경제학박사학위논문

Technological Catch-Up of Chinese Digital Platform Companies:

Analyzing the Technological Paths of Baidu, Alibaba, Tencent with Google, Amazon, Facebook as Benchmarks

중국과 미국 디지털 플랫폼 기업간의 추격 및 추월 분석:

Google, Amazon, Facebook을 벤치마크하여 Baidu, Alibaba, Tencent 분석을 중심으로

2023년 8월

서울대학교 대학원
경제학부 경제학 전공

김 준 엽

중국과 미국 디지털 플랫폼 기업 간의 추격 및 추월 분석:

Google, Amazon, Facebook을 벤치마크하여 Baidu, Alibaba, Tencent를 분석을 중심으로

지도교수 이 근

이 논문을 박사 학위논문으로 제출함
2023년 8월

서울대학교 대학원
경제학부 경제학 전공
김 준 엽

김준엽의 박사 학위논문을 인준함
2023년 7월

위 원 장 김 봉 근 (인)

부위원장 이 근 (인)

위 원 서 봉 교 (인)

위 원 오 철 (인)

위 원 정 태 현 (인)

Abstract

Technological Catch-Up of Chinese Digital Platform Companies:

Analyzing the Technological Paths of Baidu, Alibaba, Tencent with Google, Amazon, Facebook as Benchmarks

Joonyup Kim
Department of Economics
The Graduate School
Seoul National University

This paper explores the key factors behind the Chinese digital platform companies' success in recent years through comparative analyses of the Chinese and the U.S. companies. Three Chinese digital platform firms (Baidu, Alibaba, and Tencent) are studied in particular, which are matched to their U.S. counterparts (Google, Amazon, and Facebook) with respect to their business and technological areas: Baidu and Google (search engine platform), Alibaba and Amazon (e-commerce platform), and Tencent and Facebook (social media platform). Hypotheses for 1) the latecomers' creation of technological pathways and 2) the cycle times of the latecomers' technologies and the latecomers' dependence on scientific literature are constructed and tested through empirical analysis of patent data.

The study period spans from 2010 to 2019, and the European

Patent Office's patent database PATSTAT is used for the analysis. The database consists of more than 100 million patent documents and is consistent across the records from different countries. Regressions are estimated to observe the latecomers' catch−up or overtake of the forerunners, if any. Covariates are added to control for other patent−related factors, such as patent stock of the firm, patent stock of the counterpart firm, family size of the patent, number of inventors, number of patent claims, number of backward citations, number of forward citations, number of IPC classes, and technological fields. An interaction term is utilized to determine whether the catch−up or overtake has been attained. Appropriate regression models are chosen based on the numerical characteristics of the dependent variables; Poisson regressions are estimated for the quality of patents and scientific literature citations; fractional logistic regressions for self−citation and mutual citation ratios; and linear regressions for the cycle times of technology.

Results suggest that Baidu has not been catching up with Google regarding the quality and quantity of the patents. Baidu has been catching up with Google regarding technological independence (i.e., self−citation ratio) but could not reduce the level of technological dependence on Google (i.e., mutual citation ratio) to Google's level of dependence on Baidu. Baidu has been implementing niche−seeking strategies by utilizing technologies with shorter cycle times and has maintained a similar number of scientific literature citations as Google did. In short, Baidu has been seeking niches and circumventing IPR disputes but has not been able to create new technological pathways that could effectively compete with Google's technologies. The gap in technological capabilities between the two firms has correspondingly been reflected in their market performances, with

Baidu's market capitalization amounting to 4.7% of Google's in 2019.

Alibaba has caught up with Amazon in the quality of technology and overtaken it in its quantity. In terms of technological independence, Alibaba has been catching up with Amazon; however, Alibaba has not been able to reduce its dependence on Amazon to Amazon's level of dependence on Alibaba. Alibaba and Amazon have been using technologies with similar cycle times and cited scientific literatures at a similar level. These results suggest that Alibaba, too, has been taking measures to seek niches and avoid IPR disputes while attempting to pave technological pathways distinct from Amazon's simultaneously, though with limited success in the given time period. This is also correspondingly reflected in its market performances; Alibaba is closer to Amazon than Baidu is to Google, and Alibaba's market capitalization amounted to 61.1% of Amazon's in 2019.

Tencent has surpassed Facebook in terms of the quantity of technology but not quality. Tencent has also overtaken Facebook with respect to technological independence and was able to reduce its dependence on Facebook to levels lower than that of Facebook on Tencent. Tencent has been pursuing technologies with relatively shorter cycle times, and maintained similar levels of scientific literature citations to those of Facebook. This suggests that Tencent has also been seeking niches, circumventing IPR disputes, and attempting to create new technological pathways. Among the three metrics for assessing the choice of technological pathways, Tencent has achieved overtakes in self-citation ratio and mutual citation ratio but is yet to catch up with Facebook in terms of patent qualities, which lends to the conclusion that while Tencent is working towards creating a novel technological pathway, it hasn't yet completed its progress. Tencent's feat in technological growth can also be seen

through its market performance; Tencent's market capitalization has reached 78.6% of Facebook's in 2019.

In summary, this study shows that the latecomers in the digital platform industry (Baidu, Alibaba, and Tencent) have been focused on technologies with shorter cycle times to seek niches in their competition with their forerunners (Google, Amazon, and Facebook), and that they attempted to avoid IPR disputes with the forerunners by utilizing scientific literatures in their patents. Moreover, all the latecomers in the study attempted to create alternative technological pathways to compete with their forerunners, albeit with varying degrees, and the degree of successes in these efforts was proportionately reflected in their market performances.

This study expands on the existing findings on the orders in which the catch-ups in the technological capability metrics happen and the relative difficulties in achieving such catch-ups. Results for the comparisons in the market performances and the technological capabilities metrics suggest that the catch-ups in the number of patents and technological independence precede the catch-ups in the quality of patents and reduced technological dependence. In other words, it is more difficult for the firms to have their patents cited than to simply increase the number of patents (i.e., it is more difficult to catch up in terms of the quality than the quantity of the patents), and it is more difficult to refrain from citing their forerunners than to cite their own patents (i.e., it is more difficult to reduce technological dependence than to strengthen their technological independence). Among these metrics, the quality of patents seems to be the most demanding metric to surpass the forerunners in.

Moreover, this study adds to and supports the perspectives of the existing body of work that applies the theory of technological catch−up. While previous studies focused on the application of such theory on manufacturing firms, this study sheds light on the firms in the up−and−rising digital platform industry and shows that the theory can likewise be applied in this setting. Furthermore, this study differentiates from most other studies, which investigated the cases in which the latecomer has completed the catch−up or overtake, by examining the firms that haven't yet achieved such a feat and investigating the latecomers' strategic behaviors and technological capabilities in the process of accumulating market and technological successes.

Finally, this study presents the results with methodologies that haven't been widely utilized in this line of work. Previous studies that investigated the catch−ups in manufacturing firms draw conclusions based on graphs and simple comparisons of various metrics; this study presents a rigorous statistical analysis based on regressions and offers interpretations controlled for relevant covariates.

Keyword: Digital platform companies, patent analysis, technological catch−up, technological pathway creation, self−citations, mutual citations, cycle time of technology, scientific literature citations

Student Number: 2011−30071

Table of Contents

List of Tables

List of Figures

Chapter I. Introduction

1. Motivation and research objectives

It is no exaggeration that the remarkable developments in digital technologies such as big data and artificial intelligence (AI) have brought about a seismic shift in how people interact with each other and, consequently, how businesses serve their customers. Services that were once thought to be only possible through physical interactions have now moved into digital spaces and are provided through digital platforms, connecting billions of customers and businesses worldwide. The global digital platform ecosystem emerged in the early 2000s with technologies such as mobile operating systems and search engines and was flourished by advanced telecommunication technologies such as 5G that made it more accessible than ever. Technological innovations that not only support the growth of the digital platform ecosystems, such as cloud computing, but also enable entirely new types of products and services that were not provided previously, such as social media, e-commerce, and online payments, are being developed and created even as of now, and digital platform companies are fiercely competing with each other as rapid technological progress is being made around the world.

The World Economic Forum predicts that the global digital platform sales will grow to approximately 60 trillion U.S. dollars (7.2

quadrillion Korean won), and 30% of all global corporate sales will be achieved through digital platform businesses by 2025. UNCTAD (2020) suggests likewise, predicting that the price competitiveness from accumulated data through digital platforms and competitive advantage gained from network effects will lead to the expansion of the digital platform economy.

Business opportunities from such technological innovations are prevalent all over the globe, including, but not limited to, the United States and China. While U.S. digital platform firms dominate the global market, Chinese firms are actively carving out the market share and staying competitive amidst the cutthroat international competition. Digital platform companies are no longer the minorities in the business world. In 2009, Microsoft and Google were the only digital platform companies in the list of top 10 companies with the biggest market capitalization worldwide; in 2019, the same figure rose to seven, comprised of Microsoft, Apple, Amazon, Google, Facebook, Alibaba, and Tencent. The three major Chinese digital platform companies – Baidu, Alibaba, and Tencent – have grown at an exceptional pace over the past few decades and are advancing into the international market. Google, Amazon, and Facebook – the three major U.S. digital platform companies – are, however, relatively struggling to expand further than where they are right now. Competitions between these U.S. and Chinese digital platforms are now escalating into a competition for technological hegemony between the U.S. and China, leading to an expansion in the focus of the competition from products and technologies to corporate business models and national policies.

Studies and media tend to attribute the success of Chinese digital platform companies to the asymmetric government regulations and policies that explicitly provide support to Chinese firms while blocking out the entrance of U.S. firms to domestic markets. Although government regulations and supports are undeniably essential for firm growth, they are by no means the only and the most important. Myriad factors such as cost reduction, creation of profit models, mergers and acquisitions (M&A), organizational culture improvements, and marketing strategies are known to affect corporate growth, and technological innovation is often credited as one of the key drivers that enable sustainable corporate growth. Considering that the Chinese digital firms are achieving success not just in the domestic market but also in the global market, attributing their successes solely to government support is more of a hasty misconception than anything. As Chinese firms continue to expand and transform the global digital platform market, it is now more important than ever to better understand how they emerged, achieved exponential growth, and are attempting to catch up with and overtake their forerunners in the U.S.

In this study, I explore the technological aspect of the growth of Chinese digital platform firms and characterize the ways in which those firms have achieved their successes through empirical analysis. Three Chinese digital platform firms (Baidu, Alibaba, and Tencent) are studied in particular, which are matched to their U.S. counterparts (Google, Amazon, and Facebook) with respect to their business and technological areas: Baidu and Google (search engine platform), Alibaba and Amazon (e–commerce platform), and Tencent and Facebook (social media platform). The study period spans from 2010 to 2019, and the European Patent Office's patent database PATSTAT is used for the analysis. Five metrics – the quality of patents, the quantity of patents, self–citations, mutual citations, the cycle time of technology, and scientific literature citations – that describe a firm's technological development and pathway are calculated using the patent data. Regressions are estimated to examine the factors, and their statistical significance, associated with the Chinese latecomers' technological catch–ups with their U.S. forerunners.

2. Structure of the study

This study is structured as follows. In Section 1, I introduce the rapid progress the digital platform industry and the major U.S. and Chinese firms has made, and the need to study the efforts of the Chinese companies to achieve their success through technological innovation in light of the claims that the Chinese firms have mostly grown through the asymmetric support from the national government. In Section 2, I introduce the existing body of work related to this study, state the contributions that this study makes, and formally hypothesize the research questions. In Section 3, I outline the empirical framework and methodologies used in this study. In Section 4, I describe the source of data used in this study in detail. In Section 5, I present the results of the empirical analysis that compare Baidu with Google, Alibaba with Amazon, and Tencent with Facebook. In Section 6, I offer interpretations to the results in terms of technological innovations and catch-ups of the latecomers, and summarize the contributions and implications of this study.

Chapter II. Literature review and hypothesis

1. Literature review

At the firm level, the theory of economic catch-up studies how the latecomer firms catch up with or overtake the forerunner firms. But not all latecomers attain catch-ups or overtakes; some experience stunted growth or failures. For these reasons, it would be more appropriate to name the theory as the theory of ‘catching up, forging ahead, and falling behind’ (Lee, 2013; Kwak and Baek, 2017). Nevertheless, the theory of catch-up is widely applied to analyze the catch-ups of various entities, from nations, industries, and firms to inventors and patentees. Recent studies also use the theory at the city and local levels to examine the catch-ups in light of emerging issues such as decentralizations, smart cities, and regional extinctions. Methodologies used in the studies of catch-ups range from qualitative analysis of specific cases to empirical analysis using country-level, industry-level, and firm-level data, building theoretical models, and running computational simulations.

In the context of this study, catch-up refers to the latecomers’ narrowing of the gaps with their forerunners in terms of technological capabilities and market performances (Bell and Figueiredo, 2010; Hobday, 1995; Mathews, 2002). The theory of catch-up may focus on the latecomers’ strategies to adopt the tried-and-true technologies of the forerunners in the initial stages for rapid assembly of finished products and process innovations, and develop proprietary technologies once they have accumulated enough technological capabilities to drive innovations (Kim, 1980; Kim, 1997; Lee et al., 1988). The theory may also focus on the latecomers' attempts to follow the forerunners' technological pathways, skip a few steps, or create their own technological pathways entirely (Lee and Lim, 2001; Lee, 2005). While many studies investigate the cases of latecomers' catch-up with the forerunners in the manufacturing industry, such as automobiles, digital televisions, digital communications parts, and mobile phones, there has been a relative lack of studies on firms in the service industry.

In this section, I introduce several factors that catalyze the growth of firms, as identified by an existing body of work, and build the foundations for my hypotheses through the examination of prior literature and the profiles of the digital platform companies of interest in this study, after which I present five hypotheses for the catch-ups and overtakes of the latecomers that would be testable with empirical analysis.

1) Corporate growth and catch-up

Traditional theories of catch-ups emphasized the role of production costs to increase the company's competitiveness. In this framework, latecomers achieve the catch-up with the forerunners not by developing proprietary technology or expanding their technological capabilities but with business model strategies such as lower wages, reduced costs, and mergers and acquisitions (M&A).

Latecomers can grow and catch up with their forerunners with production cost advantages, such as economies of scale, larger market shares, and cost advantages in various production processes. Scherer (1980) investigates the minimum efficiency scale and concentration ratio of each sector and reports that the concentration ratio gradually increases in sectors with clear economies of scale. Yelle (1979) shows that the production costs decrease as cumulative production output increases, and Buzzel, Gale, and Sultan (1981) report positive correlation between market shares and firm profitability through empirical analysis. Wells (1983) and Agmon and Kindleberger (1977) draw attention to the fact that companies in developed countries tend to mass-produce limited items through standardized production processes to secure price competitiveness of production parts.

The limitations of catch-ups through low production costs are highlighted in many Schumpeterian studies from the 2000s, such as Lee (2001, 2005), Lee and Lim (2001), Lee et al. (2005), and Malerba (2002, 2004), that emphasize the latecomers' accumulation of technological capabilities as their basis of catch-ups. These studies focus on the concept of technological systems and stress innovations and technological capabilities as key factors that enable the success of the latecomers' catch-up with their forerunners. Moreover, the studies argue that while innovations and technological capabilities are crucial for catch-ups, the firms being in different technological areas result in different types and characteristics of technological innovations.

Other non-Schumpeterian studies also emphasize the importance of technological capabilities in catch-ups. Saviotti and Metcalfe (1984) and O'Neil and Sohal (1999) investigate the nature of technological development and highlight the importance of technological capabilities by delineating the radicality of technological innovation in the U.S. Cooper and Schendel (1976) stress the importance of technological capability when it comes to the firms' handling of the threats to their outdated technologies, and argue that the dual strategy to develop existing and new technologies simultaneously is not effective. In other words, it is difficult for companies to effectively develop new products with novel technologies while attempting to improve upon existing technologies at the same time. Wheelwright and Clark (1992) suggest the roles that the corporate leaders must take on in each level of technological development.

2) Corporate growth and M&A

M&A strategies of latecomers are known to affect their growth and catch-ups with their forerunners. M&A is typically implemented to achieve strategic goals such as risk diversification, entry into new fields, and acquisition of new technologies, and is considered one of the core business strategies of a firm (Lamont and Anderson, 1985; Porter, 1987). Companies in developing countries are reported to utilize M&A to reduce the knowledge gap with the forerunners and attain a competitive edge in the global market (Deng, 2007; Elango and Pattnaik, 2011), and have the tendency to target the companies from developed countries for acquisition (Makino et al., 2002). Studies on Chinese firms have shown positive correlations between M&A and corporate performance (Zhang et al., 2018).

Not all M&As, however, are positively correlated with corporate innovations and performances. Tsai and Wang (2008), through the analysis of Taiwanese electronic parts firms, show that the acquisition of new technologies through methods such as M&A does not have a statistically significant relationship with the market performances of a firm. Shin, Han, Marhold, and Kang (2017) show that the effect of M&A on innovation varies on the firm's level of expertise on its technology and the technological similarity and complementarity with the firm it is acquiring.

3) Imitations and innovation of business models

Business models are frequently used as a tool to classify firms, measure firm performance, and investigate the level of innovation (Foss and Saebi, 2017). Studies have demonstrated that firms utilize business models to adapt to the market and gain a competitive edge.

While most studies agree that latecomers may reap more benefits from innovating their business models rather than imitating their forerunners, other studies also point out that the latecomers do not always have to make a choice between the two and that they can achieve growth through innovation after a period of imitation.

Zhao, von Delft, Morgan, and Buck (2020) describe various cases of imitations and innovations by Chinese digital platform firms. The study defines simple imitations as companies' way of studying their competitors' business models and replicating the most easily adaptable part into their own business models, and complex imitations as the companies starting by imitating the innovative business models of the competitors but eventually creating an amalgamation of the competitors' business models and their own business models; the study emphasizes that complex imitation is a more sophisticated type of imitation as the companies are able to make improvements upon their imitations. Kim (2021) argues that Tencent's success in the video game business can be attributed to its imitation of Facebook's business model and that latecomers can massively benefit from simply imitating an innovative business model when they are technologically lagging. In fact, Pony Ma, the founder of Tencent, directly mentions 'creative imitation' in Tencent's internal publication in 2008 and admits that Tencent's business model bases itself on the imitation of forerunners' business models. Dai, Shen, and Zheng (2011) analyze Tencent's strategic choices around business models to achieve growth and argue that Tencent avoids modifying the core elements of its business model and does not engage much in exploring new business models. In other words, Tencent is actively searching for different business models to replicate and develop upon but not so much in innovating one itself. Peng, Zhou, Sadowski, and Sun (2021) demonstrate that the effect of imitative strategies to catalyze firm growth differs between the firms in the OECD countries and non-OECD countries and that the effect is more pronounced for the firms in the latter group. The study implies that the firms in China, a non-OECD country, are utilizing imitative strategies and that they are effective and valid, but also emphasizes that the latecomers' imitative strategy only promotes short-term outcomes and not long-term outcomes.

Business model innovation refers to the complete redesign of a business model or a transformation of an existing business model through reconstruction. Firms are known to take different types of paths for business model innovation. Amit and Zott (2012) suggest three different paths; firms may 1) create a new business (e.g., IBM's provision of service and consulting), 2) provide a new method of connections (e.g., a platform that connects the consumers rather than the supplier directly providing for the customers), and 3) reorganize the structure of those in charge of the management. Cantrell and Linder (2000) suggest four paths – realization model, renewal model, extension model, and journey model – that are each classified by the degree of changes in the business model. In particular, Tencent's success through business model innovation has been extensively studied; Bereznoi (2015) argues that while Tencent initially sought to imitate the business strategies of successful Western social media companies, it eventually chose to expand its video game business through the user base it accumulated through its social media service, rather than to operate an online advertising–focused business. Fu (2020) suggests that Tencent's business model that focuses on user accessibility to its products through the service of a wide range of products such as QQ, Tencent Friends, and Qzone, as well as collaborations with major telecommunications companies such as China Unicorn, led to business model innovations and garnered a wide success.

