China Technological Transformation: A Case Study of Telecommunications Equipment Industry

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A B S T R A C T

China is the world's biggest telecommunications equipment exporter. Several telecommunications equipment companies from China dominate the global market, for example, Huawei and ZTE. This paper examines what factors contribute to China's rapid technological transformation, particularly in the telecommunications equipment industry. In addition, how the relationship among government policy, State-Owned Enterprises (SOEs), and entrepreneurship shaping the sector are. This study uses qualitative and quantitative approaches, data collection through literature study and observation, and data analysis using descriptive data analysis, patent analysis, and network analysis that span about 35 years (1985-2020). The results show that government technology policy, human resource development and education, foreign technology adoption and adaptation, together with indigenous R & D efforts are essential factors in China's technological transformation process in the telecommunications equipment industry. Due to China's government's encouragement, SOEs can innovate and encourages the growth of domestic entrepreneurship. Therefore, Indonesia can learn several things from China, including fostering innovation through various strategies such as implementing technology transfer, mentoring with overseas experts, increasing R & D financing support, providing support for industry and researchers in the form of tax incentives or patent subsidies. Furthermore, strengthening collaboration and cooperation with the foreign telecommunications equipment industry with win-win schemes can offer benefits to Indonesia.

1. Introduction

The telecommunications equipment industry is one of the industries with an intensive research and development (R & D) role. In 2018, R & D spending by multinational corporations engaged in this industry reached $15 billion - $20 billion or 10% - 20% of total revenue (Knight, 2019). One of the characteristics of this industry is the strong linkages between sub-sectors as a result of the high intensity of R & D. The telecommunications equipment industry can be divided into five sub-sectors; optical transmission systems, access systems, data communication systems, switch systems, and mobile communication systems (Fan, 2006).

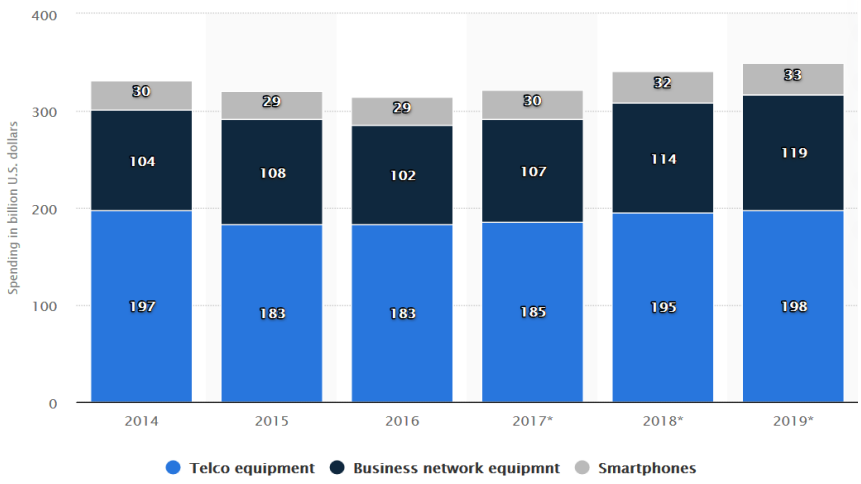


Figure 1. Global telecommunications equipment market size 2014-2019 by product in billion USD (Alsop, 2020a)

Figure 1 shows the global spending on telecommunications equipment by-products from 2014 until 2019. The global telecom equipment market size was around $185 billion in 2017, increasing of 1.09% over the previous year (Alsop, 2020a).

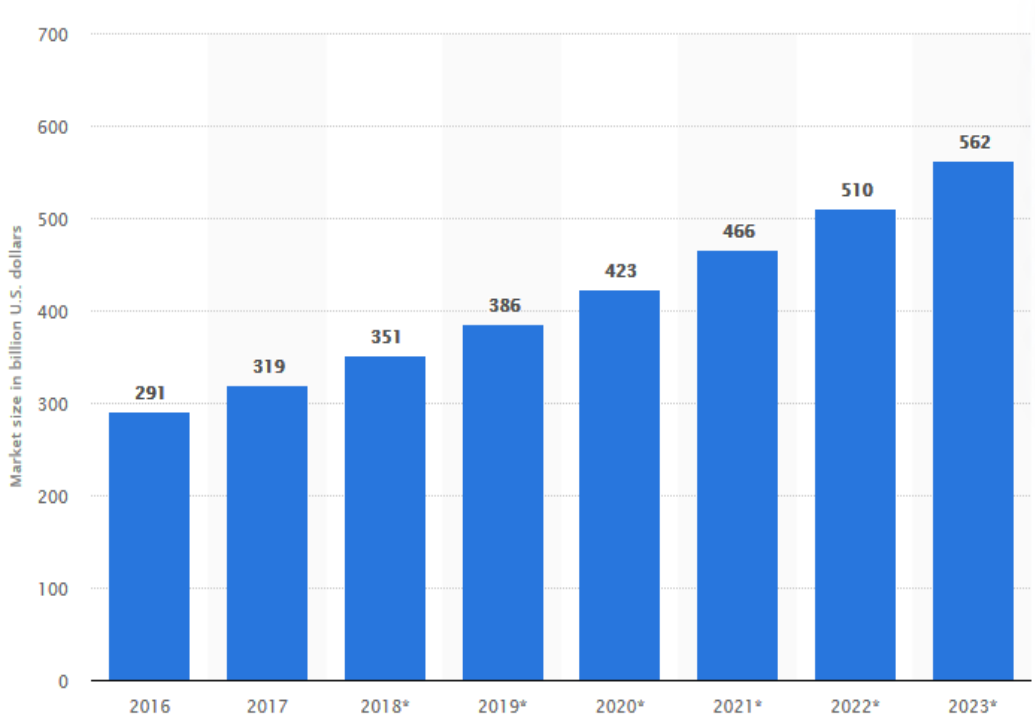


Figure 2. Global telecommunications equipment market size 2016-2023 in billion USD (Holst, 2018)

Figure 2 informs the telecom market size worldwide from 2016 to 2023. The global telecom equipment market was forecast to achieve $562 billion in 2023, increasing 10 % over the previous year (Holst, 2018).

