ways. First, this paper is one of the first study that suggests a quantitative method to assess whether a latecomer is taking the same or a different technological path from its forerunners. The lack of a proper yardstick has often impeded in-depth catch-up research. Our method can be applied to other catch-up cases. Second, the paper provides quantitative evidence that
supports the assertion that a latecomer catches up with the forerunner and finally forges ahead by taking a different technological path from the forerunner. Although the argument needs to be further investigated with more cases before it can be applied more generally, our study casts serious doubt on the idea that a latecomer can forge ahead simply by following the same technological path as the forerunner. Third, our study finds that some successful latecomer firms utilize the basic research and up-to-date technologies more than the forerunning firm, which is somewhat contrary to conventional impression. While this also needs further investigation, it suggests that a successful catching-up may happen quite differently from what we had expected. Although we cannot make any strongly generalizable conclusions based on a single case, we believe our study has shed a new light on the process of latecomer’s innovation and catch-up.

References


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