Chang, Kim, Song, and Lee (2015) argue that unless the forerunners are stagnant, the latecomers' heavy dependence on either one of imitation or innovation lowers the chance for the latecomers to take over as the leaders of the technology and that the latecomers must initially seek to imitate, and then transition into innovation. This aligns with the widely accepted idea that latecomers typically benefit from absorbing mature technologies in the initial phase and investing in innovations down the road when the technological gap narrows with the forerunners. Dai, Shen, and Zheng (2011) point to this process as the primary driver of Tencent's success, describing how Tencent began with a business model focused on its instant messaging service in its early stages, but its eventual success was derived from moving onto a different business model by branching out to other related businesses with services such as QQ Games and developing innovative ways to integrate online advertising into its products. In addition, Tencent is constantly changing and improving its business model through its ability to connect to diverse business areas (Yu & Kwon, 2020). However, Tencent has also faced criticisms that its remarkable growth through QQ and video game sales is mostly due to its imitations of the competitors' products and services. Pony Ma, Tencent's founder, addressed this claim by pointing out that Tencent was able to survive and achieve its success through its 'creative imitation' when most other Chinese technology companies that were founded around the same time ended up closing down. He also emphasized that Tencent didn't just replicate its competitors but instead innovated on top of existing products and services, and that this type of innovation has been the core driver behind Tencent' s ascent to the top of its competitors (김환표, 2016; Kim, 2021).

4) Asymmetric government regulation and support

As the U.S. and Chinese digital platform companies are engaging in fierce competition, especially amidst the U.S.−China trade war since 2018, the national governments are actively shaping the playing fields in their domestic markets. The Chinese government is a frequent subject of criticism that voices concerns regarding its severely asymmetric regulation and support for its domestic firms. In fact, the Chinese government is actively stunting the growth and spread of American digital platforms in China by providing massive tax benefits and subsidies to domestic firms and engaging in censorship and control of the digital space through its cybersecurity law.

Several studies point to government policies as factors behind the growth of digital platform companies in China (Casey & Koleski, 2011; Li & Woetzel, 2011). China has provided intensive support to the digital platform industry following the 12th 5-year economic development plan promulgated in 2011. China especially sought to transition from export-oriented growth to domestic demand and consumption-oriented growth, which eventually proved effective to a certain extent. Following this, China has implemented various policies to accelerate the domestic companies' growth and encouraged them to secure their competitiveness with intensive investments in R&D and M&A. Along with policies that implicitly impede the success of foreign companies, Chinese companies grew, and the domestic market was protected (Casey & Koleski, 2011; Li & Woetzel, 2011).

China's corporate tax rate is 25%, but companies in the video game industry enjoy a tax rate of 20%, which can be reduced even further to 15% if the industry is recognized as high-tech. Companies can also benefit from subsidies provided by the local government depending on the location and the type of operation that the company engages in. Tencent's AI and video game businesses enjoy tax benefits from the Chinese government; Kim (2017) argues that the tax benefits and subsidies from the Chinese government to its domestic digital platform companies enabled their expansion.

In addition, the Chinese government strengthened its censorship and control of the internet by enforcing the cybersecurity law that went into effect in June 2017 and further solidifying the so-called 'Great Firewall of China,' a portmanteau that combines the famous Great Wall of China and the firewall, a network security device. The cybersecurity law and the Great Firewall of China were created to achieve social stability by blocking traffic inflow from overseas. Specifically, this blocks the services provided by U.S. digital platform firms such as Google, Twitter, and Facebook and stipulates that foreign firms must agree to the Chinese government's terms on regulations and requirements to be able to provide the parts of their services that the government permits. Such policy provided domestic digital platform companies with opportunities to build their ecosystems without foreign interferences and flourish into success (Kalathil, 2017; Shen, 2019; Chandel et al., 2019).

2. Research hypothesis

In this section, I explore prior work on the latecomers' choice of technological pathways in catching up with or overtaking their forerunners, especially for digital platform firms. Moreover, I construct five hypotheses regarding the catch-up of the three Chinese latecomers – Baidu, Alibaba, and Tencent – with the three U.S. forerunners – Google, Amazon, and Facebook – based on the company profiles and relevant literature on technological catch-ups.

Lee and Lim (2001), in their study distinguishing the three types of catch-ups, argue that latecomers face different types of technological pathways to choose from when they attempt to catch up with the forerunners. According to the study, one of the options involves the latecomers following the footsteps of their forerunners to catch up; another is to follow, but skip some of the steps that the forerunners took to save time and resources; and the last is to create a pathway different from the ones that the forerunners took.

Latecomers tend to imitate the technology of the forerunners in the initial stage of catching up but eventually attempt to create new and distinct technologies to set themselves apart and surpass their forerunners. Latecomers may fail to compete and ultimately be completely overshadowed by their forerunners; those that manage to overtake their forerunners are reported to have created technological pathways different from their forerunners' (Joo and Lee, 2010; Oh and Joo, 2015; Joo et al., 2016). In other words, latecomers may initially attempt to follow the forerunners' paths and narrow the gap to a certain extent but would eventually find it difficult to overtake them just by imitating. Lee (2013) argues that the latecomers' imitation of their forerunners is not a sufficient condition for them to overtake their forerunners and that the latecomers must create a technological pathway different from their forerunners' to achieve the overtake.

A body of work in the technological catch-up offers several concepts to define what constitutes technological catch-up and how they manifest in the real world. One major concept explores the catch-up in terms of the quality of the patents. Patent records delineate the scope of intellectual property protection sought in a patent application, how each patent claims to differ from other existing patents, and the detailed citation records (Verspagen, 2007). Patent citations imply that the cited patents have been used in the creation of other technologies (Jaffe and Trajtenberg, 2002), and hence, a larger number of citations received would portray the usefulness, and therefore the value, of the patent (Hall, 2001). Lanjouw and Schankermann (2003) use the number of citations received as a proxy to measure the quality of the patent and demonstrate its usefulness in predicting whether the patent would be renewed in the future and whether it would be involved in IPR-related litigations. Hall, Jaffe, and Trajtenberg (2005) report the evidence that patent quality is a better indicator of the value of innovation than the patent quantity by showing that the number of patents does not correlate with social surplus but the number of patents weighted by numbers of citations received has a strongly positive correlation. Verspagen (2007) constructs a network of fuel cell technologies using patent database and observes the technological pathways through the network. Joo and Lee (2009), Oh and Joo (2015), and Joo et al. (2016) demonstrate that the quality of the patents can be measured by the average number of citations received and utilize it to show the latecomers' catch-up with the forerunners.

Self-citation is another valuable metric in investigating technological pathways. Self-citation of a patent represents a company's technological capability to monopolize profits from its own innovations by protecting them from being copied by others, and can be calculated as the ratio of the number of citations directed to the company's own patents to the total number of citations (Trajtenberg et al., 1997). The lower the level of self-citation, the higher the risk of knowledge being copied by other patentees and used elsewhere, and therefore, the lower the return on innovation for the company. Joo and Lee (2010), Oh and Joo (2015), and Joo et al. (2016) show that the latecomers in their studies have overtaken the forerunners in terms of self-citations, and argue that the latecomers have achieved technological independence from their forerunners and that this can be seen as the latecomers' attempt to create technological pathways distinct from those of the forerunners to catch up.

Mutual citation is also used as a metric to observe the creation of technological pathways. Mutual citation shows the level of technological dependence of a firm on another firm and is calculated as the ratio of the number of citations directed to its competitor or forerunner to the total number of citations. When the latecomer cannot break free from the technologies of its forerunner or tries to imitate those technologies, it inevitably cites the forerunner's technologies in its patents; thus, the higher the level of technological dependence, the higher the mutual citation ratio. Joo and Lee (2010), Oh and Joo (2015), and Joo et al. (2016) report that the latecomers in their research reduced the numbers of citations directed to their forerunners and eventually were able to reduce the level of mutual citations to the level lower than that of the forerunners'. Based on this evidence, the studies suggest that the latecomers have achieved technological dependence and that this shows the latecomers' attempt to create alternative technological pathways to catch up.

Digital platform companies are usually able to scale their technologies to numerous other business and technological areas (Agyeman et al., 2021; Sukarmi et al., 2021). This phenomenon can also be observed in the six Chinese and U.S. firms of this study; although Google and Baidu began with their search engine platforms, Alibaba and Amazon with their e-commerce platforms, and Tencent and Facebook with their social media platforms, they all eventually sprawled out to many other business and technological areas. In this study, each Chinese firm is paired with a technologically similar U.S. firm that operate in similar business areas.

In this study, I examine the company profiles and history, as well as the metrics for the technological catch-ups and overtakes (such as the quality of patents, self-citations, and mutual citations), to assess the latecomers' creation of alternative technological pathways to catch up with the forerunners and how such results are reflected in the market performance indicators. I also show how the latecomers of this study are utilizing scientific literatures to avoid IPR disputes with the forerunners and whether they are using technologies with short cycle times to seek niches and compete with the forerunners.

1) Hypothesis for Baidu's technological pathways

Baidu is a Chinese digital platform company with search engine as its core business area. Baidu ranks third in the global search engine market and first in the Chinese market with a share of 78%. Baidu was the first among Chinese companies to be included in the NASDAQ-100 index, and has market capitalization of approximately 42 billion U.S. dollars and revenue of approximately 17 billion U.S. dollars as of 2023.

Baidu's roots can be traced back to RankDex, a search engine developed by Robin Li, who was then employed at IDD Information Services in the U.S. and working on developing a better search algorithm. RankDex was released in 1996, which predates Google's PageRank by two years. Baidu was later founded and incorporated by Robin Li and Eric Xu in 2000, and began using advertising as its primary source of revenue in 2001.

Baidu provides a diverse set of services based on information technology and specializes in Chinese language-based search engine technology and providing local information. Baidu offers maps and navigation services within China through Baidu Maps; cloud storage services through Baidu Wangpan; news through Baidu News, knowledge and experience platform through Baidu Knows; translation services through Baidu Translate; social media through Baidu Space; and web browsers through Baidu Browser, among others. Baidu invests in a wide array of technologies including self-driving technology and artificial intelligence (AI). With the support of the Chinese government, Baidu showcased its autonomous buses with test drives in several Chinese cities. Baidu is also active in the AI arena with 7,000 AI-related patents in China alone, making it the largest number of AI-related patents owned by a single company in China. Baidu also provides an open-source deep learning platform named PaddlePaddle, which is used by more than 84,000 companies. In 2014, Baidu appointed Dr. Andrew Ng, one of the most prominent AI scholars globally, as chief scientist.

Google is a multinational digital technology and platform company based in the U.S. and conducts business in diverse areas such as online advertising, search engines, cloud computing, artificial intelligence, and many more. Google was officially founded in 1998 by Larry Page and Sergey Brin, but its roots can be traced back to 1996 when the two founders and Scott Hassan developed the PageRank algorithm as part of a research project. Initially, Page and Brin opposed the idea of hosting advertisements on their website to generate revenue; in 2000, however, Google began having advertisements in the search outputs, and advertisements remain the primary source of revenue for Google to this day. Google became the primary search engine for Yahoo! in the same year, and by 2011, Google was processing approximately 3 billion searches per day. As the number of unique users per month exceeded 1 billion, Google built 11 data centers around the world to handle the workload. Google dominates the search engine market with 91.9% share of the global market, with annual revenue of 278.1 billion U.S. dollars and market capitalization of 1.396 trillion U.S. dollars.

Google's history of expanding into a wide range of businesses include acquiring key companies in the industry. Google acquired Android, a mobile operating systems company, in 2005, and YouTube, a video sharing platform, in 2006; these two areas still remain Google's core business areas. In 2011, Google acquired Motorola Mobility to bolster its mobile phones and wireless technology business, and in 2013, Google also acquired Waze to strengthen its GPS-based navigation technology. Google also acquired DeepMind Technologies in 2014, further expanding its portfolio in AI and robotics technologies.

In 2015, Google established Alphabet Inc. as its parent company and restructured its various interests and technologies, resulting in a narrower scope of technology for Google and greater autonomy for its subsidiaries in other businesses. Along with technological areas that Google operates in, Alphabet now encompasses a far wider range of technologies, including self-driving cars, artificial intelligence, drone-based logistics, drug discovery, robotics, and healthcare, through its other subsidiaries. Google, being the largest subsidiary of Alphabet, provides services not only in search engine and online advertising but also in email (Gmail), maps (Google Maps), cloud storage (Google Drive), online word processor (Google Docs), translation (Google Translate), video sharing and streaming (YouTube), mobile operating services (Android), web browser

(Google Chrome), cloud computing (Google Cloud Platform), laptop (Chromebook), and many more, to consumers and business customers across the globe and sectors.

Recent market performance results show a significant gap between Baidu and Google in terms of the size of revenue, net profit, and market capitalization. Google also overshadows Baidu in terms of most market indicators, including the global search engine market share. Nevertheless, they are operating in similar business areas and technological fields. They both have search engine services as their core business, derive a significant portion of revenues from online advertising, provide a similar range of services such as maps and cloud computing, invest in a similar set of technologies such as autonomous vehicles, and are active in the international artificial intelligence community (Rikap and Lundvall, 2021). I thus hypothesize as follows, based on the similarities in their business areas and technology portfolios:

> **(Hypothesis 1)** Baidu, the latecomer, would not have created a technological pathway distinct from that of Google, the forerunner, if it has not caught up with or overtaken Google.

2) Hypothesis for Alibaba's technological pathways

Alibaba is a Chinese multinational technology company centered around e-commerce business. Alibaba also operates in diverse business areas outside of e-commerce, such as electronic payments, cloud computing, and artificial intelligence, to name a few. Alibaba's market capitalization is 213.7 billion U.S. dollars as of 2023; in 2022, Alibaba recorded a revenue of 134.5 billion U.S. dollars. Alibaba was listed on the New York Stock Exchange in 2014.

Jack Ma, Alibaba's founder, established a Chinese translation company in 1994 when he first learned of the internet. In 1995, Jack Ma and his friend built a website that provided information about China and generated about 640,000 U.S. dollars in revenue over three years. From 1998 to 1999, Jack Ma managed an information technology firm established by the Chinese government; in 1999, he quit his job to establish Alibaba with his friends.

Alibaba began as an online business-to-business (B2B) marketplace, mostly targeting small and medium-sized businesses in China. Three years after establishment, Alibaba recorded its first net profit. Alibaba expanded into consumer-to-consumer (C2C) business in 2003 by launching Taobao Marketplace, an online e-commerce platform that facilitate C2C retail. Online advertising quickly grew as a major source of revenue for Alibaba, comprising 75% of Alibaba's total revenue in 2009. After initial success, Alibaba went on to launch assorted types of online marketplaces, such as

Taobao Mall (platform for global brands), Juhuasuan (marketplace offering flash sales), and AliExpress.com (online retail service selling products offered by Chinese small businesses), among others. Alibaba also expanded into offline retail business by launching Hema, a supermarket chain, in 2017 and acquiring a majority stake in Sun Art, China's biggest hypermarket operator, in 2020.

Alibaba's expansion was not limited to retail businesses; in 2009, Alibaba established Alibaba Cloud, which enabled Alibaba's data-based e-commerce technologies and led to services such as AliOS, a mobile operating system, and AliGenie, an intelligent personal assistant. Alibaba rose to fame in the electronic payments business with the launch of Alipay, an online payment platform that eventually seized about half of China's electronic payments market in 2014. Alipay was spun off from Alibaba in 2010 and rebranded as Ant Financial Services (now Ant Group) in 2014; in 2022, Ant Group was the second largest financial services globally after Visa and the largest in China.

Alibaba has also been active in the entertainment industry, launching platforms for online ticket sales, live events, and music streaming. In addition, Alibaba acquired controlling stakes in Youku Tudou, an online video broadcasting service, and ChinaVision Media Group, a Chinese film company. It continues to sprawl into diverse business areas, such as instant messaging service, mobile search engine, collaboration tools, and emails.

Amazon.com is an American digital platform company providing services such as, but not limited to, e−commerce, online advertising, artificial intelligence, and cloud computing. Amazon began as an online bookstore but later expanded into other business and technological areas ranging from traditional retail and logistics to entertainment and mass media. Amazon recorded an annual revenue of 513.9 billion U.S. dollars in 2022, and its market capitalization as of 2023 is 1.47 trillion U.S. dollars.

Amazon was founded by Jeff Bezos in 1994 and began its operation as an online bookstore from Bezos' personal garage. Within two months of launching the service, Amazon expanded its business to 50 U.S. states and 45 countries and recorded weekly revenue of $20,000. Amazon went public in 1997, and announced its plans to expand its range of products. Amazon currently ships to more than 100 countries, handles about 2.2 billion users per month, and provides Amazon Prime membership services to over 200 million members worldwide.

Amazon evolved from being an online bookstore to hosting a wide array of services such as Amazon Prime, a membership subscription with a flat annual fee, and Fulfillment by Amazon, a platform connecting small businesses and customers. Amazon also expanded into offline retail business; in 2015, Amazon opened a physical bookstore, and in 2017, acquired Whole Foods Market, a supermarket chain in the U.S. In 2018, Amazon showcased Amazon Go, a supermarket with unmanned payment technology; in 2020, Amazon Fresh, which was only provided as an online service, was opened as physical stores that integrated novel technologies such as smart shopping carts. In 2022, Amazon launched Amazon Prime Air, a drone-based logistics service, and established itself as a pioneer in applying technological innovations in what have traditionally been brick-and-mortar industries, such as retail, sales, and logistics.

Amazon entered the cloud computing industry in 2002 by establishing Amazon Web Services and currently enjoys being the most dominant cloud computing business in the world. Amazon has been active in the hardware business as well, through the launches of Kindle, an e-book reader, and Amazon Echo, a wireless speaker and voice command service enabled by intelligent personal assistant Alexa. Amazon entered the entertainment and arts industry with services such as Amazon Prime Video and Amazon Music and acquisitions such as Twitch, an online video game live streaming service, and Metro-Goldwyn-Mayer Studios. Through its services and subsidiaries, Amazon is also investing in areas such as self-driving cars, computer hardware, and healthcare technologies.

Alibaba and Amazon generally operate in similar business areas, but differences between the two firms certainly exist. While Amazon's e-commerce business primarily consists of Amazon making purchases from the sellers and selling directly to its customers, Alibaba's e-commerce services are mostly marketplaces that provide platforms for small businesses and customers to interact with each other, from which Alibaba collects commission fees. Amazon's physical store operations began to take off in 2017 when it acquired Whole Foods Market; by that time, Alibaba had already expanded into 13 physical stores across Beijing and Shanghai with Hema, as well as providing unmanned convenience stores and marketplaces in rural areas through more than 30,000 physical Taobao stores.

Though Alibaba has been showing both quantitative and qualitative edge in the physical store business, Amazon has made much more progress in the logistics business; Amazon has established its own logistics network and warehouses, whereas Alibaba is currently on its way to expand its own smart logistics network that would enable deliveries within 24 hours to anywhere in China and within 72 hours to anywhere in the world.

Alibaba's progress in the financial services far outpaces that of Amazon. Amazon is implementing Amazon Pay, an online payment service, and Amazon Lending, a financing product for small businesses, but they are no match to Alibaba's electronic payments successes, with Alipay being one of the largest electronic payment services in the world, and other financial products with total sales figures larger than those of many traditional banks and financial institutions. In 2017, Wall Street Journal reported that the deposited assets of Yu'ebao, Alibaba Group's money market fund, increased to 211 billion U.S. dollars and became the world's largest in just four years.

Amazon is dominating the global market in the cloud computing business with its Amazon Web Services. Though the gap with Amazon persists, Alibaba is also active in the arena and dominates the Chinese market. Alibaba, along with SoftBank, established SB Cloud and expanded its cloud computing business into Japan. Amazon is also known to enhance its various services with big data, integrating the data it collects from the customers and their behaviors into its AI–based algorithms; Alibaba has similar approaches with its data and AI.