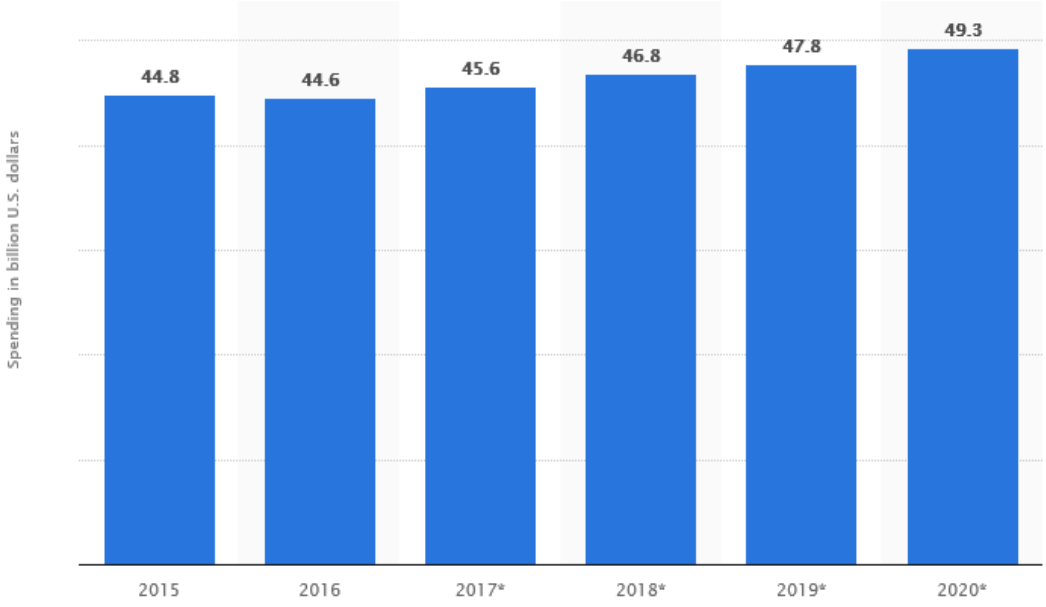


Figure 3. Worldwide telecommunications equipment spending forecast 2015-2020 in billion USD (Alsop, 2020c)

Figure 3 illustrates the spending on worldwide telecom equipment in 2015-2020. It was forecast to reach around $49.3 billion U.S. dollars in 2020, a higher 3.13 % over the previous year (Alsop, 2020c).

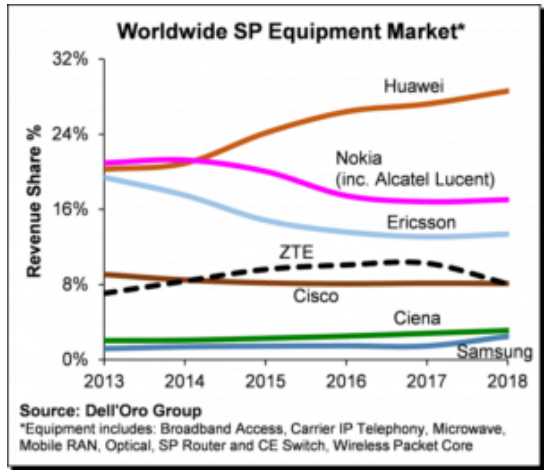


Figure 4. Worldwide service provider telecommunications equipment market 2013-2018 (Pongratz, 2019)

Huawei, Nokia, Ericsson, Cisco, ZTE, Ciena, and Samsung took the top positions as telecommunication equipment manufacturers in 2018. The contribution of these companies to the revenue of the global telecommunications equipment provider market was around 80%. The proportion of Huawei's revenue in the last five years has consistently increased by two percentage points every year, including in 2018.

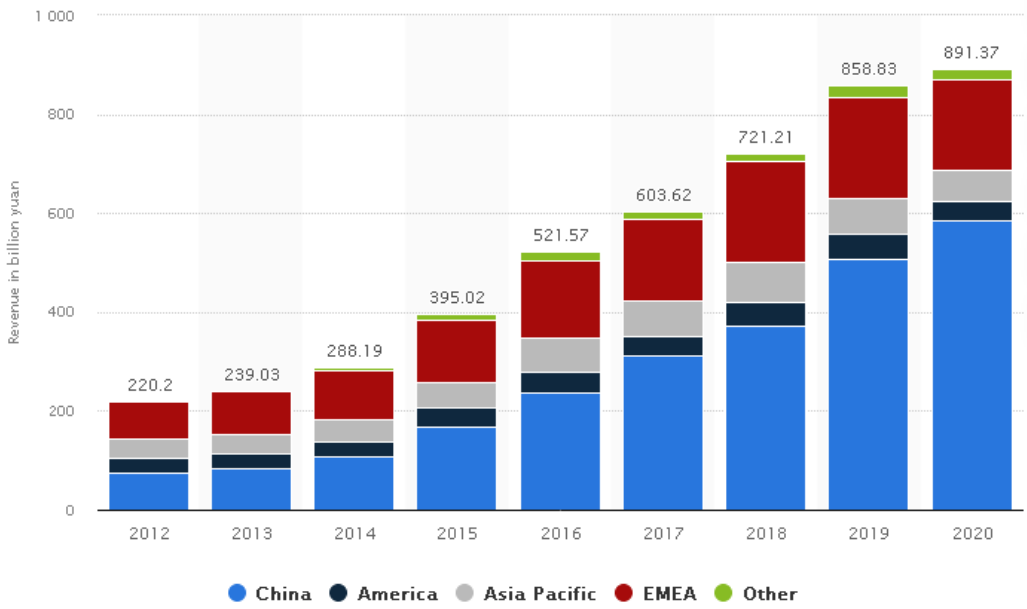


Figure 5. Huawei revenue from 2012-2020 by geographical region in billion yuan (Slotta, 2021)

In 2020, Huawei generated a revenue of about 891.37 billion yuan globally or an increase of about 70% compared to 2016. This huge amount of increase in revenue is basically because of the technological innovation capability by Huawei and supported by the government. This trend contrasts with that experienced by Ericsson and Nokia, which experienced an average decline of 1 percentage point every year in the same period. The US trade banned imposed on ZTE in 2018 even caused ZTE's stock to decline by two percentage points from its normal value of 10%. This condition caused ZTE to close several businesses in the second quarter (Pongratz, 2019).

Figure 6 illustrates the ranking of telecommunications equipment companies sorted by total revenue in 2018. It can be seen from the graph that the top position was held by Huawei, with total revenue in 2018 reaching $104 billion. This figure crowns Huawei as the largest telecommunications equipment manufacturer (TEM) in all business segments (Alsop, 2020b). Huawei is the world's largest manufacturer of equipment and devices used in the telecommunications industry located in China. China is the world's biggest telecommunications equipment exporter. According to World Trade Organization (WTO), China exported

$592 billion in telecom equipment, 32% of the world's total in 2017. This achievement was reached in three decades (Yeung & Zhou, 2019).

What is behind the rapid transformation of China's technology in the telecommunications equipment industry is an important topic to be learned by other countries to develop their telecommunications equipment industry, including Indonesia. This paper examines what factors are causing the rapid technological transformation in China's telecommunications equipment industry? How is the relationship between government policies, State-Owned Enterprises (BUMN), and entrepreneurship in shaping the sector?

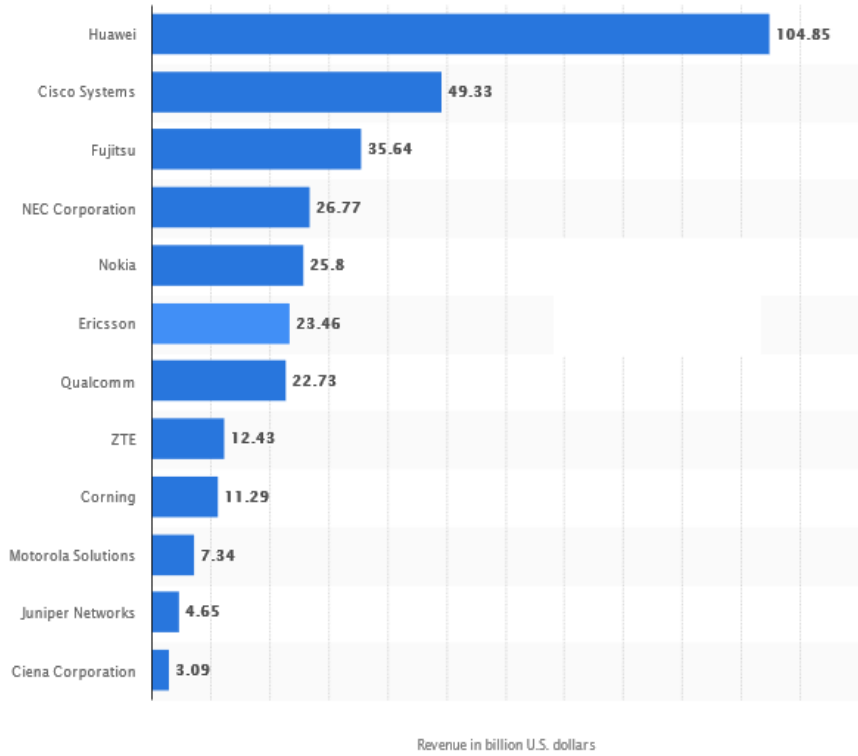


Figure 6. Total revenue global telecommunications equipment companies in 2018 in billion USD (Alsop, 2020b)

2. Literature Review

2.1 Telecommunication Equipment in China

Based on the obligation to fulfill an access license to the network, telecommunications equipment connected to the telecommunications network in China can be divided into three categories: 1) Equipment used in the interconnection between networks, 2) Wireless telecommunication equipment, and 3) Telecommunication terminal equipment (BWTCmall, 2021; Fu, 2010; Wang, 2017).

Telecommunication Regulation of PRC-The Decree of the State Council No. 291 of 2000 states that telecommunications equipment connected to public networks must meet the standards and be subject to the licensing system set by the state. Its purpose is to ensure the smooth operation (interconnection) of all telecommunications networks in China, maintain network and information security, and protect the rights and interests of users and operators. The licensing system for these needs is known as the Network Access License (NAL). NAL is a network access license agreement that applies to telecommunications equipment connected to the public telecommunications network using wired or wireless. The Ministry of Industry and Information Technology of China (MIIT) is responsible for developing and revising standards in the electronics and communications sector and NAL approval. MIIT publishes the list of NAL products. NAL approval can be granted for the three categories of telecommunications equipment in Figure 7 (BWTCmall, 2021; Fu, 2010; Wang, 2017).

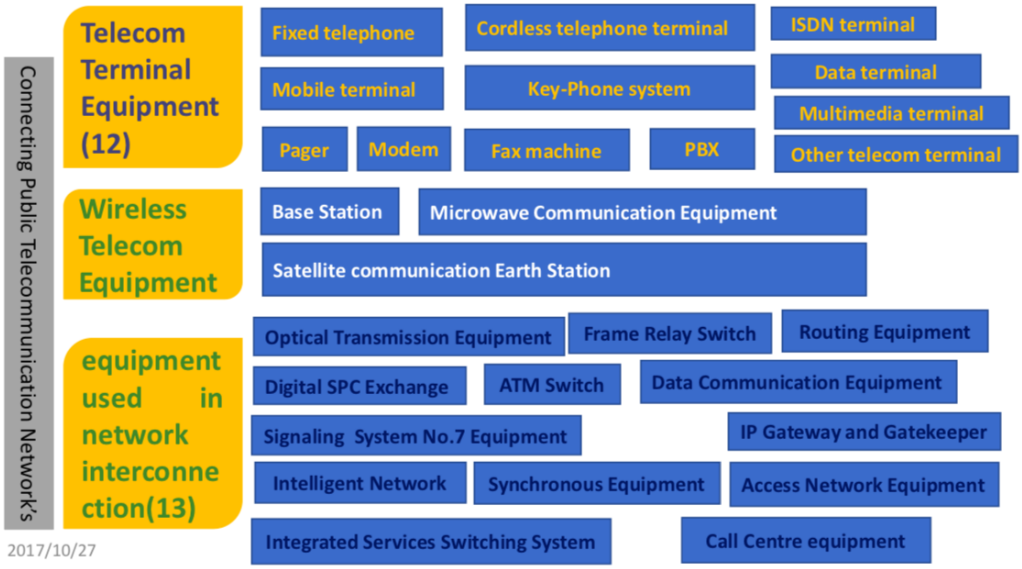


Figure 7. Equipment categories (Wang, 2017)