Amazon and Alibaba exhibit similarities across different business and technological areas, such as e–commerce, physical stores, logistics, AI, and big data, but each with varying degrees of advancements. Based on the many similarities between the two companies, I hypothesize the relationship between market performances and Alibaba's creation of technological pathways to catch up with Amazon, the forerunner, as below:

(Hypothesis 2) Alibaba, the latecomer, would have created a technological pathway distinct from that of Amazon, the forerunner, to catch up with or overtake Amazon.

3) Hypothesis for Tencent's technological pathways

Tencent is a Chinese technology and entertainment company. WeChat, an instant messaging application, is one of its most well–known products; it is also known as the largest video game company in the world. Tencent's business areas comprise not only video gaming and instant messaging but also artificial intelligence, cloud computing, search engines, music, and movie production, to name a few. As of 2021, Tencent's revenue was 86.24 billion U.S. dollars and net profit was 35.32 billion U.S. dollars; as of 2022, its market capitalization was 435.62 billion U.S. dollars.

Tencent is a digital platform company founded on the 11th of November, 1998, by Pony Ma and Tony Zhang. Tencent began as a venture company supporting pager-related technology to overseas companies, which was one of the most effective business items for Chinese technology venture firms at the time. Tencent rose to fame with OICQ, an instant messenger; in 2001, OICQ was renamed QQ messenger and recorded 50 million cumulative users. In 2002, the record jumped to 100 million, and QQ began to emerge as the most widely used messenger in China. Tencent was able to take advantage of the business opportunity in the early phase of the internet-based content market in China.

After the rapid growth in the messenger-based internet content business, Tencent entered the entertainment industry in August 2003 by launching the internet-based video game platform QQ Games, which eventually recorded 200 million cumulative users. In 2007, Tencent established the Tencent Research Institute to conduct research on topics such as information security, intellectual property, and entertainment technologies and businesses. While Tencent has expanded into numerous areas such as transportation, travel, music, healthcare, finance, and electronics, games and media remain its core business area; this, in part, stems from the Chinese government's decision in 2012 to officially recognize and support the entertainment industry as part of China's cultural industry.

Tencent's rapid growth in international expansion began in 2010;

in April, it invested 300 million U.S. dollars in DST, and in June, it signed an MOU with Cisco, an American communications technology company. Tencent has continued to invest in and acquire a multitude of companies overseas; notable cases include the acquisition of Riot Games in 2011 and Supercell in 2016.

Facebook is an American digital platform company providing Facebook is an American digital platform company providing social media services to more than 1.9 billion users worldwide. Facebook began exclusively as a social media company; its business areas now include artificial intelligence, cryptocurrency, and virtual reality. In 2021, it recorded revenue of 117.929 billion U.S. dollars and net profit of 39.37 billion U.S. dollars; in July 2022, its market capitalization was 433.09 billion U.S. dollars. It changed its name from Facebook to Meta Platforms, Inc., but maintains the names of its core services, such as Instagram, WhatsApp, and Facebook, and its corporate structures.

Facebook was born as a test service named FaceMash on 28 October 2003 by Mark Zuckerberg, a then–sophomore at Harvard. Joined by Dustin Moskovitz, Andrew McCollum, Chris Hughes, and Eduardo Saverin, Zuckerberg expanded the service as The FaceBook on 4 February 2004; the service was later renamed Facebook in 2005. At its beginning, FaceMash was only serviced to Harvard students; after a month of launch, the service was expanded to the students of Columbia University, Stanford University, and Yale University, and to the students of 800 universities and high schools, and eventually to the general public, gathering more than 6 million cumulative subscribers. The service initially only featured a simple guestbook function; many more features were added later, especially in 2006 when it launched the mobile version with the news feed feature that allowed the users to view all their friends' activities within a single page. After the launch of the mobile version, Facebook gathered more than 12 million cumulative users. The number of users continued to increase with the network effect, and Facebook saw an explosive increase in overseas subscribers after removing the membership registration condition. In 2008, Facebook set up its first international headquarters and began structuring its business model around online advertising.

Facebook continued to add more features to its service, and the number of users steadily increased. Facebook recorded 145 million cumulative users in 2008. In 2009, Facebook added the ‘like’ feature and recorded 360 million cumulative users. In 2010, Facebook began collecting users’ location data with features such as social graphs, open graphs, and social plugins and built data centers to support its operation. In 2011, timeline feature was added, enabling users to stay connected to real-time updates of their friends and laying the foundation of Facebook’s ambition to eventually build a metaverse of social network. In the fiscal year of 2021, Facebook reported having 1.929 billion daily users for the fourth quarter, a 1 million decrease from the 1.930 billion recorded in the third quarter. This was the first-ever decrease in the number of daily users Facebook has registered; while the number of daily users for the Asia Pacific region increased during this period, the number decreased for the North American region, Facebook's core market. Facebook has increasingly faced competition from other social media services such as TikTok and Snapchat and has begun losing younger demographics. Since 2012, Facebook has shown a steady decline in the number of users aged 18 to 24; according to a 2021 survey, younger Americans were mainly using Instagram and Snapchat as their primary social media, and only 27% responded that they were using Facebook.

Both Tencent and Facebook were founded as social media companies but distinct initial approaches to their businesses set them apart as they expanded and diversified (이승훈, 2019). Tencent began with an instant messaging application and expanded into other businesses through the app; Facebook focused on enabling the users to share their stories openly and later on evolved into the distributor of contents through features such as news feeds (이승훈, 2020). The difference in the technological and business areas has been amplified through their constructions in business portfolios and diversification strategies. Tencent provides a wide range of services such as social media, games, online advertising, electronic payments, ride-sharing, and food deliveries through its core service WeChat. In 2020, Tencent was reported to have the largest share in China's social media and games markets and the second largest share (40%) in the mobile payments market (易观, 2021). In contrast, Facebook has separated its various business areas and services such as Facebook, Instagram, WhatsApp, and Facebook Reality Lab, and online advertising is its major source of revenue. The two companies show mixed levels of success in market performances across different time points. Based on the similarities in the business and technological areas between the two companies, I hypothesize the relationship between market performances and Tencent's creation of technological pathways to catch up with Facebook, the forerunner, as below:

> **(Hypothesis 3)** Tencent, the latecomer, would have created a technological pathway distinct from that of Facebook, the forerunner, to achieve its catch-up or overtake.

4) Hypothesis on the cycle times of the latecomers' technologies and the latecomers' dependence on scientific literature

Latecomers frequently strategize with the cycle time of the technology they use and the level of dependence on scientific literature when they develop new technologies. The cycle time of the technology being used reflects the recency of the technologies that the company relies on (Narin, 1994) and is calculated as the difference between the patent's filing date and the filing dates of the patents being cited (Hall, Jaffe, and Trajtenberg, 2001). This shows the amount of time between the company's patent and the patents being used and measures the average cycle time of the technology that the company uses. Joo and Lee (2010) compare Samsung and

Sony and show that Samsung utilized technologies with shorter cycle times than those of the technologies that Sony used in the 2000s. Oh and Joo (2015) report that Hyundai Motors used technologies with much longer cycle times than those of the technologies that Mitsubishi Motors used in the 1990s when Hyundai was still a latecomer, but Hyundai significantly reduced the gap in the cycle times of technologies with Mitsubishi in the late 2000s. Joo et al. (2016) show that using technologies with shorter cycle times was one of the key strategies for Huawei, the latecomer, to catch up with Ericsson, the forerunner.

When a company cites scientific literatures in its patents, it demonstrates its ability to use basic sciences to create new technologies. Scientific literature citations have also been one of the ways for companies to circumvent intellectual property right (IPR) disputes with other companies. Oh and Joo (2015), in their study on Hyundai and Mitsubishi, show that Hyundai, the latecomer, began increasing its scientific literature citations in the early 2000s and surpassed those of Mitsubishi in the late 2000s, indicating its successful construction of technological foundations. Joo et al. (2016) report similar results in the case of Huawei and Ericsson, showing that Huawei, the latecomer, made more scientific literature citations than Ericsson. Park and Lee (2015) argue with evidence that the latecomers utilize not only patents but also scientific literatures as sources of knowledge in the field with rapid technological changes.

(Hypothesis 4) When the latecomers attempt to catch up with or overtake the forerunners, the technologies that the latecomers use would be more recent than those that the forerunners use.

(Hypothesis 5) When the latecomers attempt to catch up with or overtake the forerunners, they would have a larger number of scientific literature citations than the forerunners.

Chapter III. Methodology

A growing body of work presents diverse strategies to quantify and measure the overall technological capabilities of a company, mainly through the analyses of data such as R&D expenditures, patent records, and new product statistics (Schoenecker and Swanson, 2002). Among these, patent records are known to provide a wide range of information on the company's innovative endeavors, such as, but not limited to, the technology field of the patent, patent application time and country, and the number of citations and references that a patent has made. Studies have shown that patent data is a useful and reliable source of information for the analysis and evaluation of a company's technological capabilities (Narin et al., 1987; Patel and Pavitt, 1997). In this work, I leverage the patent data from the European Patent Office (EPO) to analyze the technological catch-up and overtake of the three Chinese digital platform companies with their U.S. counterparts. In particular, I utilize the patent data to examine the technological catch-up in terms of the quality and quantity of the patents, technological independence and dependence, niche-seeking behaviors, and citations of scientific literatures in the development of new technologies, and discuss the results and implications with the estimations from regressions. In calculating and deriving such indicative metrics from the patent data, I draw on the methodologies developed by prior literatures in the area of technological catch−up, innovation, and patent analysis (Joo and Lee, 2010; Oh and Joo, 2015; Park and Lee, 2015; Joo et al., 2016; Frietsch et al., 2010).

1. Technological proximity

To ensure that the two companies being compared to each other are operating in a similar technological field and are thus comparable in terms of technological innovations and catch−ups, I make use of the theory that the larger the overlapping technological area between the two companies, the higher the level of competitions between the two (Podolny et al., 1996).

Technological proximity of the two firms can be calculated using the technological field information in the patent data (Jaffe, 1986), with a higher value implying that the two companies are in similar technological fields, and therefore, in competition with each other. Mathematically, technological proximity of firm i and j is defined as follows:

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

where:

P_{it} is the proportion of firm i’s patents in the technological field t among all its patents

T is the total number of technological fields

Technological proximity takes on a value between 0 and 1, and the closer the value is to 1, the larger the size of overlaps of technological fields that the two companies operate in. Specifically, a high value of technological proximity in this equation denotes a high similarity in the distributions, as derived from the Cauchy–Schwarz inequality, of the patent portfolio over all available technological fields.

The calculations of the technological proximity between the Chinese and the analogous U.S. companies are presented in Table 3–1. Calculations are based on the three sources of patent data - EPO, USPTO, and CNIPA - and while all three sources result in similarly high levels of technological proximities between the two companies, values from the USPTO and CNIPA are not used in establishing technological proximity, as different forms of biases that could affect the corporate R&D practices might be present in the home countries of the companies. In fact, evidence of potential biases can be seen through the fact that the number of patents applied by the firms with the patent office of their home countries over the years of investigation far surpasses the number of patents applied by the counterpart firms with the same office, and vice versa.

Almost all figures from the EPO data have values around 0.9, indicating that all pairs of companies have been technologically homogenous to each other over this time period. Comparisons with previous literatures that used the same metric show that the value of around 0.9 for the technological proximity of two companies is substantially high and is an acceptable level to carry out any comparative studies. Therefore, any comparisons made in this context between the designated pairs in Table 1 are justified.

(Table 3-1) Technological proximity of U.S. and Chinese digital platform companies, over 10 years

	Baidu vs. Google	Alibaba vs. Amazon	Tencent vs. Facebook
EPO	0.889	0.968	0.903
USPTO	0.940	0.983	0.968
CNIPA	0.982	0.981	0.915

Table 3-2 dissects this metric even further, with separate calculations for the patents applied in the first 7 years of the study and in the last 3 years of the study. Such grouping of time period considers the fact that the duration between the filing and the grant of the patent is usually from a year to a year and a half, and that the patents in the latter three years having shorter time frame in which they can receive citations usually results in truncations of observations. In other words, the patents in the latter three years are largely grouped to distinguish the patents that spent majority of the study period getting examined by the patent office and did not have sufficient window of time to accumulate stationary number of citations. This method of dividing the 10-year time period into the first seven and the last three years is used consistently throughout this study, including as a dummy variable in regressions.

(Table 3-2) Technological proximity of U.S. and Chinese digital platform companies, divided by first 7 years and last 3 years

	First 7 years	Last 3 years
	Baidu vs. Google	Baidu vs. Google
EPO	0.962	0.786
USPTO	0.972	0.905
CNIPA	0.979	0.980
	Alibaba vs. Amazon	Alibaba vs. Amazon
EPO	0.980	0.925
USPTO	0.988	0.966
CNIPA	0.983	0.949
	Tencent vs. Facebook	Tencent vs. Facebook
EPO	0.903	0.860
USPTO	0.965	0.946
CNIPA	0.874	0.819

All the values in the table are around 0.8-0.9, indicating that the technological proximity has been well maintained over the 10 years of study, although slight decrease in values can be observed for the last 3 years compared to the first 7 years. Additional examinations into each technological field on the patent data reveal that the companies have been strategically concentrating on some of the key technological fields and increasing diversifications in some others. For example, in the last 3 years of study, Baidu has been focusing on filing the patents related to transportations and autonomous vehicles and collaborating with European firms, such as Continental and Bosch, that specialize in vehicles, machineries, parts, transportations, and logistics; this is also indirectly reflected in Table 3-2, in which the technological proximity calculated with EPO patent data for Baidu vs. Google in the last 3 years is noticeably lower than most other values.

2. Patent analysis

1) Technological pathways that the latecomer opts in to catch up with the forerunner

(1) Quality of the patent

A patent's worth as a technological asset is determined by the extent of its use and citation by other patents (Albert et al., 1991; Hall et al., 2005). The quality of the patent can be directly observed through the number of citations the patent has received. However, simply adding up the number of citations of a company can conflate a high number of low-quality patents with the quality of the patents being high. The formula below takes such consideration into account, and is used throughout this study to compare the aggregate quality of patents of a company across different years:

$$\text{Patent Quality}_i = \frac{\text{Total number of citations received by firm } i\text{'s patents}}{\text{Total number of firm } i\text{'s patents}}$$

(2) Self-citations

Firms that have attained a certain level of technological capability would inevitably utilize and combine their technologies from the past to develop a new set of technologies to minimize costs and stay competitive in the field. If a company already possesses useful technology to build upon, utilizing external knowledge protected by patents would be relatively more expensive and time-consuming, and will potentially result in less technological novelty. A higher frequency of such practices signifies a higher capability to create its proprietary technology; this is observed through the ratio of the patent citations directed to the patents that the company owns to the total number of citations its patents make.

$$\text{Technological Independence}_i = \frac{\text{Firm } i\text{'s citations directed to firm } i\text{'s patents}}{\text{Total citations in firm } i\text{'s patents}}$$

(3) Mutual citations

Latecomers commonly attempt to catch up with the forerunners by first learning and acquiring their technologies and eventually building upon the knowledge to develop and create newer and more innovative technologies themselves (Kim, 1980). Latecomers that lack the proprietary technology would have to continue relying on the technologies of the forerunners; conversely, latecomers' relying less on the forerunners' technologies would be a sign that the latecomers have developed enough capabilities to pave their own technological path. The technological dependence of a firm on another can be measured by the proportion of citations directed to the counterpart firm among all patent citations (Joo & Lee, 2010), as shown in the equation below:

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

2) Latecomer's strategies to seek niches and avoid IPR issue

(1) Cycle time of technology

The cycle time of the technology utilized by a company is a valuable piece of information describing the type of technology the company chooses to engage with. This is measured by the backward citation lag of a patent, which is the difference between the time of patent filing and that of patents being cited. A patent having a short cycle time means that the company has rapidly created a new technology based on a relatively recent patent. The cycle time of technology is calculated as below:

$$\mathrm{BWL}_i = \frac{\sum_{j=1}^{\mathrm{NCITING}_i} \mathrm{BLAG}_j}{\mathrm{NCITING}_i}$$

where:

$\mathrm{NCITING}_i$ is the total number of citations made by patent i

BLAG_j is the difference in the filing date between the patent i and the cited patent j

(2) Scientific literature citations

Companies frequently choose to use the findings and results presented in scientific publications, rather than the technologies protected by patents, as the basis of their innovations. These approaches allow the companies to break away from the technological ecosystem built by the forerunners and develop a more original and independent set of technologies. Such behavior can be measured by the number of citations made to scientific literatures.

3. Assessing the technological catch-ups and overtakes

1) Graphs

Graphs are constructed as supplementary visual tools to assess the technological catch-ups and overtakes in terms of general trends over the study period. The annual values of the metrics for each pair of companies are calculated and plotted as 3-year moving averages on the graph.

2) Regressions

Regressions are estimated to observe the effects of the forerunner/latecomer status on the patent-based metrics, adjusted for key covariates. The dependent variables are the quality of patents, self-citations, mutual citations, cycle time of technology, and scientific literature citations, and different regression models are used for each dependent variable. Poisson regressions are used for the quality of patents and scientific literature citations; fractional logistic regressions are used for self-citations and mutual citations; and linear regression is used for the cycle time of technology. A key interaction term between the forerunner/latecomer status and the time period (first 7/last 3 years) variable is used to determine the catch-up and overtake. Three different models are constructed to ensure the robustness of the model and to observe the individual effects of the variables. Three significance levels – 1%, 5%, and 10% – are employed in this study to determine statistical significance. The estimated model is specified as below:

$$y = \beta_0 + \beta_1 \text{Latecomer} + \beta_2 \text{Period} + \beta_3 \text{Latecomer} \cdot \text{Period} + \boldsymbol{X}'\boldsymbol{\gamma} + \epsilon$$

Chapter IV. Data

1. Data source

1) Patent data

In this paper, I draw on the EPO Worldwide Patent Statistical Database (PATSTAT), which contains data from around 90 countries worldwide for the patents that have been applied. Each patent record has bibliographic and legal details such as the application date, technological field, citation information, number of claims, and IPR type, among many others. The database consists of more than 100 million patent documents and maintains consistency across the records from different countries, proving to be a convenient and valuable tool for statistical analysis. Among the data spanning several decades, I limit my investigations to the 10-year period from 2010 to 2019.

PATSTAT comprises multiple data tables, each at different levels of information, such as patents, publications, and citations, that form a relational database altogether. For practical reasons involving its sheer size, the PATSTAT database is typically hosted in relational database management systems such as MySQL, where a relevant subset of data can be queried and manipulated. In this study, all the operations with data, including extraction, manipulation, and analysis, are done through RStudio with R and SQL, with the aid of the RMySQL package hosted by CRAN.

2) Suitability of EPO patents over PCT patents as the data source

Controlling for the heterogeneity between different regions or countries in patent analysis is crucial. Two different subsets of data can be considered - patents applied with Patent Cooperation Treaty (PCT) and patents applied with EPO - to achieve this at the data level and maintain homogeneity within the data. Through a single patent application, PCT assists with providing legal protections for the invention in all of its member states, whereas applying with EPO would do the same but for the European Union (EU) countries. Applying with PCT does not automatically grant the rights in all member countries; while a PCT application establishes a filing date in all the member countries, it needs to be followed up with separate processes in each country to be granted and ensured legal protections. Similar rules and procedures apply to the patents filed with EPO, but for the EU member states.