If the device has an RF function, it is necessary to have a State Radio Regulation Committee (SRRC) certification, a radio type approval that must be met for wireless devices before being NAL licensed. After obtaining the NAL, some devices also need to get the China Compulsory Certification (CCC), China's national security and quality mark. Each approved product will be marked with a certification number and a Network Access Identifier (NAI) (BWTCmall, 2021).

Table 1. Sample of license certificate and NAL label

Valid Term	3 Years	Less than 1 year (probation)
License Certification		
NAL Label		

Source: Wang (2017)

The NAL certificate consists of information on the certificate number, application unit, manufacturer, device name, device model, place of origin, description, certificate issuance date, and the certificate's effective date. Products that have been certified or have obtained permission to access the network must be affixed with the NAL label by the telecommunications equipment manufacturer. This label is printed and issued uniformly by MIIT. The NAL label includes code (certification number), model of the device, and product ID information. MIIT announces a list of devices and manufacturers that get NAL every two weeks via the website. In August 2017, 7,000 manufacturers had received 88,000 licenses. However, only 1,800 manufacturers had 14,000 valid licenses (BWTCmall, 2021; Fu, 2010; Liu, 2014; Wang, 2017).

2.2 Telecommunication Equipment Industry in China

The telecommunication equipment industry in China is basically a state-driven mix with entrepreneurship by the Chinese innovators. The state has a pivotal role in developing the Chinese telecom industry (Li, 2017).

This enduring role of the government and the importance of relational management conducted by the SOEs between firms and institutions are unique institutional and cultural characteristics of China different from private enterprises by the western firms. It is believed that a contextual framework of the evolution of China's telecommunication equipment market in which foreign manufactures, local manufactures, government policies, and SOEs investment have shape rapid technology transformation in China's telecommunication industry (Low, 2005).

Chinese SOEs are the driver, regulator, and upbringing of the private enterprises under the guidance of opening up China to catch up the technologies and benefit from trading market access technology. This policy is basically a win-win situation for foreign manufacturers to share their technology know-how with the nascent Chinese industry to leapfrogged by joint cooperation or joint ventures. The output of this cooperation then developed ingeniously by Chinese firm domestic incubator by the SOEs and those who are far excellence will be supported by the government via a patent application and other incentives (Yuan, 2020). This is why this study focuses on SOEs in China because all the non-SOEs in the telecommunication equipment industry in China that flourished right now essentially emerge from the SOEs and government policies that are conducive for them to grow up.

2.3 State-Owned Enterpreneurship (SOE) in China

In terms of the legal system, there is a law in China for SOEs. This law is essential because now SOEs are under the process of reform. With this, SOEs have enjoyed more and more independent decision-making on business operations. To accommodate this move, the government (the State Council/SC) has created an institution directly under the management of SC in 2003 called The State-owned Asset Supervision and Administration Commission of the State (SASAC). SASAC operates as a government agency. SASAC carries out function as a manager in SOEs management in 97 inter-state companies. It is related to the market mechanism issue in China that needs to be controlled by the government and not surrender wholly to the market mechanism.

In this scheme, the government has three primary roles: shareholder, market regulator, and order competitionfirst, the government's role as a shareholder or property investor does not intervene in day-to-day commercial operation. Second, the government's role as market regulator make sure standard and maintain the market. Third, the government promotes a more level playing field where 'ordering competition' takes place as part of the standard quality control. The SASAC provides state-owned assets supervision, state-owned assets management, and other services. In other words, the government established this special agency to focus on the asset, not on the day-to-day business operation of China's SOEs. The government only focuses on asset supervision and administration. This institution was formed explicitly through the consolidation of ministries related to the industry.

Nearly 50% of SOEs were sold in shares in the economic reform, while SASAC managed the rest. Some of the responsibilities assigned to SASAC include appointing top executives, approving the sale or merger of shares or assets, and drafting laws related to SOEs. Currently, there are 97 centrally owned companies under the supervision of SASAC. In 2008 there were 150 companies. The number of companies being managed continues to decrease due to mergers which are part of the SOE structuring plan. SASAC's combined assets in 2017 were CNY 161 trillion ($26 trillion) with revenues of over CNY 23.4 trillion ($3.6 trillion) and a share value of CNY 50 trillion ($7.6 trillion). This figure makes SASAC the largest economic entity in the world. Private firms suffer from a lack of access to financial capital compared to SOEs. Many founders of many SMEs share their stories that they use their house and car as security for loans. Although they have become successful in the end, their cases are still not replicable by others. That is why SOE's innovation capabilities are very tricky. There are very innovative SOEs while others are not. In China, how SOEs are managed is the key. If Industrial experts manage SOEs with long-term tenures, the SOEs tend to be innovative. If SOEs has been appointed an outsider as the top manager who is likely to leave in 4-5 five years, the SOE tend to be less innovative (Bloomberg News, 2018; Wu, 2017; Xinhua, 2017).