(1) Objectivity

To explore any potential issues with objectivity, I use PATSTAT to compare the two data sources and observe the descriptive figures, such as the number of patents, the overlap of patents between the two sources, and the region the patent belongs to. PCT data is shown to have a larger number of patents than the EPO data for the Chinese and U.S. digital platform firms of this study, except for Baidu. Baidu and Facebook each have 37% and 44% overlaps in their EPO patents with the PCT patents; all the other firms have around 90% overlaps. However, the percentage level does not hold in reverse; EPO patents only comprise a small percentage of the PCT patents, showing the strategic nature of the choice for the firms to apply their patents with the PCT. Further breakdown of the analysis into the three different regions - the U.S., China, and Europe - shows that both the PCT and EPO patents are influenced by the home country advantage bias in the U.S. and China but not in Europe. These results indicate that the differences in objectivity between using the PCT and the EPO patents are minimal and that the level of objectivity is ensured when limited to Europe, as they have a substantial amount of overlap in terms of the patents, and neither of them demonstrate any biases related to the firms' home countries. However, assessing the technological catch-up or overtake with the number of patents could be sensitive to the choice of the data source, as PCT generally has a higher number of patents. PCT is chosen strictly for the comparison of patent quantities only, as the larger sample size in PCT ensures a higher level of confidence in the analysis and better accentuates the changes and the trends in the technological catch-up.

(2) Homogeneity and consistency

Ensuring objectivity in the data is not enough; the data also needs to be homogenous to meet the conditions of the regressions. While both PCT and EPO do not display any signs of home country advantages in Europe in Table 4-1, PCT fails to meet the condition of homogeneity as the companies must go through separate processes to have their patents granted, thus introducing the element of heterogeneity in the data. In this sense, EPO patents are considered to meet the requirements for the analyses as they are managed and evaluated by the same system consistently within its region (i.e., Europe). (Frietsch et al., 2014). Consequently, this study uses the EPO data in estimating the regressions to maintain objectivity, homogeneity, and consistency in the results.

(Table 4-1) Annual number of patents applied, by patent office and company

	Patent office	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Google	EPO	195	261	419	583	539	499	866	605	592	264	4,823
	USPTO	966	2,629	4,028	3,823	2,948	2,300	2,388	2,250	1,458	1,431	24,221
	CNIPA	86	88	203	418	416	446	807	615	509	150	3,738
Baidu	EPO	0	0	4	6	66	77	42	58	63	227	543
	USPTO	0	0	9	9	94	129	199	261	519	646	1,866
	CNIPA	194	370	833	792	1,053	1,446	1,332	1,605	3,014	2,943	13,582
Amazon	EPO	38	43	86	70	176	121	123	114	69	12	852
	USPTO	605	771	1,237	1,642	2,047	2,105	1,776	1,665	1,193	693	13,734
	CNIPA	28	26	29	22	98	55	78	92	59	7	494
Alibaba	EPO	68	51	67	59	57	147	210	276	307	173	1,415
	USPTO	67	50	80	123	139	290	322	357	606	801	2,835
	CNIPA	152	423	539	426	1,378	2,783	2,901	2,418	4,411	3,058	18,489
Facebook	EPO	5	13	24	66	93	40	61	70	109	32	513

	USPTO	122	267	648	485	670	792	1,015	1,363	893	693	6,948
	CNIPA	3	11	33	57	89	28	47	66	89	50	473
Tencent	EPO	6	39	62	158	13	37	57	108	130	93	703
	USPTO	40	52	117	427	705	577	331	419	524	616	3,808
	CNIPA	509	926	2,086	2,391	2,137	1,811	2,668	2,606	2,964	5,180	23,278

2) Variables

As mentioned in the previous section, the analysis targets the 10-year period from 2010 to 2019 and uses the PATSTAT data. Application dates are used for any date-based categorizations and calculations. Descriptive statistics of the variables used in this study are shown in Table 4-2.

The five dependent variables are defined as follows. Quality of patent is the number of citations the patent has received, represented by non-negative integers. Self-citation is treated as a ratio of the number of patent citations directed to the patents of the same company to the total number of citations that the patent has made. Likewise, mutual citation is defined as the ratio of the number of patent citations directed to the patents of the counterpart firm to the total number of citations that the patent has made. Cycle time of technology is a positive real number representing the average time differences, in years, between the filing times of the patent and the cited patents. Scientific literature citations are non-negative integer values of the number of citations the patent has made to scientific literatures.

The independent variables in the regressions are as follows. The latecomer/forerunner status of the company that filed the patent is constructed as a dummy variable, with 0 for the U.S. firms and 1 for the Chinese firms. The time period is also a dummy variable, with 0 for the first seven years (2010–2016) and 1 for the later three years (2017–2019); the rationale for such characterization of the time period variable is as explained in the previous chapter. These variables also form an interaction variable so that catch-ups and overtakes of the latecomers can be assessed through the model.

Each covariate controls for the factors that could influence the value of the patent in other ways (Frietsch et al., 2010). The sum of the firm's patent stock and the sum of the counterpart firm's patent stock are each included as covariates to control for the increase in the number of citations received made from factors other than the quality of the patent itself, such as the patent gaining citations as the number of patents in the field simply grows - as well as to account for the different magnitude and directions of the effects they would each have on the dependent variables. The family size variable controls for the number of countries that the patent is filed with; the number of inventors variable controls for the number of inventors that contributed to the patent; the maximum number of claims variable controls for the number of patent claims; the number of forward citations variable controls for the number of citations the patent makes; the number of backward citations variable controls for the number of citations the patent receives; the number of IPC classes variable controls for the number of distinct IPC classes, categorized by the full IPC symbols down to the subgroup level; and the technological field dummy variables control for the technological field(s) that the patent belongs to.

(Table 4-2) Descriptive statistics for PATSTAT, 2010-2019, n=8,849

Variable	Mean	Std. Dev.	Min	Max
latecomer (0: US, 1: China)	0.3007	0.4586	0	1
period	0.6269	0.4837	0	1
quality of patent	0.1741	1.1816	0	57
self-citation ratio	0.0949	0.1952	0	1
mutual citation ratio	0.0040	0.0379	0	1
cycle time of technology	6.5097	3.9011	0	98.56
scientific literature citation	0.8472	1.6612	0	56
Sum of patent stock (self, unit: 100)	6.7864	8.2271	0	45.92
Sum of patent stock (counterpart, unit:100)	2.0514	4.4838	0	48.27
Family size	6.9597	4.8224	1	64
No. of inventors	3.1969	2.3655	0	25
No. of claims (Max)	7.6851	8.3957	0	120
No. of forward citations	0.1741	1.1816	0	57
No. of backward citations	4.9874	3.4526	0	38
No. of IPC classes	3.0493	2.2244	1	22
2010 dummy	0.0353	0.1844	0	1
2011 dummy	0.0460	0.2095	0	1
2012 dummy	0.0748	0.2631	0	1
2013 dummy	0.1065	0.3084	0	1
2014 dummy	0.1067	0.3087	0	1
2015 dummy	0.1041	0.3054	0	1
2016 dummy	0.1536	0.3606	0	1
2017 dummy	0.1391	0.3461	0	1
2018 dummy	0.1435	0.3506	0	1
2019 dummy	0.0905	0.2869	0	1
technology field 01-35	-	-	0	1

Chapter V. Analysis of patent data for target firms

1. Baidu's catch-up with Google

1) Patent analysis for Baidu and Google

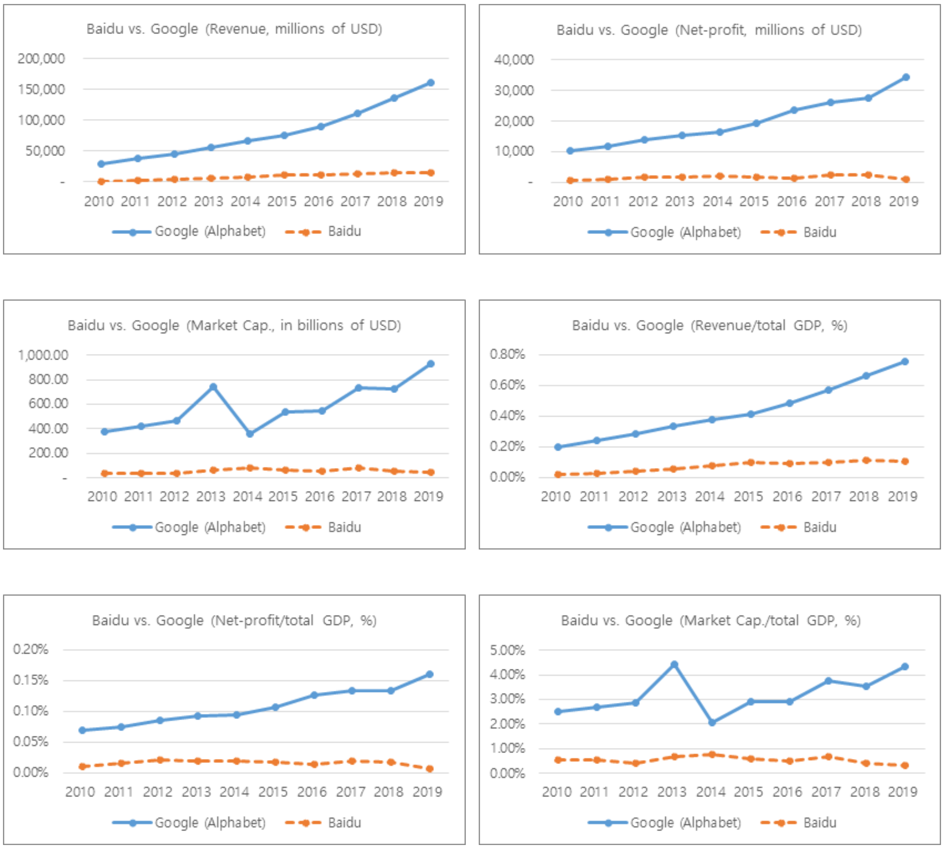
(1) Market performance of Baidu and Google

Baidu and Google owe much of their growth to their web search services. Figures 5-1 to 5-6 present and compare the growth and expansion of Google, the forerunner of this study, and Baidu, the latecomer, in terms of key market performance metrics over the ten years from 2010 to 2019. The two search engine companies are two of the most successful companies in their business area worldwide, with Google and Baidu each taking up the largest and the third largest share of the market respectively; they are also the most dominant search engines in their respective home countries. In this section, I examine the catch-up and the overtake of the latecomer in terms of market performances prior to examining the phenomenon in terms of technological innovations.

Figures 5-1 to 5-3 portray the nominal yearly trends for revenue, net profit, and market capitalization; Figures 5-4 to 5-6 normalize the same figures as their proportions in the total GDP of the companies' respective home countries. The former allows direct comparisons in the size of the metrics without ignoring the size of their respective home markets; the latter accounts and controls for the size of the markets and economic growths of the respective countries in comparing the market performances.

Results show that Baidu lagged behind Google in all three nominal-valued metrics, and the gap between the two were even greater with normalizations throughout the study period.

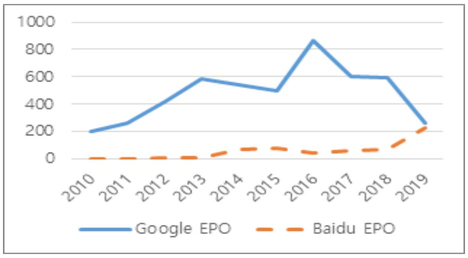
(Figures 5-1 to 5-6) 1. Top left: Comparisons of Baidu's and Google's annual revenue (in millions of U.S. dollars); **2. Top right**: Comparisons of Baidu's and Google's annual net profit (in millions of U.S. dollars); **3. Middle left**: Comparisons of Baidu's and Google's average annual market capitalization (in billions of U.S. dollars); **4. Middle right**: Comparisons of Baidu's and Google's annual revenue, normalized (in percentages); **5. Bottom left**: Comparisons of Baidu's and Google's annual net profit, normalized (in percentages); **6. Bottom right**: Comparisons of Baidu's and Google's average annual market capitalization, normalized (in percentages)

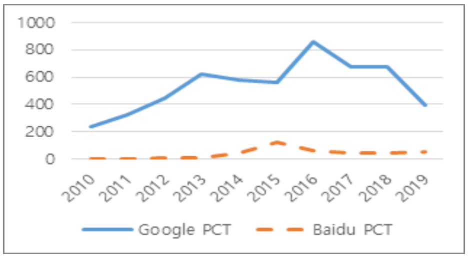


Figures 5-7 and 5-8 report the yearly numbers of patent applications based on the EPO and the PCT data. As mentioned previously, PCT captures a larger number of patents than EPO without loss of objectivity; hence, I use the figures from PCT to assess the technological catch-up in terms of the numbers of patents.

While Baidu did not display the signs of market catch-up in previous figures, it slightly narrowed the gap with Google in terms of number of patent applications with PCT, as seen in Figure 5-8. Previous literatures such as Joo and Lee (2010) and Joo, Oh, and Lee (2015) demonstrate that the latecomer overtakes the forerunner with the number of patents before overtaking with the market performances; such results are not observed in this case of Baidu and Google.

(Figures 5-7, 5-8) 7. Left: Comparisons of Baidu's and Google's quantity of patents (EPO patents, 2010-2019); **8. Right**: Comparisons of Baidu's and Google's quantity of patents (PCT patents, 2010-2019)





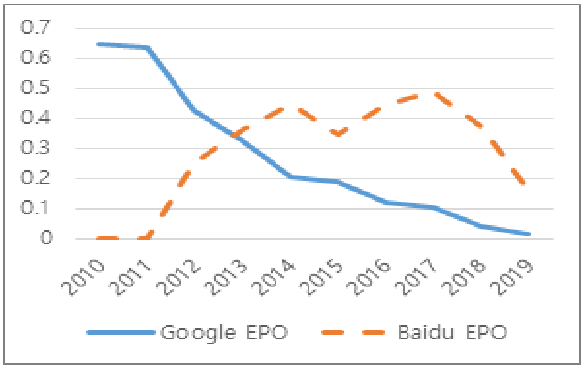
(2) Baidu's technological pathways

A. Quality of patents

Figure 5-9 presents the yearly quality of the patents Baidu and

Google filed with EPO from 2010 to 2019. Google's patents are of higher quality in the earlier years of the study period; Baidu overtook Google in 2013 and maintained a higher quality with its patents until the end of the study period. Both companies experienced decreases in their quality of patents at the end of the study period, but this warrants some cautions in interpretations as patents that are more recent suffer from lack of sufficient time to be cited by other patents, which may result in a decrease in the number of citations received regardless of the actual quality.

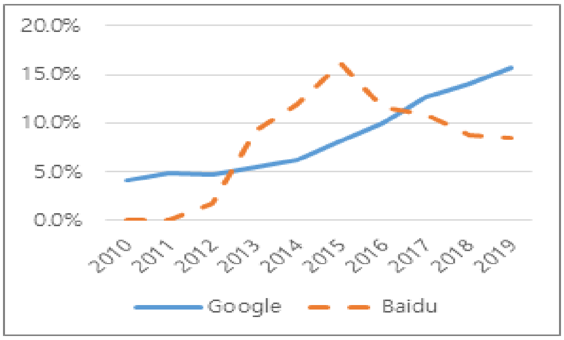
(Figure 5-9) Quality of patents, Baidu vs. Google (EPO patents, 2010-2019)



B. Self-citations

Figure 5-10 shows the ratio of the citations directed to the companies' own patents over the total number of citations over the 10 years. Baidu's self-citation ratio rapidly increased in the first half of the study period, overtaking Google at around 2012, followed by a marked decrease until the end of the study period, re-overtaken by Google with its consistent increase in the self-citation ratio throughout the study period. In sum, Baidu has not caught up with or overtaken Google regarding self−citations during this period.

(Figure 5−10) Self−citation ratio, Baidu vs. Google (EPO patents, 2010−2019)

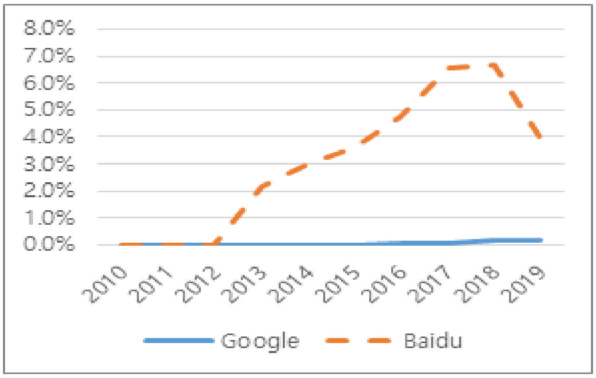


C. Mutual citations

The ratio of mutual citations in this study shows how much the company relies on the counterpart firm when developing new technologies. A decrease in the latecomer's ratio of mutual citations signals that the latecomer is accumulating technological expertise and is on their way to catching up with the forerunners. The latecomer is said to have overtaken the forerunner if the latecomer's ratio of mutual citations is lower than that of the forerunner.

Figure 5−11 plots the yearly ratio of mutual citations for the 10 years. Google's ratio of citations to Baidu's patents has been negligible throughout the study period, showing how little Google relied on Baidu's technologies. Baidu relied significantly more on Google than the other way around, although the ratio of mutual citations decreased for Baidu in the later years. While Baidu remained dependent on Google's technologies throughout the study period, it has been catching up with Google by lowering its ratio of reliance.

(Figure 5-11) Mutual citation ratio, Baidu vs. Google (EPO patents, 2010-2019)

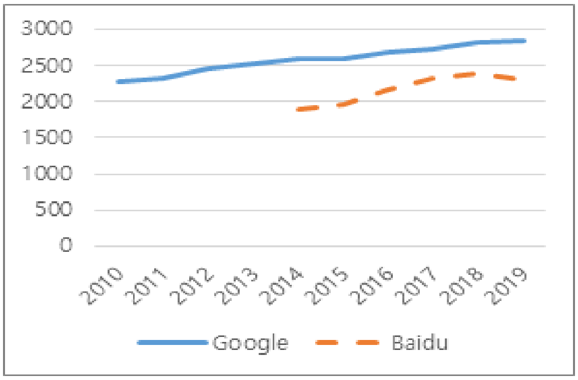


(3) Baidu's strategies to seek niches and avoid IPR issue

A. Cycle time of technology

Figure 5-12 shows the cycle time of the technologies that Baidu and Google utilized in the 10-year period. The cycle time of Baidu's technologies has been consistently shorter than Google's throughout the time period. Both firms leaned towards technologies with longer cycle times over the years, with Baidu maintaining shorter cycle times until the end.

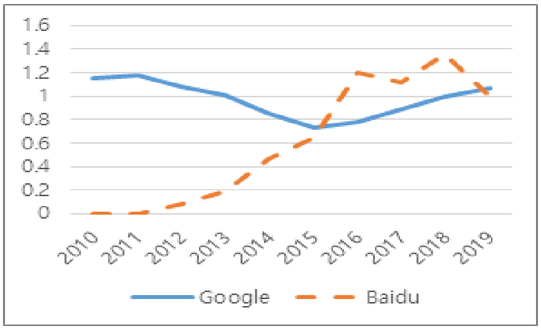
(Figure 5-12) Cycle time of technology, Baidu vs. Google, in days (EPO patents, 2010-2019)



B. Scientific literature citations

Figure 5-13 portrays the trends in the citations of scientific literatures over the years for Baidu and Google. Google led in the number of scientific literature citations at the beginning of study period, but Baidu quickly narrowed the gap and overtook Google. The two companies remained at similar levels of scientific literature citations at the end of the study period, though Baidu has surpassed Google for a few years prior.

(Figure 5-13) Number of scientific literature citations, Baidu vs. Google (EPO patents, 2010-2019)



2) Regressions for the patent metrics

In addition to the visual assessment of Baidu’s catch−up in the previous section, I present the result for the regressions to assess the catch−up controlling for the covariates. Table 5−1 illustrates the descriptive statistics for the regression variables, and Table 5−2 presents the estimates from the regression. As mentioned previously, different models are applied for different dependent variables: Poisson regressions are used for the quality of patent and number of scientific literature citations, fractional logistic regressions for self−citations and mutual citations, and linear regression for the cycle time of technology.