2.4 Previous Research

Several researchers have carried out research related to the development of the telecommunications equipment industry in China:

Lee et al conducted a study entitled "Industrial Catch-Up in China: A Sectoral Systems of Innovation Perspective" and found that the opportunities for new players to catch up in the industry in China are not only influenced by the regime of the technology sector but also by government and corporate actions. Local industries must be able to develop on their strength and not depend entirely on foreign investment. The technology transfer policy is also related to the achievement of the industry to catch up. In addition, the dominance of the Chinese market with various segments is also one of the keys for domestic companies to survive in the competition (Lee, Gao, & Li, 2016).

In their article "Related Yet Diverging Sectoral Systems: Telecommunications Equipment and Semiconductors in China," Yu and colleagues examine the evolution of telecommunications equipment and the semiconductor industry in China. The study results found that the characteristics of a vertically integrated industry can be viewed as two integrated sectoral systems. This relationship can affect the speed and direction of innovation from industrial development in each industry (Yu, Malerba, Adams, & Zhang, 2017).

Tan, in his article "Disruptive Innovation and Technology Ecosystem: The evolution of the Intercohesive Public-Private Collaboration Network in Chinese Telecommunication Industry," informed that the government formed a strategic group by involving various institutions to overcome obstacles and reconfigure industrial networks (Tan, Wang, Zhang, & Li, 2020).

Previous studies have found that ecosystem-driven innovation, government and corporate actions, and market dominance through industrial or institutional cooperation and integration impact the development of the industry in general and the telecommunications industry in particular in China. The study will also focus on developing the telecommunications equipment industry in China and specifically analyze the factors that drive the rapid technological transformation. Do the factors mentioned in previous studies also apply in this process, or are other factors contributing to it? In addition, it will also examine the relationship between the government, state-owned enterprises, and companies in the development of the telecommunications equipment industry in China. SOE is one of the entities in the telecommunications equipment industry that is interesting to be studied.

3. Method

This study uses mixed-method, qualitative and quantitative approach. In this mixed method, we collect, analyze, and integrate both quantitative and qualitative data in a single study of China's technological transformation in telecommucations equipment to address our research questions. In our quantitative method, we seek out factors, determinants, relationships, causes, influences, or effects from our data to answer our research questions. On the other hand, our qualitative focus on exploration and creation, figuring out the meaning to answer our research questions.

This mixed method will address what factors of a rapid technology transformation in China's telecommunications equipment industry. A convergent parallel mixed-methods design is used. It is a type of design in which qualitative and quantitative data are collected in parallel and analyzed separately. Data collection was carried out through a literature study and observations related to the focus of the study, technological transformation in China, especially for the telecommunications equipment industry. Data was obtained from books, journals, news, reports, previous research, and other types of resource documents.

The data is analyzed to answer the questions in this study, the factors contributing to the rapid technological transformation in China, especially in the telecommunications equipment industry. In addition, the relationship among the government, SOE, and entrepreneurs, which use patent data as part of data analysis sources, is also identified (patent analysis).

In this study, quantitative data from Web of Science (WoS) and the China Knowledge Center for Engineering Sciences and Technology (CKCEST) will be used to test the theory of strategic innovation from a follower (catch-upper) to leader (first-mover) supported by government policy to spur indigenous technological capability that predicts that China's policy environment and entrepreneurship will positively influence China's

technological transformation in telecommunications equipment. The patent data was retrieved from WoS databases with Derwent Innovations Index (DII). WoS is the world's most trusted publisher-independent global citation database. DII combines unique value-added patent information indexed from over 50 patent issuing authorities in the Derwent World Patent Index (1963-present) with patent citations indexed from the Derwent Patents Citation Index that analyzed from 1985-2020. Query patent data according to the research focus (keywords telecommunication equipment and formula TI= (telecommunications equipment OR telephone sets OR cellular networks OR wireless networks*) AND TS= (transmission OR reception images data OR high-speed data processing OR 4G OR 5G)). The patent data was analyzed through CKCEST. The relationship between leadership and innovation was analyzed through linear regression and correlation. While the data for network analysis was obtained and analyzed by Ucinet software.

CKCEST is a non-profit open knowledge resource aggregation and service platform in China's national technical science and technology field. The existence of this platform is approved by the Chinese government and is an essential part of the national informatization strategy. This platform committed to provide information support and knowledge services in national policy-making with priority in engineering sciences and technology, engineering science and technology projects, business innovation and talent development, data mining centers, and knowledge service centers for engineering science and technology (CKCEST, 2012).

Figure 8. Display of the China Knowledge Center for Engineering Sciences and Technology website homepage (Chen, 2020)

Patent data is processed quantitatively using the patent analysis feature provided on the CKCEST before being analyzed with the following steps:

a. After logging in, select the "patent analysis" feature, then select the "create a new task" menu.
b. Uploading data files from query results. The only file types that can be uploaded are txt, zip, and gz. Then fill in the existing fields such as data type and file description.
c. Select the analyzed data and move directly to the results page. The results are displayed in several forms, including line charts and rose charts. Data can also be presented in histograms, bar charts, pie charts, radar charts, and several other formats.
d. Data is also processed in the form of word cloud and 2-dimensional analysis.
e. Images or charts are downloaded so that they can be presented in data analysis.

Figure 9. Patent analysis feature on the China Knowledge Center for Engineering Sciences and Technology website (Chen, 2020)

Data processing results were analyzed to answer questions about the relationship between government, SOE, and entrepreneurship. Using this method and focus, the factors that lead China in rapid technology transformation, especially in the telecommunication industry, can be answered. Thus, the strategy can be learned. The data processing used differs (chart, world cloud, 2-dimensional, and network) depending on the analysis needs. Conclusion and recommendations are provided at the end of the paper.

The patent application is essential for China to broaden their invention strategy and protect their indigenous technology from their interaction with the foreign manufactures after the opening up of China in 1978. As we have explained above, the data that we obtain from this patent analysis and network analysis may describe the rapid technological transformation of China in telecommunication equipment and the relationship between government policy, SOES, and entrepreneurship for shaping the Chinese telecommunications equipment industry as what it is like now.

4. Result and Discussion

The development of the telecommunications industry in China shows that domestic manufacturers have succeeded in catching up with the capabilities of multinational companies (MNCs) in gaining domestic market share. This success has made Chinese domestic companies able to occupy leading positions in the industry. It was driven by the Chinese government's industrial policy and domestic TEM innovation capabilities.

The keys of the implemented industrial policy role are economic goals planning, cooperation with SOEs for policy implementation in areas identified with high risk, and sponsorship from the government in research and development. Industry development led by the government has collaborated with the acquisition of innovation capabilities. The acquisition of the capability is an increase in the ability to innovate and self-developed technologies.

This strategy is in contrast to the strategy of imitating or assimilating outdated technology from other developed countries. Two giants Chinese TEM companies, Huawei and ZTE, have increased their innovation capabilities by applying two ways; developing internal R & D and building group collaborations with external stakeholders (Fan, 2006).

Table 2. Leadership and innovation capability of major domestic telecommunications equipment manufacturers

Companies/Type	Type	Leadership in Telecommunications Equipment Industry (Y)	Rank in Innovation Capability (X)
Huawei Technology Corporation	Private	1	1
ZTE Corporation	Semi-Private	2	2
China Post Communications Equipment	SOE	4	7
Datang Telecom Technology	SOE	5	4
Wuhan Research Institute of Posts and Telecommunications	SOE	6	5
Changfei Optical Fiber and Optical Cable	SOE	7	6

Source: Huawei (2019); ZTE Corporation (2019)

The analysis of the relationship between telecommunications equipment industry leadership and rankings in innovation ability of the seven telecommunications equipment manufacturers shown in Table 2 gives the results in Figure 10. Figure 10 shows that the R^2 value is 0.60. This result can be interpreted that innovation capability has a close relationship with leadership in the telecommunications equipment industry.

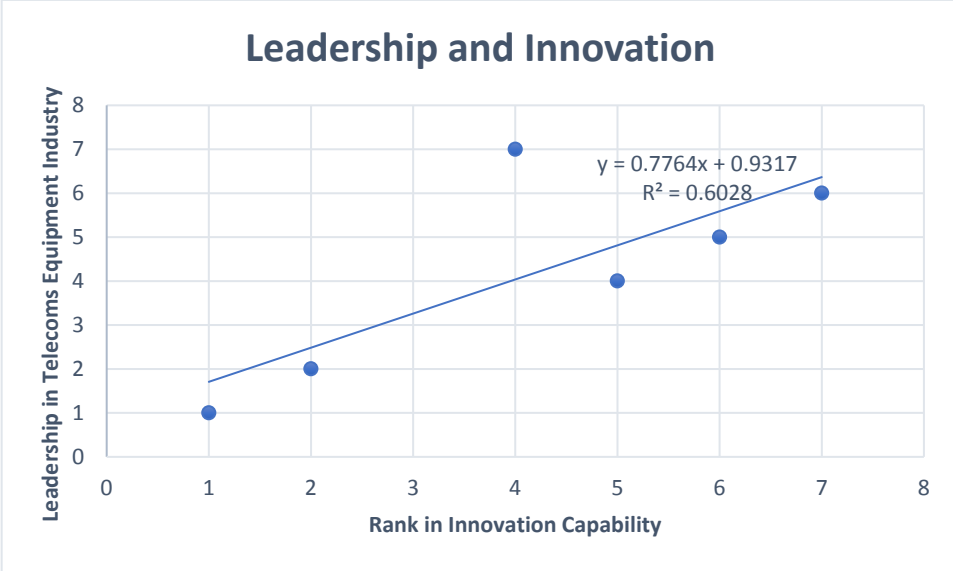


Figure 10. Linear regression and correlation between leadership and innovation (Source: Data Processed)

China is still a follower in various sectors as part of its innovation strategy. But the change has been shown from just imitating to making improvements on existing technology. Some companies in China are well known to the world even though they are small companies. They started business in this industry as an OEM factory to foreign buyers and continued developing their innovation capabilities through active learning. These efforts make them the world's leading supplier of certain products. Their product market is mainly sold limited to specific companies, thus unknown by the public. Continuous innovation and development based on shop-floor innovation are the keys. In addition, the implementation of a cultural and managerial strategic organization and increasing R & D and design capabilities are also essential parts. Technology is not easy to understand and easy to transfer to new locations.

China's telecommunications equipment technology is not just products and processes but also embedded in innovators (people). The government accelerate this technological knowledge via public knowledge, by buying patents and latest high-tech telecom equipment, and endow patent rights to a private, proprietary knowledge to SOEs or research institution. Government has a key role in almost all stages of development. Therefore, industrial policy is essential and has a positive role in developing the telecommunications equipment industrial sector. The development of telecommunications equipment in China began in 1978 through political and strategic decisions taken by the Chinese government. Foreign companies are allowed to enter the Chinese telecommunications market but must follow the mechanism established by the state.

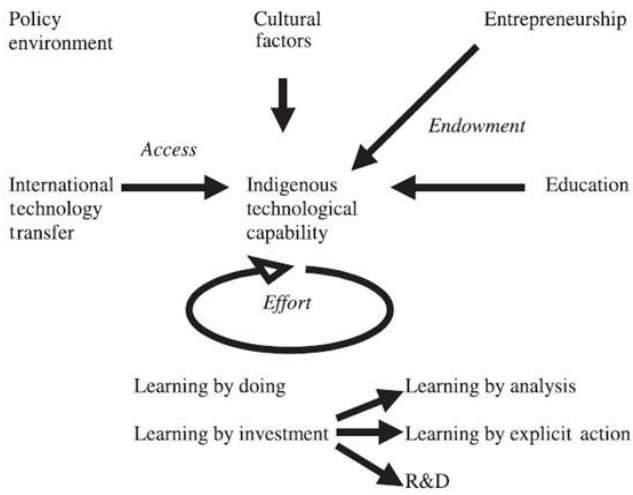


Figure 11. Understanding technical capability in firms (Yuan, 2020)

Based on the PRC Law on Sino-Foreign Equity Joint Ventures (JV) in 1978, China developed an official Trading Markets for Technology (TMFT) strategy that promotes and encourages the formation of JVs between

SOEs and foreign companies. This strategy emphasizes technology sharing with SOEs as a licensing requirement for foreign companies to access the Chinese market. The manifestation of this strategy can be divided into 6 (six) phases (Emiroğlu, 2014, 2015):

Phase I: Establish a JV for digital phone switch, which aims to open up opportunities for foreign companies to enter with various products through infrastructure and encourage domestic companies that was just entering the industry to develop their products.