Results from Table 5−2 indicate that Baidu has yet to catch up with Google regarding the quality of patents and mutual citations but has been catching up regarding self−citations. Whether Baidu employed alternative technological pathways strategy and attempted to avoid IPR issues, the well−known strategies for the latecomers, can be observed through the results for the scientific literature citations and cycle time of technology. On average, Baidu engaged with technologies with shorter cycle times and cited as much scientific literature as Google did. In other words, there is statistical evidence that Baidu sought niches with new technologies but insufficient evidence that Baidu has been attempting to avoid IPR disputes by utilizing more scientific literatures than Google.

(Table 5-1) Descriptive statistics for Baidu vs. Google, 2010-2019, n=5,366

Variable	Mean	Std. Dev.	Min	Max
latecomer (0: Google, 1: Baidu)	0.1011	0.3016	0	1
period	0.6628	0.4727	0	1
quality of patent	0.1593	1.2857	0	57
self-citation ratio	0.1022	0.2163	0	1
mutual citation ratio	0.0039	0.0393	0	1
cycle time of technology	6.5822	4.1114	0	98.56
scientific literature citation	0.9276	1.8529	0	56
Sum of patent stock (self, unit: 100)	9.4633	9.3480	0	45.92
Sum of patent stock (counterpart, unit:100)	1.9861	5.5058	0	48.27
Family size	6.6857	5.1554	1	64
No. of inventors	3.2402	2.2679	0	25
No. of claims (Max)	6.3522	7.2016	0	70
No. of forward citations	0.1593	1.2857	0	57
No. of backward citations	4.2575	3.3064	0	26
No. of IPC classes	3.0198	2.2403	1	22
2010 dummy	0.0363	0.1871	0	1
2011 dummy	0.0486	0.2151	0	1
2012 dummy	0.0788	0.2694	0	1
2013 dummy	0.1097	0.3126	0	1
2014 dummy	0.1127	0.3163	0	1
2015 dummy	0.1073	0.3095	0	1
2016 dummy	0.1692	0.3749	0	1
2017 dummy	0.1235	0.3291	0	1
2018 dummy	0.1220	0.3273	0	1
2019 dummy	0.0915	0.2883	0	1
technology field 01-35	-	-	0	1

Indicators of the scope of the patent, such as family size and number of IPC classes, are shown to be factors associated with lower quality of patents. Conversely, the number of inventors, number of claims, number of backward citations, and number of forward citations are shown to be positive factors for the quality of patents, although some variables show statistical insignificance. Moreover, a linear increase in the values of these metrics does not directly lead to a linear increase in technological independence or a decrease in technological independence. Similarly, there is no evidence of a consistent relationship between the positive increases in the value of these metrics and the cycle time or scientific literature citations. In conclusion, Baidu shows statistical evidence of having been catching up with Google regarding technological independence but not regarding the quality of patents and lower technological dependence, implying that Baidu hasn't created a new technological pathway in competing with Google.

(Table 5-2) Regression estimates to assess the catch-up/overtake, Baidu vs. Google

Variables	Quality	Self-citation ratio	Mutual citation ratio	Cycle time of technology	Scientific literature citation
Baidu	-1.20*** (0.21)	0.69 *** (0.13)	6.28*** (0.85)	-1.48*** (0.36)	0.02 (0.10)
Baidu * Period	-0.22 (0.34)	-0.59*** (0.16)	0.18 (0.99)	-0.42 (0.43)	-0.56*** (0.12)
Period	-1.37*** (0.21)	0.08 (0.09)	0.34 (0.96)	0.12 (0.18)	0.06 (0.05)
Sum of patent stock (self)	-0.09*** (0.01)	0.04*** (0.00)	0.11** (0.05)	0.01 (0.01)	-0.02*** (0.00)
Sum of patent stock (counterpart)	0.00 (0.01)	0.02*** (0.01)	-0.06* (0.03)	0.02 (0.02)	0.02*** (0.01)
Family size	-0.03*** (0.01)	-0.02*** (0.00)	0.07** (0.04)	0.01 (0.01)	-0.01* (0.00)
No. of inventors	0.04** (0.02)	0.02** (0.01)	0.02 (0.03)	-0.07*** (0.02)	0.03*** (0.01)
No. of claims (Max)	0.09*** (0.00)	-0.005 (0.004)	-0.03* (0.02)	0.03*** (0.01)	-0.02*** (0.00)
No. of forward citations	-	-0.05 (0.04)	0.07 (0.07)	-0.06 (0.04)	0.03*** (0.01)
No. of backward citations	-0.11*** (0.01)	-	-	0.22*** (0.02)	-0.21*** (0.01)
No. of IPC classes	-0.04* (0.02)	-0.01 (0.01)	0.10** (0.05)	-0.05 (0.03)	0.09*** (0.01)
Tech_field	Yes	Yes	Yes	Yes	Yes

Constant	-1.73*** (0.13)	-2.28*** (0.09)	-10.40*** (1.04)	6.27*** (0.20)	0.61*** (0.06)
N	5,366	5,366	5,366	5,366	5,366
Pearson residual or R-squared	18836.60 (1.00)	0.094	0.383	0.081	28782.93 (1.00)

Note: Coefficients are shown up to 3 decimal places; standard errors are shown in parentheses

* 10% level of significance.

** 5% level of significance.

*** 1% level of significance

3) Conclusion

Baidu has not yet caught up with Google regarding the quantity (i.e., number of patents) and the quality (i.e., number of citations received) of patents, and could not close the gap in reducing technological dependence (i.e., mutual citations), but has been catching up in terms of technological independence (i.e., self-citations). Baidu has been engaging in niche-seeking behaviors by focusing on technologies with shorter cycle times and maintaining a similar number of scientific literature citations with Google. The overall results indicate that Baidu has been seeking niches and avoiding IPR disputes in general but could not create alternative technological pathways that could compete with Google. Such gaps in technological capabilities could reasonably explain Baidu's lagging market performance compared to Google; Baidu's market capitalization in 2019 was significantly smaller, amounting to 4.7% of Google's market capitalization.

2. Alibaba's catch-up with Amazon

1) Patent analysis for Alibaba and Amazon

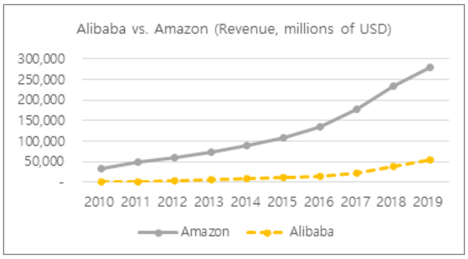
(1) Market performance of Alibaba and Amazon

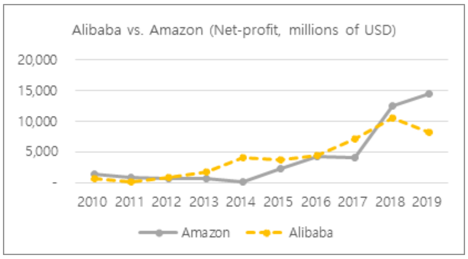
Amazon and Alibaba owe much of their growth to their online retail businesses. Figures 5-14 to 5-19 portray such growth over 10 years, and show how Alibaba, the latecomer, and Amazon, the forerunner, compares in terms of market performances. Amazon and Alibaba, both with online retail operations, each ranks the first and the second in the world, respectively, among all businesses in the same business area; in domestic markets, they are both the largest and the most successful online retail businesses.

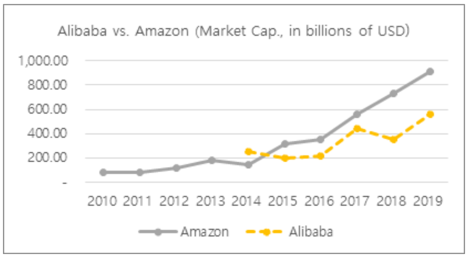
Figures 5-14 to 5-16 show the nominal revenue, net profit, and market capitalization over ten years from 2010 to 2019, and Figure 5-17 to 5-19 show the same figures normalized as the proportion of the domestic GDP. The former group of figures reflects the size of the respective domestic markets and directly compares the nominal figures, and the latter controls for the size of the markets and economic growth of their respective home countries; each provides different insights into the market performances of Alibaba and Amazon.

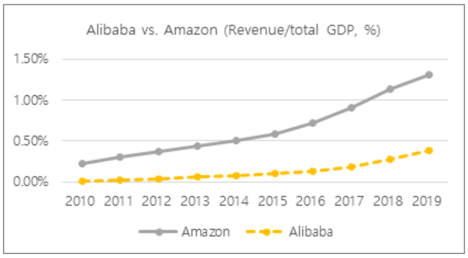
Results demonstrate that Alibaba still had considerable gaps with Amazon for annual revenues, normalized or not, but the gap is much narrower for net profits and market capitalization.

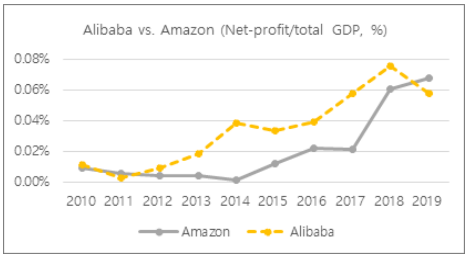
(Figures 5-14 to 5-19) 14. Top left: Comparisons of Alibaba's and Amazon's annual revenue (in millions of U.S. dollars); **15. Top right**: Comparisons of Alibaba's and Amazon's annual net profit (in millions of U.S. dollars); **16. Middle left**: Comparisons of Alibaba's and Amazon's average annual market capitalization (in billions of U.S. dollars); **17. Middle right**: Comparisons of Alibaba's and Amazon's annual revenue, normalized (in percentages); **18. Bottom left**: Comparisons of Alibaba's and Amazon's annual net profit, normalized (in percentages); **19. Bottom right**: Comparisons of Alibaba's and Amazon's average annual market capitalization, normalized (in percentages)

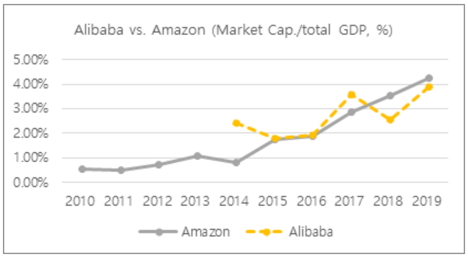






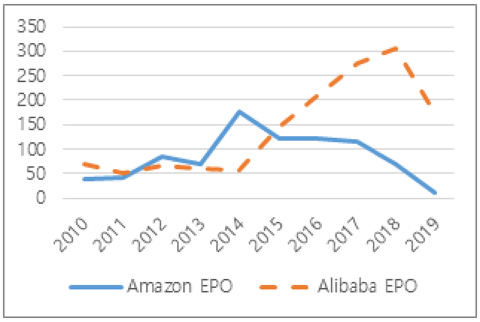


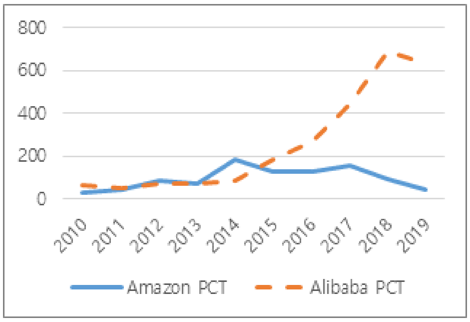




Figures 5-20 and 5-21 plot the yearly numbers of patent applications with both PCT and EPO for Amazon and Alibaba over the ten years. Alibaba is shown to have surpassed Amazon in the number of patents. Joo and Lee (2010) and Joo, Oh, and Lee (2015) report that the catch–up in the number of patents precedes the market catch–up, but this does not hold up for Amazon and Alibaba; the figures from the previous section show that Alibaba has been catching up to a certain extent without a clear–cut overtake, while Alibaba has markedly overtaken Amazon in the number of patents. Although Alibaba catching up with Amazon in market performances in the future could be a possibility, it is not possible to determine whether the results of the previous studies are consistent with the case of Alibaba and Amazon at this point.

(Figures 5–20, 5–21) 20. Left: Comparisons of Alibaba's and Amazon's quantity of patents (EPO patents, 2010–2019); **21. Right**: Comparisons of Alibaba's and Amazon's quantity of patents (PCT patents, 2010–2019)



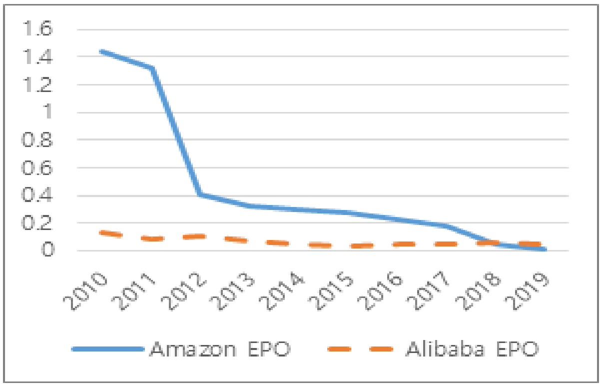


(2) Alibaba's technological pathways

A. Quality of patents

Figure 5–22 depicts the quality of patents Amazon and Alibaba filed with EPO from 2010 to 2019. Alibaba's patents are shown to have been of significantly lower quality than Amazon's throughout the years, with Amazon experiencing a decrease in the quality of their patents as the time progressed. The gap between the two is narrowed and closed at the end of the study period, leading to Alibaba's eventual catch−up.

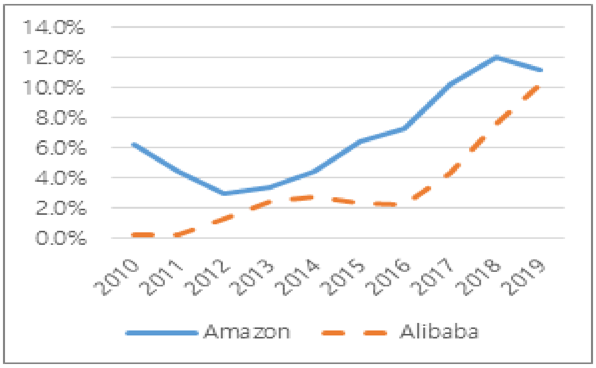
(Figure 5−22) Quality of patents, Alibaba vs. Amazon (EPO patents, 2010−2019)



B. Self−citations

Self−citation ratio indicates the proportion of citations directed to the patents of the same company in the total number of citations and denote the degree of technological capability and independence for a company. Figure 5−23 shows the yearly self−citation ratio for the two company from 2010 to 2019. Alibaba's self−citation ratio was much lower than Amazon's at the beginning of the study period, but eventually closed in at the end. Both companies display increasing trends in the ratio of self−citations.

(Figure 5−23) Self−citation ratio, Alibaba vs. Amazon (EPO patents, 2010−2019)

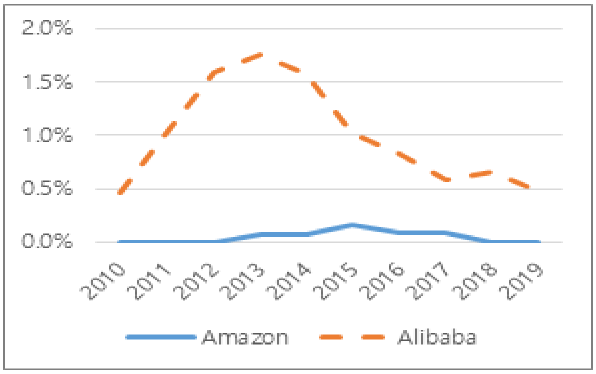


C. Mutual citations

Mutual citation ratio measures the degree of technological dependence between the two companies with the proportions of citations directed to the patents from the counterpart firm in the total number of citations. In general, a decrease in the mutual citation ratio for the latecomer is a positive signal that the latecomer is catching up; a lower mutual citation ratio for the latecomer compared to the forerunner indicates an overtake by the latecomer.

Figure 5-24 depicts the mutual citation ratio for Amazon and Alibaba over the ten years. Alibaba maintained much higher mutual citation ratio throughout the study period and showed a greater dependence on Amazon's technologies than the other way around. Alibaba's dependence on Amazon decreased towards the end of the study period, signaling that Alibaba has been catching up with Amazon.

(Figure 5-24) Mutual citation ratio, Alibaba vs. Amazon (EPO patents, 2010-2019)

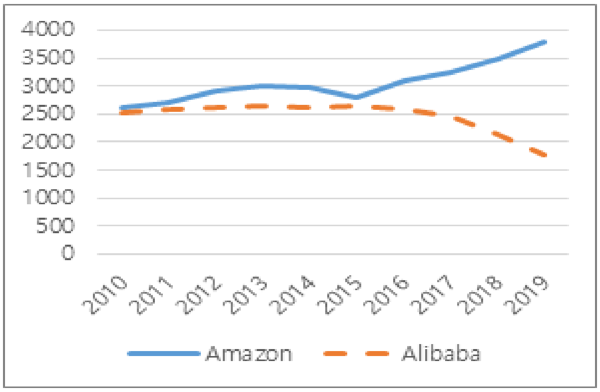


(3) Alibaba's strategies to seek niches and avoid IPR issue

A. Cycle time of technology

Figure 5-25 presents how the cycle time of the technologies that Amazon and Alibaba utilize has changed over the 10-year period. The two companies entered the period with similar cycle times for their technologies, with Alibaba moving towards technologies with shorter cycle times and Amazon towards technologies with longer cycle times.

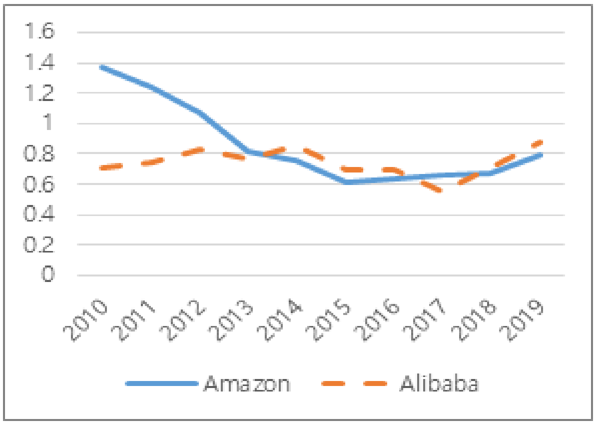
(Figure 5-25) Cycle time of technology, Alibaba vs. Amazon, in days (EPO patents, 2010-2019)



B. Scientific literature citations

Figure 5-26 shows the number of scientific literature citations for Amazon and Alibaba. The beginning of the study period saw a much higher number for Amazon, which then markedly decreased over time. Conversely, Alibaba somewhat increased its number of scientific literature citations. Graphically, Alibaba has closed in on the number of scientific literature citations and has maintained a similar level for some time.

(Figure 5-26) Number of scientific literature citations, Alibaba vs. Amazon (EPO patents, 2010-2019)



2) Regressions for the patent metrics

Regressions are estimated for the metrics seen in the previous section for further investigation into Alibaba's catch-up with Amazon. Table 5-3 shows the descriptive statistics for the variables in the regressions. Different characteristics of the dependent variables necessitate different regression models; Poisson regressions are estimated for the quality of patents and scientific literature citations as dependent variables, fractional logistic regressions for the self-citation and mutual citation ratios, and linear regression for the cycle time of technology. Table 5-4 presents the estimations for the regressions.