Phase II: Transfer of knowledge on digital switch technology from the first JV Shanghai Bell to Huawei and research consortium. In addition, at this stage, the Chinese government also conducts industrial promotion.

Phase III: Awareness efforts about the national digital transition. The research consortium developed a new switch type, HJD-04, in 1991 by adapting a multi-processor distributed control system. In this phase, original equipment suppliers was promoted through technology diffusion in technology transfer and local R&D efforts by domestic companies.

Phase IV: Focus on mobile technology, developed the third generation Time Division-Synchronous Code Division Multiple Access (3G TD-SCDMA) standard. In this phase, China also tried to produce systems and equipment based on its TD-SCDMA infrastructure without signing expensive license agreements with EU and US patent holders.

Phase V: Industrialization of TD-SCDMA as China's original innovation in the telecommunications industry. This strategy was followed by Huawei's breakthrough in 2004 in the European market. Huawei collaborates with the Dutch operator Telfort to implement a particular solution for 3G enhancement (Soo & Tao, 2019).

Phase VI: 5G development and battle plans from the United States. The United States has long sought to limit the manufacture of Chinese telecommunications equipment. For security and economic reasons, the United States lobbied Western allies to follow suit. The monopoly of US telecommunications equipment manufacturers is the reason the United States does not want China to excel in 5G technology. This has become a major issue in the economic and geopolitical competition of the two world economic giants, China and the United States (Benner, 2020).

Amid political obstacles, Huawei and ZTE delivered encouraging results for China. In 2018, Huawei recorded revenues of CNY 721.2 billion, or the equivalent of $105.19 billion. This figure is increasing by about 19.5% every year. In 2019, Huawei's revenue reached CNY 858.8 billion. Nearly half of Huawei's revenue comes from overseas markets (Huawei, 2019). ZTE also showed an increase in operating income of 6.1% in 2018-2019, CNY 85.5 billion ($12.7 billion) in 2018 to CNY 90.7 billion in 2019 (ZTE Corporation, 2019, 2020). TEM China is predicted to actively occupy the telecommunications industry market because it excels in low costs.

4.1 Factors in Rapid Technology Transformation in China's Telecommunications Equipment Industry

In terms of telecommunications equipment technology, at first, China is an early adopter and early majority because China just bought from the market leader and prepared to learn how to use and seek significant strategic advantage from radical innovation. In terms of market evolution, Chinese telecommunications equipment is adopting both technology push and adopters pull. It means that Chinese telecommunications equipment firms have their experiment involving interaction with users. Many of its innovations are designed or drawn by users or so-called lead user innovation. Chinese telecommunications equipment firms are applying aggressive price business models to generate revenue as their competitive advantage. Compare with other telecommunications equipment firms, Chinese firms are still playing on revenue-generating models instead of value propositions, value architectures, or value-capturing models.

Considering that China is still followers in innovation, as it also happens in telecommunications equipment technology, China emphasizes efficiency to obtain significant economic returns. It is because getting returns requires entrepreneurial innovation, not all about leading-edge technology. Entrepreneurial innovation consists of more meaning and elements, and the government fully supports it in China.

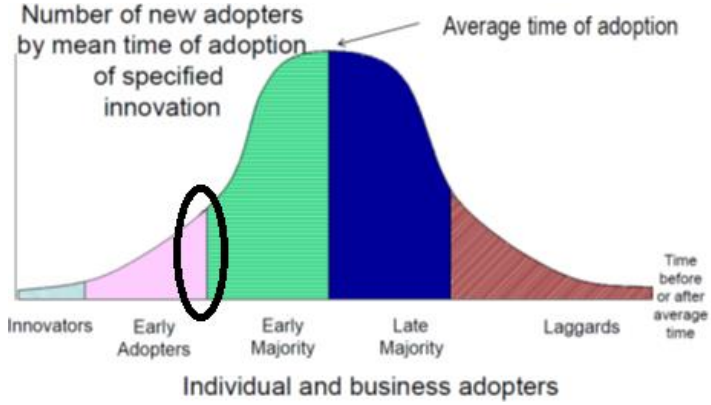


Figure 12. Types of adopters (of innovation) segmented by sequence of adoption (Yuan, 2019)

The Chinese government runs a technology development program and makes innovation plans with strong intentions using adequate resources. All stakeholders also support this intention. China has officially stated its intention since launching the National Standardization Strategy at its 2001 accession to the WTO and is currently realizing that intention.

China plans to contribute to international industry regulations by launching China Standards 2035, a continuation of Made in China 2025. Standards are not based on where global goods are made but to determine production, exchange, and consumption. In 2015, China launched its Made in China 2025 strategy, which aims to transform China from a major producer of the world's manufactured goods to a producer of the high-tech powerhouse.

China is working with private investors to buy foreign technology companies. Made in China 2025 is related to strategic investments abroad and developing country chains in manufacturing. China does this to make better products than foreign products in their own country. The government has played critical roles in the catch-up of many technologies in China, like in the telecommunications equipment industry. The role of the Chinese government is mainly to protect specific sectors that are unable to compete with foreign firms at the moment. After the technological capability has been formed in China, the government will gradually exit the market.

In the 19th CPC Chinese National Congress, President Xi Jinping said that China had transformed its economy towards a high-quality real economic development stage from the previous stage, rapid growth, one of which is developing power grids and optical communications.

China is trying to push its industry to occupy an upper-middle position in the global value chain and become advanced manufacture on a world scale. The strategy chosen is to make the company a major player in formulating a market-oriented innovation system strategy that involves synergies between universities, research institutions, and companies.