(Table 5-3) Descriptive statistics for Alibaba vs. Amazon, 2010-2019, n=2,267

Variable	Mean	Std. Dev.	Min	Max
latecomer (0: Amazon, 1: Alibaba)	0.6241	0.4844	0	1
period	0.5805	0.4935	0	1
quality of patent	0.1138	0.7470	0	18
self-citation ratio	0.0690	0.1499	0	1
mutual citation ratio	0.0049	0.0369	0	0.71
cycle time of technology	6.6392	3.8484	0	40.75
scientific literature citation	0.7534	1.2831	0	10
Sum of patent stock (self, unit: 100)	3.4157	3.4510	0	17.67
Sum of patent stock (counterpart, unit:100)	2.7198	2.2810	0	13.60
Family size	7.8672	3.4079	1	27
No. of inventors	2.9316	2.3234	0	20
No. of claims (Max)	8.0423	9.7847	0	120
No. of forward citations	0.1138	0.7470	0	18
No. of backward citations	5.9827	3.2034	0	19
No. of IPC classes	3.0426	2.0625	1	15
2010 dummy	0.0467	0.2111	0	1
2011 dummy	0.0414	0.1994	0	1
2012 dummy	0.0674	0.2509	0	1
2013 dummy	0.0569	0.2317	0	1
2014 dummy	0.1027	0.3037	0	1
2015 dummy	0.1182	0.3229	0	1
2016 dummy	0.1468	0.3540	0	1
2017 dummy	0.1720	0.3774	0	1
2018 dummy	0.1658	0.3720	0	1
2019 dummy	0.0816	0.2738	0	1
technology field 01-35	-	-	0	1

Results of Table 8 indicate that Alibaba has been catching up with Amazon in terms of quality of patents and self−citation ratio but not for reduced mutual citation ratio. Amazon and Alibaba had similar cycle times of technologies and numbers of scientific literature citations.

(Table 5−4) Regression estimates to assess the catch−up/overtake, Alibaba vs. Amazon

Variables	Quality	Self-citation ratio	Mutual citation ratio	Cycle time of technology	Scientific literature citation
Alibaba	-1.53*** (0.19)	-1.00*** (0.18)	3.35*** (0.88)	-0.29 (0.20)	-0.07 (0.07)
Alibaba * Period	1.51** (0.63)	0.87*** (0.23)	14.88 (1441.91)	-0.52 (0.43)	0.32** (0.16)
Period	-1.52*** (0.55)	0.10 (0.20)	-15.16 (1441.91)	-0.45 (0.36)	-0.26* (0.13)
Sum of patent stock (self)	0.06 (0.08)	0.01 (0.03)	-0.23* (0.14)	-0.23*** (0.06)	0.09*** (0.02)
Sum of patent stock (counterpart)	-0.25** (0.12)	0.23*** (0.05)	0.32* (0.19)	0.15 (0.09)	-0.09*** (0.03)
Family size	0.01 (0.02)	-0.01 (0.01)	-0.12** (0.06)	-0.04* (0.02)	0.06*** (0.01)
No. of inventors	0.03 (0.03)	0.03* (0.02)	-0.13 (0.09)	0.02 (0.03)	-0.02 (0.01)
No. of claims (Max)	0.01 (0.01)	0.02*** (0.00)	-0.03** (0.02)	-0.02*** (0.01)	-0.02*** (0.00)
No. of forward citations	-	0.08** (0.03)	0.01 (0.41)	-0.16* (0.09)	0.03 (0.03)
No. of backward citations	0.07*** (0.02)	-	-	0.09*** (0.02)	-0.12*** (0.01)
No. of IPC classes	-0.08* (0.04)	-0.04* (0.02)	-0.15 (0.09)	0.08* (0.04)	0.04*** (0.02)
Tech_field	Yes	Yes	Yes	Yes	Yes
Constant	-2.49*** (0.28)	-2.41*** (0.16)	-6.25*** (1.02)	7.46 *** (0.33)	0.26** (0.11)
N	2,267	2,267	2,267	2,267	2,267
Pearson residual or R-squared	5593.61 (1.00)	0.126	0.191	0.259	4175.83 (1.00)

Note: Coefficients are shown up to 3 decimal places; standard errors are shown in parentheses

* 10% level of significance.

** 5% level of significance.

*** 1% level of significance

Scope-of-patent variables, such as family size and number of IPC classes, are negatively associated with the quality of patents for Amazon and Alibaba, much like the results for Baidu and Google. Number of inventors, number of patent claims, number of backward citations, and number of forward citations are positively associated with the quality of patents, with statistical insignificance for some variables. The direction of the associations indicates that higher patent value metrics do not consistently lead to more technological independence or less technological dependence. Moreover, there is no consistent relationship between cycle times and scientific literature citations and patent value metrics.

3) Conclusion

Overall results suggest that Alibaba has caught up with Amazon regarding the quality of patents and technological independence but not regarding reduced technological dependence. The technologies that Alibaba and Amazon each engage with had similar cycle times. There is no statistical evidence that Alibaba cited scientific literatures more than Amazon did; Alibaba maintained a similar number of scientific literature citations as Amazon did. This result can be interpreted as Alibaba having been pursuing niche-seeking and IPR dispute-avoiding strategies, following Amazon's technological pathways, and attempting to pave its own technological pathways simultaneously. Alibaba's somewhat limited feat of technological innovation has been proportionately reflected in the market by the fact that Alibaba has been catching up with Amazon to a certain extent, with its market capitalization reaching 61.1% of Amazon's, but has yet to achieve an overtake.

3. Tencent's catch-up with Facebook

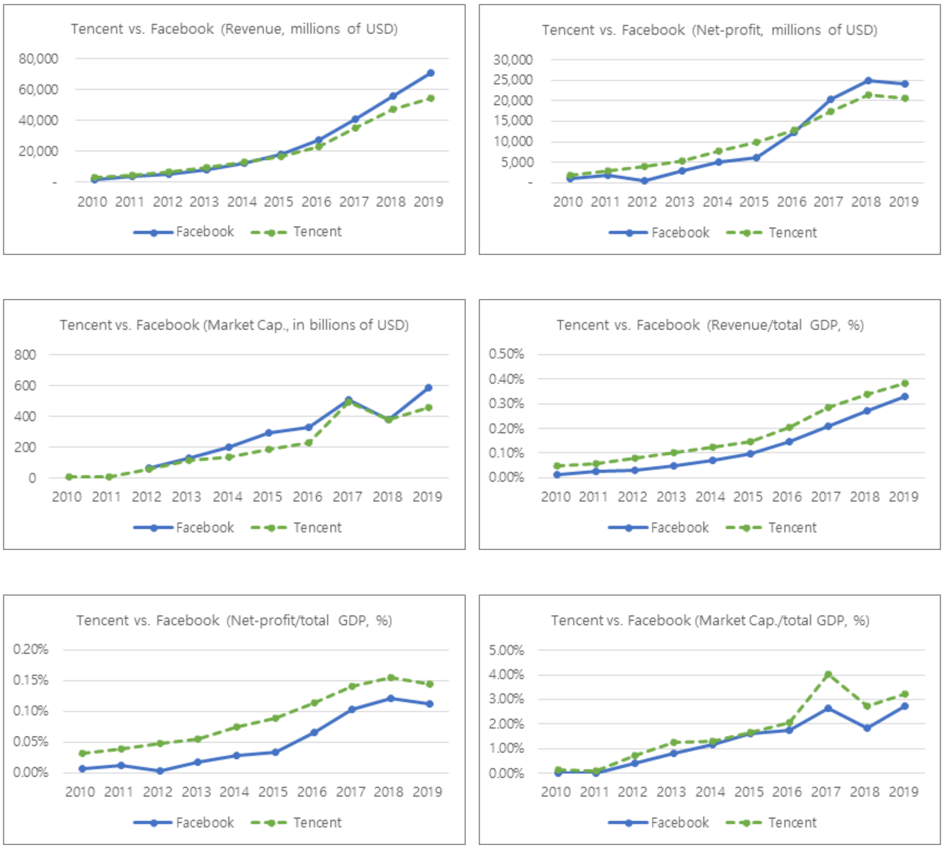
1) Patent analysis for Tencent and Facebook

(1) Market performance of Tencent and Facebook

Tencent and Facebook both grew and branched out from their core business of social networking services over the years and have demonstrated remarkable success in the market. Their social media platforms dominate the market, with Facebook and Tencent each ranking first and second, respectively, in the size of the market shares globally, and being the most dominant in their domestic markets.

Figures 5-27 to 5-32 show the history of their market performances from 2010 to 2019 through key market performance metrics. Figures 5-27 to 5-29 plot the nominal revenue, net profit, and market capitalization; Figures 5-30 to 5-32 normalize this value as the proportion of their home countries' GDPs. The former offers direct comparisons between the nominal values and reflects the size of their markets; the latter provides comparisons in market performances with the market size and economic growth controlled for.

(Figures 5-27 to 5-32) 27. Top left: Comparisons of Tencent's and Facebook's annual revenue (in millions of U.S. dollars); **28. Top right:** Comparisons of Tencent's and Facebook's annual net profit (in millions of U.S. dollars); **29. Middle left:** Comparisons of Tencent's and Facebook's average annual market capitalization (in billions of U.S. dollars); **30. Middle right:** Comparisons of Tencent's and Facebook's annual revenue, normalized (in percentages); **31. Bottom left:** Comparisons of Tencent's and Facebook's annual net profit, normalized (in percentages); **32. Bottom right:** Comparisons of Tencent's and Facebook's average annual market capitalization, normalized (in percentages)



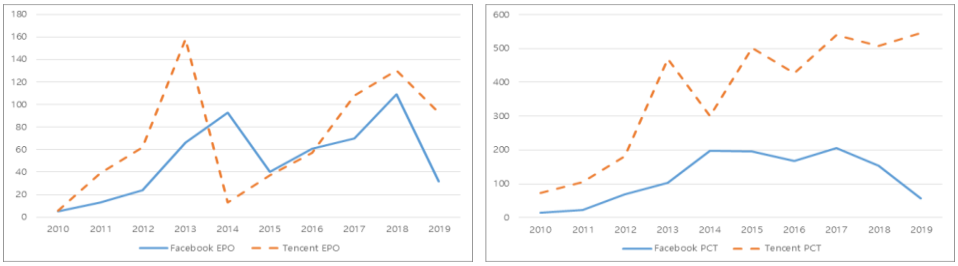
Tencent has made significant progress towards catching up with Facebook regarding the revenue. The two companies entered the study period with similar sizes of revenue and rates of growth, with Facebook picking up the pace in the latter period. Tencent has also considerably narrowed the gap in net profits. The beginning of 2010s saw significant investments in Tencent by the Chinese government with policies to stimulate the growth in the arts and entertainment sectors; Tencent was also actively expanding its overseas investment portfolio. Tencent's rapid business success is depicted as higher net profits at the beginning of the decade. Facebook overtook Tencent in the middle, but Tencent continued to stay in the increasing trend. Finally, Tencent has also been closing in on the market capitalization. The figures show a few instances in which Tencent caught up with Facebook but did not show any instances of clear overtakes.

Figure 5-30 and 5-31 show that Tencent had already overtaken Facebook at the beginning of the study period in terms of sales and net profit when normalized by GDP and remained so throughout the decade. Figure 5-32 shows Tencent entering the time period with the normalized market capitalization similar to that of Facebook and widening the gap as time progresses.

These results illustrate how Tencent's market performances in terms of nominal revenue, net profit, and market capitalization have substantially caught up with those of Facebook but have yet to complete the catch-up. When these metrics are normalized, however, Tencent is shown to have overtaken Facebook throughout the study period.

Figures 5-33 and 5-34 show the yearly numbers of patent applications with EPO and PCT, respectively, for the two companies. Results from the PCT patents indicate that Tencent has filed more patents than Facebook during this period. While this result, along with Tencent's relative market success compared to Facebook, may seem counterintuitive against the results from Joo and Lee (2010) and Joo, Oh and Lee (2015) that the overtake in the number of patents by latecomers precedes the market overtake, the results from this study cannot verify nor counter this as the study period is not sufficiently long enough to make such conclusion.

(Figures 5-33, 5-34) 33. Left: Comparisons of Tencent's and Facebook's quantity of patents (EPO patents, 2010-2019); **34. Right**: Comparisons of Tencent's and Facebook's quantity of patents (PCT patents, 2010-2019)

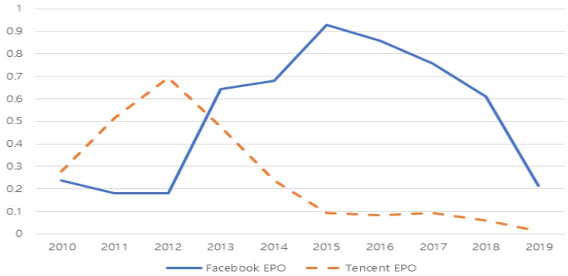


(2) Tencent's technological pathways

A. Quality of patents

Figure 5-35 plots the quality of the patents applied by Facebook and Tencent for the 10-year period. Tencent's patents were of higher quality at the beginning of the study period, but this trend was soon reversed, with Facebook having higher quality patents from 2013 to the end of the study period. Although the gap between the two narrows from 2015 onwards, a conclusion that Tencent has therefore been catching up with Facebook warrants caution as they both suffered from decreases in their patent qualities in the later years.

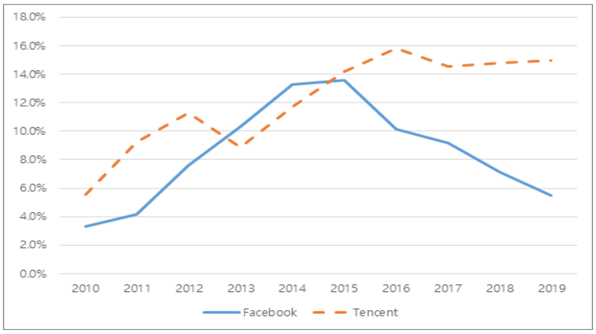
(Figure 5-35) Quality of patents, Tencent vs. Facebook (EPO patents, 2010-2019)



B. Self-citations

Figure 5-36 shows the self-citation ratio of the two companies from 2010 to 2019. Tencent led in the self-citation ratio during the earlier years, after which the two companies took turns to take over each other. Tencent overtook Facebook in 2016 and maintained higher ratio of self-citations until the end of the study period. Facebook's self-citation ratio showed a noticeable decrease from 2016 and continued to widen the gap with Tencent's throughout the remaining study period.

(Figure 5-36) Self-citation ratio, Tencent vs. Facebook (EPO patents, 2010-2019)

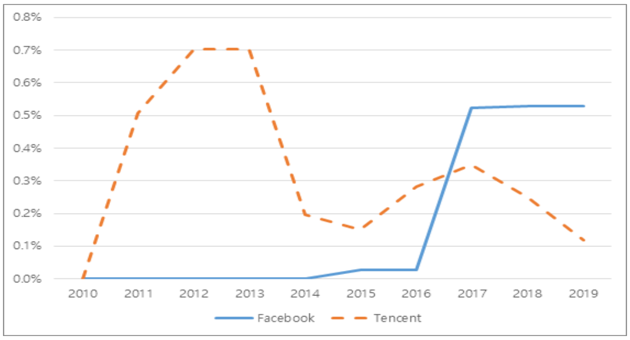


C. Mutual citations

Mutual citation ratio of the patents shows how much a company cites the patents from its counterpart compared to the total number of citations. A decrease in this metric is a positive signal for the latecomers, as it would mean less technological dependence on the forerunners. Here, the overtake is defined as the latecomer having a lower ratio of mutual citations than the forerunner.

Figure 5-37 plots the mutual citation ratios for Tencent and Facebook over the study period. Tencent showed higher ratio of mutual citations at the beginning of the study period, but the gaps narrowed over time. Facebook began to cite Tencent more than Tencent did Facebook in 2017 and continued to have higher ratio of mutual citations. In contrast, Tencent's mutual citation ratio consistently decreased until the end of the study period and further widened the gap.

(Figure 5-37) Mutual citation ratio, Tencent vs. Facebook (EPO patents, 2010-2019)

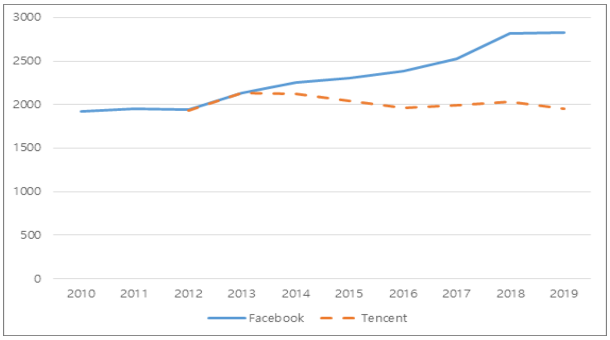


(3) Tencent's strategies to seek niches and avoid IPR issue

A. Cycle time of technology

Figure 5−38 shows the cycle time of the technologies Tencent and Facebook engaged with from 2010 to 2019. Tencent used technologies with similar cycle times as Facebook did, but the trend diverged as time progressed, with Tencent increasingly using technologies with shorter cycle times.

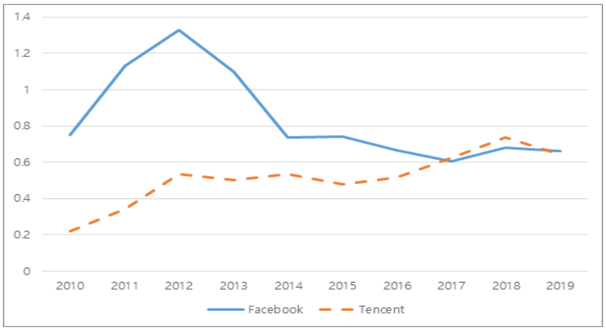
(Figure 5−38) Cycle time of technology, Tencent vs. Facebook, in days (EPO patents, 2010−2019)



B. Scientific literature citations

Figure 5−39 plots the number of scientific literature citations that Tencent and Facebook made over the study period. Facebook cited more scientific literatures than Tencent at the beginning of the decade. Tencent gradually increased the number of scientific literature citations over time, while Facebook showed a decreasing trend. At the end of the study period, Tencent showed similar numbers of scientific literature citations to Facebook.

(Figure 5-39) Number of scientific literature citations, Tencent vs. Facebook (EPO patents, 2010-2019)



2) Regressions for the patent metrics

In this section, I present the analysis with regression estimates. Table 5-5 shows the descriptive statistics of the variables used in the regressions.

(Table 5-5) Descriptive statistics for Tencent vs. Facebook, 2010-2019, n=1,216

Variable	Mean	Std. Dev.	Min	Max
latecomer (0: Facebook, 1: Tencent)	0.5781	0.4940	0	1
period	0.5542	0.4972	0	1
quality of patent	0.3519	1.3368	0	19
self-citation ratio	0.1125	0.1704	0	1
mutual citation ratio	0.0024	0.0332	0	1
cycle time of technology	5.9484	2.8622	0	31.85
scientific literature citation	0.6669	1.3364	0	19
Sum of patent stock (self, unit: 100)	1.2575	1.1771	0	6.12
Sum of patent stock (counterpart, unit:100)	1.0935	1.0391	0	5.89
Family size	6.4769	5.3134	1	45
No. of inventors	3.5008	2.7817	0	17
No. of claims (Max)	12.9013	8.3923	0	84
No. of forward citations	0.3519	1.3368	0	19
No. of backward citations	6.3527	3.6514	0	38

No. of IPC classes	3.1902	2.4310	1	20
2010 dummy	0.0090	0.0947	0	1
2011 dummy	0.0427	0.2024	0	1
2012 dummy	0.0707	0.0707	0	1
2013 dummy	0.1842	0.3878	0	1
2014 dummy	0.0871	0.2822	0	1
2015 dummy	0.0633	0.2436	0	1
2016 dummy	0.0970	0.2961	0	1
2017 dummy	0.1463	0.3536	0	1
2018 dummy	0.1965	0.3975	0	1
2019 dummy	0.1027	0.3038	0	1
technology field 01-35	-	-	0	1

Different regression models are employed for different types of dependent variables. Poisson regressions are used for the quality of patents and scientific literature citations, fractional logistic regressions for self-citation and mutual citation ratios, and linear regression models for the cycle time of technology.

Table 5-6 reports that Tencent has not yet caught up with Facebook in terms of the quality of patents, but has overtaken in self-citation and reduced mutual citation ratios. Tencent utilized technologies with shorter cycle times and cited scientific literatures at a level similar to Facebook's.

Metrics for the scope of the patent, such as family size and number of IPC classes, are factors negatively associated with the quality of patents, a finding also observed in the analyses of Baidu vs. Google and Alibaba vs. Amazon. Numbers of inventors, patent claims, backward citations, and forward citations are positively associated with the quality of patents, albeit statistical insignificance for some variables. However, improvements in these variables do not always lead to a greater degree of technological independence or a lesser degree of technological dependence. Moreover, these variables do not have a consistent relationship with the cycle time of technology and the number of scientific literature citations.

Results indicate that among the quantity of patents, quality of patents, technological independence, and technological dependence, quality of patents proves to be the most challenging metric to improve upon for the firms; while the companies can directly control the rates of self-citations and mutual citations by deliberately choosing or excluding certain citations, quality of patents can only be increased through receiving more citations from other patentees by definition.

These results suggest that Tencent has been implementing its niche-seeking and IPR dispute-avoiding strategies and creating a technological pathway distinct from Facebook's. However, Tencent hasn't yet achieved a catch-up in the quality of patents, indicating that while it has been showing some signs of creating a novel technological pathway, as seen from its overtakes in the self-citation and mutual citation ratios, it has not achieved its relative success through this yet.

(Table 5-6) Regression estimates to assess the catch-up/overtake, Tencent vs. Facebook

Variables	Quality	Self-citation ratio	Mutual citation ratio	Cycle time of technology	Scientific literature citation
Tencent	-1.54*** (0.19)	-0.21* (0.13)	1.62** (0.79)	-0.79*** (0.27)	-0.16 (0.14)
Tencent * Period	-1.75*** (0.56)	0.96*** (0.20)	-2.76* (1.49)	-0.97*** (0.35)	0.32* (0.17)

Period	-1.27*** (0.19)	-0.91*** (0.19)	1.73 (1.27)	0.99 (0.29)	-0.09 (0.14)
Sum of patent stock (self)	-0.45*** (0.13)	0.21*** (0.06)	0.76 (0.49)	-0.14 (0.13)	-0.23*** (0.07)
Sum of patent stock (counterpart)	0.04 (0.11)	0.05 (0.08)	-0.85 (0.57)	-0.33 (0.15)	0.13* (0.07)
Family size	-0.04*** (0.01)	-0.01 (0.01)	-0.17 (0.13)	-0.06*** (0.02)	-0.01 (0.01)
No. of inventors	0.05*** (0.02)	0.02** (0.01)	0.05 (0.07)	-0.06** (0.03)	-0.01 (0.01)
No. of claims (Max)	0.07*** (0.01)	0.01*** (0.00)	0.01 (0.03)	-0.02 (0.04)	0.01* (0.00)
No. of forward citations	-	0.03 (0.03)	-0.07 (0.33)	0.05 (0.06)	0.04* (0.02)
No. of backward citations	-0.06*** (0.02)	-	-	0.11*** (0.02)	-0.12*** (0.01)
No. of IPC classes	-0.09*** (0.03)	0.03* (0.02)	-0.28 (0.20)	-0.04 (0.04)	0.10*** (0.02)
Tech_field	Yes	Yes	Yes	Yes	Yes
Constant	-0.83*** (0.20)	-2.01*** (0.16)	-7.67*** (1.37)	6.48*** (0.33)	0.09 (0.)
N	1,216	1,216	1,216	1,216	1,216
Pearson residual or R-squared	2871.16 (1.00)	0.120	0.194	0.239	2937.71 (1.00)

Note: Coefficients are shown up to 3 decimal places; standard errors are shown in parentheses

* 10% level of significance.

** 5% level of significance.

*** 1% level of significance

3) Conclusion

In this study, Tencent's choice and development of technological pathways as compared to Facebook is investigated. Estimates from regressions show that Tencent has not caught up or overtaken Facebook in terms of the quality of patents but has achieved overtakes in technological independence and reduced dependence metrics. Results suggest that Tencent has been the most technologically capable compared to Baidu and Alibaba, as compared to their counterparts. Tencent employed niche-seeking strategies by opting to work with technologies with shorter cycle times. Tencent used scientific literatures in its patents at least as much as Facebook did; whether it used scientific literature more than Facebook did remains inconclusive.

Among the metrics that reflect the firms' choice of technological pathways, such as the quality of patents, self-citations, and mutual citations, Tencent has achieved overtakes in self-citation and lower mutual citation ratios but not in the quality of patents, indicating that Tencent has broken away from Facebook's technological pathways to a certain extent but remained short of a completion of paving a novel and distinct pathway. Tencent's success has been well-reflected on its market performance indicators, with its market capitalization reaching 78.6% of Facebook's in 2019.

Chapter VI. Conclusion

The sustained rise and success of China's major digital platform firms, such as Baidu, Alibaba, and Tencent, in the global market is drawing much attention from academia and industry alike. This study aims to provide insights into the factors that enabled this and how this has been achieved through the perspective of technological innovations and market performances.

The companies examined in this study comprise three Chinese firms – Baidu, Alibaba, and Tencent – and three U.S. firms – Google, Amazon, and Facebook. Each Chinese firm is paired with one U.S. firm that participates in similar core business areas and has similar technologies, resulting in the following three pairs: Baidu and Google, Alibaba and Amazon, and Tencent and Facebook. This study presents comparative analyses of the latecomers' behaviors regarding technological innovations, specifically examining 1) whether the latecomers are creating new technological pathways or following the pathways created by the forerunners, and 2) how much the latecomers are relying on scientific literatures and how the latecomers are strategizing regarding the cycle time of the technologies being used and developed.

This study offers analyses based on the PATSTAT data published by the European Patent Office (EPO). PATSTAT provides detailed information on the patents filed in 90 countries worldwide and is a standardized database for the diverse set of data collected from the participating countries, making it a valuable tool for academia, industry, and government alike. Regressions, with relevant covariates and interaction terms, are estimated to observe how the latecomers in this study (Chinese firms) have been catching up with or overtaking the forerunners (U.S. firms).

The latecomers' choice of technological pathways is observed with metrics calculated with patent data, such as the patent quality, self-citation ratio, and mutual citation ratio. Studies suggest that the latecomers achieve catch-ups or overtakes by creating a technological pathway distinct from that of the forerunners. Specifically, the latecomers are known to improve the quality of their patents, seek technological independence with self-citations in their patents, and reduce technological dependence on the forerunners by refraining from citing the forerunners in their patents to catch up with or overtake their forerunners. This is in line with the paradox of catch-up, that the latecomers must first attempt to be distinct from their forerunners with new pathways of innovations to be in the equivalent position that their forerunners are.

Whether the latecomers of this study have been following the typical strategies to catch up with their forerunners is observed through the cycle time of the technologies they engage with and the number of scientific literature citations. Cycle time of technology measures the average time difference between the filing date of the patent and the filing dates of its citations; short cycle time for the latecomers' technologies implies that the latecomers are attempting to circumvent the forerunners by utilizing a more recent set of technologies. A large number of scientific literature citations hint at the latecomers' strategy to avoid IPR disputes by basing their patents on scientific literature.

The values for the five metrics mentioned above (patent quality, number of patents, self-citation ratio, mutual citation ratio, cycle time of technology, and scientific literature citations) are calculated and used for regressions comparing each pair of companies. Summary of the results is presented in Table 6-1.

Results from comparisons between Baidu and Google show that Baidu's technological capability, represented by the patents it filed, lagged behind Google's, both qualitatively and quantitatively, throughout the study period Baidu has been catching up with Google regarding technological independence (i.e., self-citation ratio) but could not reduce the level of technological dependence on Google (i.e., mutual citation ratio) to Google's level of dependence on Baidu. Baidu has been implementing niche-seeking strategies by utilizing technologies with shorter cycle times and has maintained a similar number of scientific literature citations as Google did. In short, Baidu has been seeking niches and avoiding IPR disputes but has not been able to create new technological pathways that could effectively compete with Google's technologies. The gap in technological capabilities between the two firms has adequately been reflected in their market performances, with Baidu's market capitalization amounting to 4.7% of Google's in 2019.

Alibaba has caught up with Amazon in the quality of technology and overtaken it in its quantity. In terms of technological independence, Alibaba has also been catching up with Amazon; however, Alibaba has not been able to catch up with Amazon's lower levels of technological dependence. Alibaba and Amazon have been using technologies with similar cycle times and cited scientific literatures at a similar level. These results suggest that Alibaba has also been taking measures to seek niches and avoid IPR disputes while attempting to pave technological pathways distinct from Amazon's simultaneously, though with limited success in the given time period. This has been appropriately reflected in its market performances; Alibaba was closer to Amazon than Baidu was to Google, and Alibaba's market capitalization recorded 61.1% of Amazon's in 2019.

Tencent has surpassed Facebook in terms of quantity of technology but not quality. Tencent has also achieved overtakes in technological independence and dependence, has been pursuing technologies with relatively shorter cycle times, and maintained similar levels of scientific literature citations to those of Facebook. This suggests that Tencent has also been seeking niches, sidestepping IPR issues, and attempting to create new technological pathways. Among the three metrics for assessing the choice of technological pathways, Tencent has achieved overtakes in self-citation ratio and reduced mutual citation ratio but hasn't yet caught up with Facebook in terms of patent qualities, which lends to the conclusion that while Tencent has been working towards creating a novel technological pathway, it hasn't yet completed its progress. Tencent's feat in technological growth can also be seen through its market performance; Tencent's market capitalization has reached 78.6% of Facebook's in 2019.

This paper contributes to the growing bodies of work in the latecomers' technological catch-ups with their forerunners and technological innovations in the digital platform industries. Specifically, this study shows that the latecomers in the digital platform industry (Baidu, Alibaba, and Tencent) are focused on the technologies with shorter cycle times to seek niches in their competition with their forerunners (Google, Amazon, and Facebook), and that they attempt to avoid IPR disputes with the forerunners by utilizing scientific literatures in their patents. Moreover, the latecomers attempt to create alternative technological pathways to compete with their forerunners, albeit with varying degrees, and the successes of these efforts are proportionately reflected in their market performances. Results indicate that while the three Chinese firms have not yet overtaken their forerunners in the global market, they have nonetheless achieved significant growth and expansion over the decade and have been leading and dominating in their domestic market. They have endeavored to achieve technological innovations and implemented typical strategies for the latecomers to catch up with the forerunners, results for which can be observed through the technological capabilities indicators (i.e., number of patents, quality of patents, self−citations, and mutual citations) and the technological pathways metrics (i.e., strategies to seek niches and circumvent IPR disputes).

This study also expands on the existing findings on the orders in which catch−ups in the technological capabilities metrics happen and the relative difficulties in achieving such catch−ups. Results for the comparisons in the market performances and the technological capabilities metrics suggest that the catch−ups in the number of patents and technological independence precede the catch−ups in the quality of patents and reduced technological dependence. In other words, it is more difficult for the firms to have their patents cited than to simply increase the number of patents (i.e., it is more difficult to catch up in terms of the quality than the quantity of the patents), and it is more difficult to refrain from citing their forerunners than to cite their own patents (i.e., it is more difficult to reduce technological dependence than to strengthen their technological independence). Among these metrics, the quality of patents seems to be the most demanding metric to overtake the forerunners in; one primary explanation is that this is the only metric that mostly depends on the choices that other patentees make, whereas firms can make conscious choice, to a certain extent, for themselves to improve on the other metrics. This result, however, may not generalize to companies other than the six companies in the study and warrants further investigations for generalizations.

Moreover, this study adds to and supports the perspectives of the existing body of work that applies the theory of technological catch-up. While previous studies focused on the application of the theory on manufacturing firms, this study sheds light on the firms in the up-and-rising digital platform industry and shows that the theory can likewise be applied in this setting. Furthermore, this study differentiates from most other studies, which investigated the cases in which the latecomer has completed the catch-up or overtake, by examining the firms that haven't yet achieved such a feat and investigating the latecomers' strategic behaviors and technological capabilities while still in the process of accumulating market and technological successes.

Finally, this study presents the results with methodologies that haven't been widely utilized in this line of work. Previous studies that investigated the catch-ups in the manufacturing firms draw conclusions based on graphs and simple comparisons of various metrics; this study presents a rigorous statistical analysis based on regressions and offers interpretations controlled for relevant covariates.

Limitations of this study include the absence of a detailed analysis of the catch-ups and overtakes in the market performances through imitations and innovations in the business models. Future studies could attempt to separate the effects of the firms' business model strategies from technological innovations in the analysis to observe whether technological innovation is the primary factor in the catch−up.

(Table 6−1) Summary of the latecomers' catch−up/overtake

	Index		Baidu vs. Google	Alibaba vs. Amazon	Tencent vs. Facebook
1. Technological catch−up	1) Quantity	(1) Graph	Catch−up X, Overtake X	Catch−up O, Overtake O	(Since beginning) Overtake O
		(2) Regression	−	−	−
2. Catching up by similar/different technology	2) Quality	(1) Graph	Catch−up O, Overtake O	Catch−up O, Overtake △	Catch−up O, Overtake X
		(2) Regression	Catch−up X, Overtake X	Catch−up O, Overtake X	Catch−up X, Overtake X
	3) Self−citation (independence)	(1) Graph	Catch−up X, Overtake X	Catch−up O, Overtake X	Catch−up O, Overtake O
		(2) Regression	Catch−up O, Overtake X	Catch−up O, Overtake X	(Since beginning) Overtake O
	4) Mutual citation (dependence)	(1) Graph	Catch−up O, Overtake X	Catch−up O, Overtake X	Catch−up O, Overtake O
		(2) Regression	Catch−up X, Overtake X	Catch−up X, Overtake X	Catch−up O, Overtake O
3. Seeking niches, overcoming IPR barriers	5) Cycle time	(1) Graph	Short	Short	Short
		(2) Regression	Short	Similar	Short
	6) Scientific literature citation	(1) Graph	Equivalent	Equivalent	Equivalent
		(2) Regression	Equivalent	Similar	Similar

Bibliography

Agmon, T., & Kindleberger, C. P. (1977). *Multinationals from small countries* (Vol. 1). The MIT Press.

Agyeman, F. O., Ma, Z., Li, M., & Sampene, A. K. (2021). A literature review on platform business model: The impact of technological processes on platform business. EPRA International Journal of Economics, Business and Management Studies, 8(6), 1-7.

Ahmed, S., & Weber, S. (2018). China's long game in techno-nationalism. *First Monday*.

Albert, M. B., Avery, D., Narin, F., & McAllister, P. (1991). Direct validation of citation counts as indicators of industrially important patents. *Research policy, 20*(3), 251-259.

Amit, R. H., & Zott, C. (2010). Business Model Innovation: Creating Value in Times of Change. *SSRN Electronic Journal*.

Amit, R. H., & Zott, C. (2012). Creating value through business model innovation. *MIT Sloan Management Review*.

Bell, M., & Figueiredo, P. N. (2012). *Building innovative capabilities in latecomer emerging market firms: some key issues* (Vol. 1, pp. 24-109). New York and London: Oxford University Press.

Bereznoi, A. (2015). Business Model Innovation in Corporate Competitive Strategy. *Problems of Economic Transition*, *57*(8), 14–33.

Buzzell, R. D., Gale, B. T., & Sultan, R. G. (1975). Market share-a key to profitability. *Harvard business review, 53*(1), 97-106.

Cantrell, L. J., & Linder, J. (2000). Changing business models: Surveying the landscape. *Accenture Institute for Strategic Change*, 15(1), 142-149.

Casey, J., & Koleski, K. (2011). *Backgrounder: China's 12th five-year plan*. Washington, DC, USA: US-China Economic and Security Review Commission.

Chakravarthy, B., & Yau, D. (2017). Becoming global leaders: innovation challenges for five large Chinese firms. *Strategy & Leadership*, *45*(2), 19–24.

Chandel, S., Jingji, Z., Yunnan, Y., Jingyao, S., & Zhipeng, Z. (2019). The golden shield project of china: A decade later—an in-depth study of the great firewall. In *2019 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC)* (pp. 111-119). IEEE.

Cooper, A. C., & Schendel, D. (1976). *Strategic responses to technological threats* (pp. 61-69). Herman C. Krannert Graduate School of Industrial Administrationof Purdue University.

Dai, J. J., Shen, L., & Zheng, W. F. (2011). Business-model dynamics: A case study of Tencent. In *2011 IEEE 18th International Conference on Industrial Engineering and Engineering Management* (pp. 306-310). IEEE.

Deng, P. (2007). Investing for strategic resources and its rationale: The case of outward FDI from Chinese companies. *Business Horizons, 50*(1), 71–81.

Deng, P. (2009). Why do Chinese firms tend to acquire strategic assets in international expansion? *Journal of World Business, 44*(1), 74–84.

Elango, B., & Pattnaik, C. (2011). Learning Before Making the Big Leap. *Management International Review*, *51*(4), 461–481.

Foss, N. J., & Saebi, T. (2017). Fifteen years of research on business model innovation: How far have we come, and where should we go?. *Journal of management*, *43*(1), 200-227.

Frietsch, R., Neuhäusler, P., Jung, T., & van Looy, B. (2014). Patent indicators for macroeconomic growth—the value of patents estimated by export volume. *Technovation*, *34*(9), 546–558.

Frietsch, R., Schmoch, U., Van Looy, B., Walsh, J. P., Devroede, R., Du Plessis, M., ... & Schubert, T. (2010). The value and indicator function of patents (No. 15-2010). Studien zum deutschen Innovationssystem.

Fu, K. (2020, January). Analysis on the Influence of Tencent's Business Model Innovation on Business performance. In 2019 International Conference on Management Science and Industrial Economy (MSIE 2019) (pp. 12-18). Atlantis Press.

Galloway, S. (2018). *The four: the hidden DNA of Amazon, Apple, Facebook, and Google*. Penguin.

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). The NBER patent citation data file: Lessons, insights and methodological tools.

Hall, B. H., Jaffe, A., & Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of economics*, 16-38.

Hobday, M. (1995). East Asian latecomer firms: learning the technology of electronics. *World development*, 23(7), 1171-1193.

Jaffe, A. B. (1986). Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value.

Jaffe, A. B., & Trajtenberg, M. (2002). *Patents, citations, and innovations: A window on the knowledge economy*. MIT press.

Jia, K., Kenney, M., Mattila, J., & Seppala, T. (2018). The Application of Artificial Intelligence at Chinese Digital Platform Giants: Baidu, Alibaba and Tencent. *SSRN Electronic Journal*.

Joo, S. H., & Lee, K. (2010). Samsung's catch-up with Sony: an analysis using US patent data. *Journal of the Asia Pacific Economy*, *15*(3), 271–287.

Joo, S. H., Oh, C., & Lee, K. (2016). Catch-up strategy of an emerging firm in an emerging country: analysing the case of Huawei vs. Ericsson with patent data. *International Journal of Technology Management*, *72*(1/2/3), 19.

Kalathil, S. (2017). *Beyond the great firewall: How China became a global information power*. Washington, DC: Center for International Media Assistance.

Kang, J., Han, J., & Marhold, K. (2017). Technological M&A for Core Technology Change: A Feasible Strategy for Incumbent Firms to Overcome the Challenges in the Steel Industry. *BHM Berg- Und Hüttenmännische Monatshefte*, *162*(9), 397–399.

Kim, L. (1980). Stages of development of industrial technology in a developing country: a model. *Research policy*, 9(3), 254-277.

Kim, L. (1997). *Imitation to innovation: The dynamics of Korea's technological learning*. Harvard Business School Press.

Kim, L. (2001). The dynamics of technological learning in industrialisation. *international social science journal*, 53(168), 297-308.

Kim, S. (2021). International Political Economy of the Digital Platform Competition: Evolution of the US-China Competition for Technological Hegemony. *Review of International and Area Studies*, *30*(1), 41–76.

Kim, S. O. (2017). A Study on Growth Trend and Path of Chinese ICT Companies. *Korean-Chinese Social Science Studies*, *15*(3), 301–322.

Kwak, K., & Baek, S. (2017). Catch-up and Falling Behind of Latecomers : Windows of Opportunity and Strategic Response of China and Korea in Chinese Excavator Market. J*ournal of Strategic Management*, 20(2), 79-112.

Lamont, B. T., & Anderson, C. R. (1985). Mode of Corporate Diversification and Economic Performance. *Academy of Management Journal*, *28*(4), 926–934.

Lanjouw, J. O., & Schankerman, M. (2003). *Enforcement of patent rights in the United States* (pp. 145-179). Washington, DC: The National Academies Press.

Lanzolla, G., & Markides, C. (2020). A Business Model View of Strategy. *Journal of Management Studies*, *58*(2), 540–553.

Lee, C., Park, G., & Kang, J. (2016). The impact of convergence between science and technology on innovation. *The Journal of Technology Transfer*, *43*(2), 522–544.

Lee, J., Bae, Z. T., & Choi, D. K. (1988). Technology development processes: a model for a developing country with a global perspective. *R&D Management*, 18(3), 235-250.

Lee, K. (2005). Making a Technological Catch-up: Barriers and opportunities. *Asian Journal of Technology Innovation*, *13*(2), 97-131.

Lee, K. (2013). S*chumpeterian analysis of economic catch-up: Knowledge, path-creation, and the middle-income trap*. Cambridge University Press.

Lee, K. (2021). *China's Technological Leapfrogging and Economic Catch-up: A Schumpeterian Perspective*. Oxford University Press.

Lee, K., & Lim, C. (2001). Technological regimes, catching-up and leapfrogging: findings from the Korean industries. *Research policy,* 30(3), 459-483.

Lee, K., Lim, C., & Song, W. (2005). Emerging digital technology as a window of opportunity and technological leapfrogging: catch-up in digital TV by the Korean firms. *International Journal of Technology Management*, *29*(1-2), 40-63.

Lee, M., & Jung, T. (2021). Participation in public procurement and firm growth: Focusing on the moderating effect of firm age. *The Korea Society for Innovation Management & Economics*, *29*(3), 91–119.

Li, G., & Woetzel, J. (2011). What China's five-year plan means for business. *McKinsey Quarterly*, 1-6.

Lopacinska, K. (2021). Premises and Effects of Mergers and Acquisitions Concluded by Chinese Companies in the High-Tech Sector. *EUROPEAN RESEARCH STUDIES JOURNAL, XXIV*(Special Issue 4), 344–364.

Lundvall, B. K., & Rikap, C. (2022). China's catching-up in artificial intelligence seen as a co-evolution of corporate and national innovation systems. *Research Policy*, *51*(1), 104395.

Ma, C., & Liu, Z. (2016). Effects of M&As on innovation performance: empirical evidence from Chinese listed manufacturing enterprises. *Technology*

Analysis & Strategic Management, *29*(8), 960–972.

Makino, S., Lau, C. M., & Yeh, R. S. (2002). Asset-Exploitation Versus Asset-Seeking: Implications for Location Choice of Foreign Direct Investment from Newly Industrialized Economies. *Journal of International Business Studies*, *33*(3), 403–421.

Malerba, F. (2002). Sectoral systems of innovation and production. *Research policy, 31*(2), 247-264.

Malerba, F. (Ed.). (2004). *Sectoral systems of innovation: concepts, issues and analyses of six major sectors in Europe*. Cambridge university press.

Mathews, J. A. (2002). Competitive advantages of the latecomer firm: A resource-based account of industrial catch-up strategies. *Asia Pacific journal of management*, 19, 467-488.

Narin, F. (1994). Patent bibliometrics. *Scientometrics*, 30(1), 147-155.

Narin, F., Noma, E., & Perry, R. (1987). Patents as indicators of corporate technological strength. *Research policy, 16*(2-4), 143-155.

O'Neill, P., & Sohal, A. S. (1999). Business Process Reengineering A review of recent literature. *Technovation, 19*(9), 571-581.

Oh, C., & Joo, S. H. (2015). Is the technological capability gap between Hyundai and Mitsubishi converging or diverging? Findings from patent data analysis. *Asian Journal of Technology Innovation, 23*(sup1), 109–128.

Park, J., & Lee, K. (2015). Do latecomer firms rely on 'recent' and 'scientific' knowledge more than incumbent firms do? Convergence or divergence in knowledge sourcing. *Asian Journal of Technology Innovation*, *23*(sup1), 129–145.

Patel, P., & Pavitt, K. (1997). The technological competencies of the world's largest firms: complex and path-dependent, but not much variety. *Research policy, 26*(2), 141-156.

Peng, H., Zhou, C., Sadowski, B. M., & Sun, T. (2021). Does an Imitation Strategy Promote Long-Term Firm Growth in a Dynamic Environment? A Meta-Analysis. *Frontiers in Psychology, 12*, 774071.

Podolny, J. M., Stuart, T. E., & Hannan, M. T. (1996). Networks, knowledge, and niches: Competition in the worldwide semiconductor industry, 1984-1991. *American journal of sociology, 102*(3), 659-689.

Porter, M. (1987). From Competitive Advantage to Corporate Strategy. *Harvard Business Review*.

Rikap, C., & Lundvall, B. Å. (2021). *Digital Innovation Race.* Springer International Publishing.

Saviotti, P. P., & Metcalfe, J. S. (1984). A theoretical approach to the construction of technological output indicators. *Research policy, 13*(3), 141-151.

Scherer, F. (1980). M. *Industrial Market Structure and Economic Performance*.

Schoenecker, T., & Swanson, L. (2002). Indicators of firm technological capability: validity and performance implications. *IEEE Transactions on Engineering Management, 49*(1), 36-44.

Shen, H. (2020). *China's Tech Giants: Baidu, Alibaba, Tencent*. Konrad Adenauer Stiftung. Retrieved July 6, 2022, from https://www.kas.de/en/web/politikdialog-asien/single-title/-/content/chinas-tech-giganten-baidu-alibaba-tencent.

Shin, S. R., Han, J., Marhold, K., & Kang, J. (2017). Reconfiguring the firm's core technological portfolio through open innovation: focusing on technological M&A. *Journal of Knowledge Management*, *21*(3), 571–591.

Snihur, Y., & Zott, C. (2013). Legitimacy without Imitation: How to Achieve Robust Business Model Innovation. *Academy of Management Proceedings*, *2013*(1), 12656.

Snihur, Y., Zott, C., & Amit, R. R. (2021). Managing the Value Appropriation Dilemma in Business Model Innovation. *Strategy Science*, *6*(1), 22–38.

Su, C., & Flew, T. (2020). The rise of Baidu, Alibaba and Tencent (BAT) and their role in China's Belt and Road Initiative (BRI). *Global Media and Communication*, *17*(1), 67–86.

Sukarmi, S. A. F., Tejomurti, K., & Alam, M. Z. (2021). Assessing the Merger of Online Platform Companies: Does it Lead to Monopoly or just Business Expansion?(Analysis of The Merged Company of GoTo). Jurnal Cita Hukum, 9(3), 551-566.

Tsai, K. H., & Wang, J. C. (2008). External technology acquisition and firm performance: A longitudinal study. *Journal of Business Venturing*, *23*(1), 91–112.

Verspagen, B. (2007). Mapping technological trajectories as patent citation networks: A study on the history of fuel cell research. Advances in complex systems, 10(01), 93-115.

Walsh, J. P., Lee, Y. N., & Jung, T. (2016). Win, lose or draw? The fate of patented inventions. *Research Policy*, *45*(7), 1362–1373.

Wells, L. T. (1983). Third world multinationals: The rise of foreign investments from developing countries. *MIT Press Books, 1*.

Wheelwright, S. C., & Clark, K. B. (1992). *Revolutionizing product development: quantum leaps in speed, efficiency, and quality*. Simon and Schuster.

Xiyuan, W. (2019). *Business model innovation of Chinese internet enterprises a stakeholder perspective of BAT (Baidu, Alibaba, Tencent)*. Doctoral Dissertation, University Institute of Lisbon, Portugal.

Yang, S., & Jung, T. (2020). Technological importance and breadth of standard essential patents: A comparison between practicing and non-practicing entities for mobile telecommunication technologies. *ETRI Journal*, *42*(5), 734–747.

Yang, Y., Ba, Y., & Huang, J. (2021, February). Analysis on the Motivation of Internet Enterprise Strategic Mergers and Acquisitions and Financial Synergies. In *2020 International Conference on Modern Education Management, Innovation and Entrepreneurship and Social Science (MEMIESS 2020)* (pp. 201-208). Atlantis Press.

Yelle, L. E. (1979). The learning curve: Historical review and comprehensive survey. *Decision sciences, 10*(2), 302-328.

Yu, H., Dang, J., & Motohashi, K. (2018). Post-M&A technological capability-building of emerging market firms in China: the case of *Lenovo*. *Asia Pacific Business Review*, *25*(1), 40–60.

Yu, L., & Kwon, S. J. (2020). Entertainment Contents Corporation Tencent's Growth Strategy: Focusing on Imitative Innovation and M&A. *Journal of* *the Korea Entertainment Industry Association*, *14*(3), 1–13.

Zhang, C., Tsukioka, K., Yin, D., & Motohashi, K. (2019, August). Innovation strategy and technological catch-up of Chinese Internet giants: Evidence based on patent data. In 2019 Portland International Conference on Management of Engineering and Technology (PICMET) (pp. 1-14). IEEE.

Zhang, W., Wang, K., Li, L., Chen, Y., & Wang, X. (2018). The impact of firms' mergers and acquisitions on their performance in emerging economies. *Technological Forecasting and Social Change*, *135*, 208–216.

Zhao, Y., von Delft, S., Morgan-Thomas, A., & Buck, T. (2020). The evolution of platform business models: Exploring competitive battles in the world of platforms. *Long Range Planning*, *53*(4), 101892.

김환표. (2016). 마화텅: '펭귄 제국'에서 '텐센트 연방'으로. *인물과사상*, (218), 72-86.

이슬기. (2018). 중국의 중창공간(众创空间)을 중심으로, 중국 창업지원 동향. *정보통신방송정책*, *30*(21).

민성기. (2019). 중국 인터넷 서비스 기업의 다각화에 대한 연구: BAT 사례를 중심으로. *중국과 중국학*, (36), 31-57.

이효은. (2017). 페이스북과 텐센트의 차이, 중국 인터넷 종사자들의 자신만의 방법 찾기.

백서인, 김단비. (2017). 중국의 디지털 전환 동향과 시사점. *동향과 이슈*, (42), 1-41.

易观 (2021), 中国移动阅读市场年度综合分析2020

https://www.analysys.cn/article/detail/20019738

국문초록

중국과 미국 디지털 플랫폼 기업간의 Catch-up 및 Overtake 분석:

Google, Amazon, Facebook을 벤치마크하여 Baidu, Alibaba, Tencent를 분석을 중심으로

서울대학교 대학원
경제학부 경제학전공
김준엽

이 논문은 중국의 디지털 플랫폼 기업(바이두, 알리바바, 텐센트)과 미국의 디지털 플랫폼 기업(구글, 아마존, 페이스북)을 동종업군에 대해 세 가지 경우의 각각의 쌍을 비교분석함으로써 최근 중국의 디지털 플랫폼 기업의 약진의 원천요소를 탐색하려는 연구이다. 분석을 위한 디지털 플랫폼 기업간 매칭은 기술적 유사성이 높고 동종업군의 기반을 가진 디지털 플랫폼 기업을 기준으로 하며, 그 결과 바이두와 구글(검색엔진 플랫폼), 알리바바와 아마존(리테일 플랫폼), 텐센트와 페이스북(SNS 플랫폼)과 같이 3개의 쌍을 매칭하여 분석의 대상으로 삼았다. 기업별 특허자료를 바탕으로 1) 후발자의 ‘기술경로 창출 혹은 추종’의 문제, 2) 후발자의 ‘기술수명 주기와 과학기술문헌의 의존도’의 문제에 관한 가설을 검증하고 시사점을 발굴하고자 하였다.

본 연구에서는 2010년부터 2019년까지 10년간 유럽특허청(European Patent Office: EPO)의 데이터베이스(PATSTAT)를 활용하였다. PATSTAT은 전세계 90여개 국가에서 출원 및 등록한 특허자료 및 특허의 인용자료에 대한 다양한 정보를 제공할 뿐만 아니라, 특허 통계 작성을 위한 국제적 기준을 제공하고 있기때문에 학계뿐만 아니라 정부기관에서도 광범위하게 활용되는 데이터베이스로 알려져 있다. 회귀분석 모형으로는 후발자인 중국의 디지털 플랫폼 기업이 선발자인 미국의 디지털 플랫폼 기업을 Catch-up 또는 Overtake 하는 효과를 포착할 수 있는 교호작용 변수를 추가하여 분석하였다. 통제변수는 자기 특허의 누적량과 상대방 특허의 누적량, 특허가 출원된 국가의 수, 개발자의 수, 특허 청구항의 최대값, 전방인용 횟수, 후방인용 횟수, IPC 개수, 기술분야를 추가하여 분석하였다. 회귀분석 모형은 분석하고자 하는 기술지표에 따라, 특허의 질과 과학기술문헌 인용에 대해서는 poisson regresson model을, 특허의 자기인용과 상호인용에 대해서는 fractional logit regression model을, 기술수명 주기에 대해서는 linear regression model을 각각 적용하여 분석하였다.

첫 번째 경우로, 바이두는 기술의 양적Catch-up (특허량)과 질적Catch-up (특허질)을 하지 못하고 있으며, 기술의 독립성(자기인용)은 Catch-up하고 있다는 점에서 긍정적이지만, 기술의 의존성(상호인용)은 Catch-up하지 못하고 있는 것으로 분석되었다. 또한 바이두는 구글에 대해 상대적으로 기술수명 주기가 짧은 신기술을 추구하는 틈새 전략을 추구하고 있고, 과학기술문헌을 적어도 구글과 대등한 수준으로 유지하고 있다는 사실도 확인할 수 있었다. 이와 같은 결과에 비추어 볼 때, 바이두는 틈새 전략과 IPR 회피 전략을 기본적으로 추구하고는 있으나, 구글에 대항할 새로운 기술경로를 창출하지 못하고 있는 것으로 보이며, 이러한 구글과의 기술역량 등의 격차로 인해 바이두의 시장성는 구글에 비해 상당히 낮으며 2019년 시총기준 구글의 4.7% 수준에 불과했다.

두 번째 경우로, 알리바바는 아마존에 대해 기술의 양적Overtake (특허량)을 달성하였고, 질적Catch-up (특허질) 역시도 확인할 수 있었다. 또한 기술의 독립성(자기인용)에 대해서도 아마존을 Catch-up하고 있으나, 기술의 의존성(상호인용)에 있어서는 아마존을 Catch-up하지 못하고 있다. 알리바바는 아마존과 유사한 수준의 기술수명 주기를 가지는 기술을 활용하고 있고, 과학기술문헌 또한 아마존과 대등한 수준으로 유지하고 있다는 사실을 알 수 있었다. 이와 같은 결과에 비추어 볼 때, 틈새 전략과 IRP 회피 전략을 기본적으로 추구하면서, 아마존의 기술경로를 추종하는 동시에 아마존과 다른 차별적 기술경로의 창출을 시도하고 있음을 알 수 있다. 이와 같은 알리바바의 제한된 기술경로의 창출이 시장성과에도 반영되어 알리바바가 아마존의 시장성과에 상대적으로 근접해있다고 볼 수 있다. 알리바바의 제한된 기술경로 창출은 바이두의 시장성과에도 반영되어 2019년 시총기준으로 아마존의 61.1% 수준에 이르는 것으로 조사되었다.

세 번째 경우로, 텐센트는 페이스북에 대해 기술의 양적Overtake (특허량)을 달성하였으나, 질적Overtake (특허질)은 달성하지 못하고 있음을 확인할 수 있었다. 기술의 독립성 (자기인용)과 기술의 의존성 (상호인용)에 있어서도 페이스북을 Overtake 하는 결과를 보였다. 텐센트는 페이스북보다 상대적으로 기술수명이 짧은 신기술을 추구하는 틈새 전략과 과학기술문헌을 적어도 페이스북과 대등한 수준으로 유지하고 있다는 사실도 확인할 수 있었다. 이와 같은 결과에 비추어 볼 때, 텐센트는 틈새 전략과 IRP 회피 전략을 기본적으로 추구하면서, 페이스북과 다른 차별적 기술경로의 창출을 하고 있음을 알 수 있다. 다만, 특허의 질에 대한 지표까지 Overtake 을 달성한 것은 아니므로 본 연구에서 정의하고 있는 기술경로의 창출을 판단하는 지표 기준(특허질, 자기인용, 상호인용)에 의거하여 판단해보자면 페이스북과 다른 차별적 기술경로 창출을 소위 완성했다고 단언하기는 어렵지만

텐센트가 기술경로 창출 단계에 있는 것은 분명해보인다. 이러한 텐센트의 기술역량의 성과가 시장성과에도 반영되어서 2019년 시총기준으로 페이스북의 78.6% 수준에 이르고 있는 것으로 조사되었다.

종합하면, 디지털 플랫폼 서비스 업종의 후발주자로 알려져있는 바이두, 알리바바, 텐센트 등의 중국기업(BAT)은 동종업계 선발자와 비교해 상대적으로 기술수명이 짧은 신기술을 추구하는 틈새 전략과 선발자와의 IPR 분쟁을 회피할 수 있는 과기문헌 인용 전략을 채택하는 한편, 각각의 차별적인 기술경로 창출의 정도에 따라 이에 비례하는 수준의 시장성과를 달성하고 있다는 사실을 파악할 수 있었다.

또한, 각각의 케이스를 상호비교함으로써 선발자에 대한 후발자 기술관련 지표의 Catch-up 및 Overtake 의 상대적 순서 및 난의도를 유추해볼 수 있는 토대를 제공한다. 시장성과의 Catch-up 및 Overtake 의 정도를 바탕으로 특허관련 기술지표의 Catch-up 또는 Overtake 의 결과를 비교해보면, 먼저 상대적으로 특허의 양적 Catch-up, 기술 독립성의 증가가 발생하고 추후 질적인 Catch-up, 기술 의존도의 감소가 발생할 수 있다는 점을 유추해 볼 수 있다. 다시 말해, 특허를 단순히 양적으로 증가시키는 것보다 자신의 특허가 자신 또는 상대방에 의해 인용되는 것이 어려우며, 신규 특허를 출원할 때 자신의 과거 특허를 인용하는 것보다 상대방의 과거 특허를 자신이 인용하지 않으려는 것이 어렵다는 의미이다. 즉, 양적Catch-up보다 질적Catch-up이 어렵고, 기술의 독립성 강화보다 기술의 의존성 탈피가 어렵다고 할 수 있다. 특허의 양과 질, 기술의 독립성 및 의존성 지표 중에서도 특히 특허의 질적 측면에서 Overtake 을 달성하는 것이 가장 난의도가 높고 많은 시간이 소요되는 분야로 보인다.

그 외에도, 기존 연구가 주로 제조기업에 대한 연구였다면, 본 논문을 통해서는 디지털 플랫폼 서비스 기업에 대한 연구에도 기술Catch-up 이론이 적용가능하다는 것을 보였다. 그뿐만 아니라,

선발자에 대한 후발자의 완성된 Overtake 사례에 적용했던 기술Catch-up 이론을 Catch-up을 못하거나 Catch-up 중인 사례에 적용함으로써, 기술지표를 개선하며 시장성과를 축적하는 과정에 있는 후발자의 기술적 역량 및 전략적 행태를 살펴볼 수 있었다는 점도 기존 연구의 관점을 확장하고 지지할 수 있는 기여라고 생각한다.

끝으로, 제조기업에 대한 기존연구가 주로 지표의 발굴과 가시적인 그래프에 근거하여 Catch-up과 Overtake 을 판단했다면, 본 연구에서는 그래프 외에에도 계량분석을 추가함으로써 실증모형 및 통계적 해석에 근거하여 Catch-up과 Overtake 을 엄밀히 판단하고자 시도했던 점 또한 본 연구의 기여라고 할 수 있겠다.

주요어: 디지털 플랫폼 기업, 특허분석, 기술Catch-up, 기술경로 창출, 자기인용, 상호인용, 기술수명 주기, 과학기술문헌.

학번: 2011-30071