This shows that the growth of TEM in China wasdriven by government policies and the support of SOEs and entrepreneurship development since 1982, which aims to realize public welfare and national rejuvenation (Jinping, 2017; Xinhua, 2017).

The Chinese government's role in the technological transformation of telecommunications equipment, innovation capabilities, and technological self-development are the keys to China's success in catching up with MNCs (Fan, 2006). The strategy is to utilize imported products, promote Sino-foreign JV, and then develop domestic companies. This strategy was implemented in the multi-stage network infrastructure development that began in the 1980s. China imported sophisticated network technology from abroad to replace the network equipment used because it was old.

In parallel, domestic state-owned companies continue to produce substandard equipment. Subsequently, the government encourages the establishment of cooperation between foreign companies and SOEs by giving large market shares to foreign companies. In partnership, China is also trying to transfer technology so that domestic companies are more competitive in domestic and foreign markets. However, at the end of the industrial policy, there was a change in which large private companies in China emerged as state-owned competitors in the telecommunications equipment market. China's industrial policy goals were achieved in two

decades. China managed to show good results, and the technology adoption strategy carried out was able to maintain dominance in the domestic market. The telecommunication equipment products produced by China can even compete in the international market (Harwit, 2007).

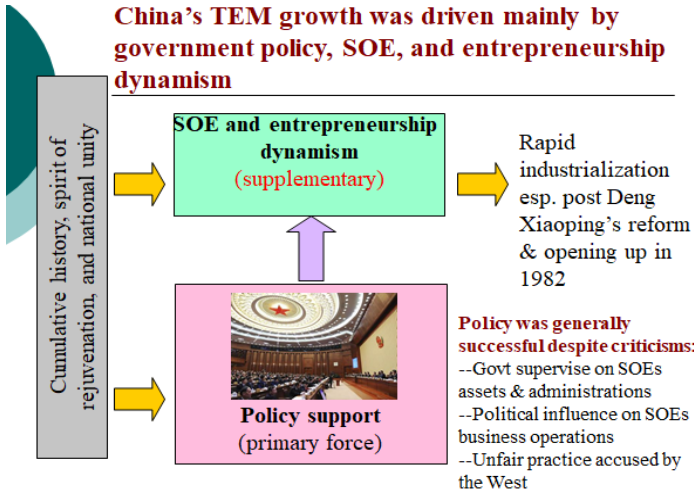


Figure 13. China's TEM growth (Source: Data Processed)

It shows that the entry of foreign firms and the entry/restructuring of local firms dramatically changed Chinese and global markets' competitive landscape. Under the CPC regime, SOEs remained largely inefficient and continued to produce lower-quality goods due to a lack of incentive to innovate (Chang, 2013). These SOEs were not able to compete effectively with MNCs. Thus, the Chinese government placed various constraints on MNCs even as they opened their markets to them. One example is the private company Huawei led by a military officer, Ren Zhengfei. Ren Zhengfei believes that the government's policy of market exchange with technology has led to MNCs' domination of the domestic market. China will not acquire foreign technology and will even harm domestic companies (Xiao, 2002). Ren Zhengfei and Huawei are highly respected by the Chinese because of their success in the telecommunications equipment industry, outperforming domestic companies and JV MNCs.

In contrast to ZTE, which was treated as an SOE in 1990, Huawei is a private company managed and owned by the private sector (siyao siying). However, both ZTE and Huawei enjoy government support in the form of protection to take over the market from foreign JVs. The two strategies that the two companies chose to seize the domestic market were 1) offering the price of head office switch product almost half of the JV's price.

This strategy contributed to a decrease in the price of head office switches, and 2) made rural China a target market by offering products that suit the more limited needs of people in the region. People in this area are among the poorest in China, so they can't afford the high-end, expensive products made by JV manufacturers. Domestic strategies in export market expansion for switching products and 3G standards to developing countries are also carried out by the two companies. In its history, Huawei experienced a turning point in 1994.

At a meeting with CCP secretary-general Jiang Zemin, Ren Zhengfei said switching technology is related to national security. A country that does not have its switching equipment is like a country that does not have its military. The government ended its particular import policy on telecommunications equipment in 1996. This move was predicted as a reaction to national security issues raised at a meeting between Jiang Zemin and Ren Zhengfei. Huawei leadership appreciates the government's role in Huawei's development. He said (Fan, 2006):

> *"... Huawei was something naïve to choose telecommunications equipment as its business domain in the beginning. Huawei was not prepared for such an intensified competition when the company was just established. The rivals were internationally companies with assets valued at tens of billions of dollars. If there had been no government policy to protect (nationally owned companies), Huawei would no longer exist ..."*

Hence, at least four factors contributed to rapid technology transformation in China's telecommunications equipment; government technology policy, human resource development and education, foreign technology adoption and adaptation, and indigenous R & D efforts. China also has a focused industrial system based on

Five-Year Plan (FYP). Therefore, China's industrial system is the government's concerted efforts, business, labor, and the general public in industrializing the economy.

4.2 Relationship Among Government Policy, SOEs, and Entrepreneurship in Shaping the Telecommunications Equipment Industry

The operating mechanism is the government-led market that supports R&D and patent subsidizing for scholars and inventors to develop technologies. Government subsidies make research more accessible. Start from the market side to encourage sponsorship, government procurement, and encourage M & A. When the MNCs come with their foreign investments, it starts with setting the technological standard to help grow technology and finally, comes back to the market again. With this Chinese market can catch up and build up production based on indigenous technology, build tech competencies via collaboration and finally come back to the market to compete.

The stressing point is government intervention is massively conducted in China in selected technological development, industry, and market. Government policy tools in china function in the cluster of public enterprises, procurement, and price instruments. Supply-side feed-in R&D, demand policy on procurement, and institutional on its general and sustainable technological development policy. Consequently, the relationship between government policy, SOEs, and entrepreneurship in shaping the telecommunications equipment industry was complicated, but its underlying stories were interesting and divided into three tiers.

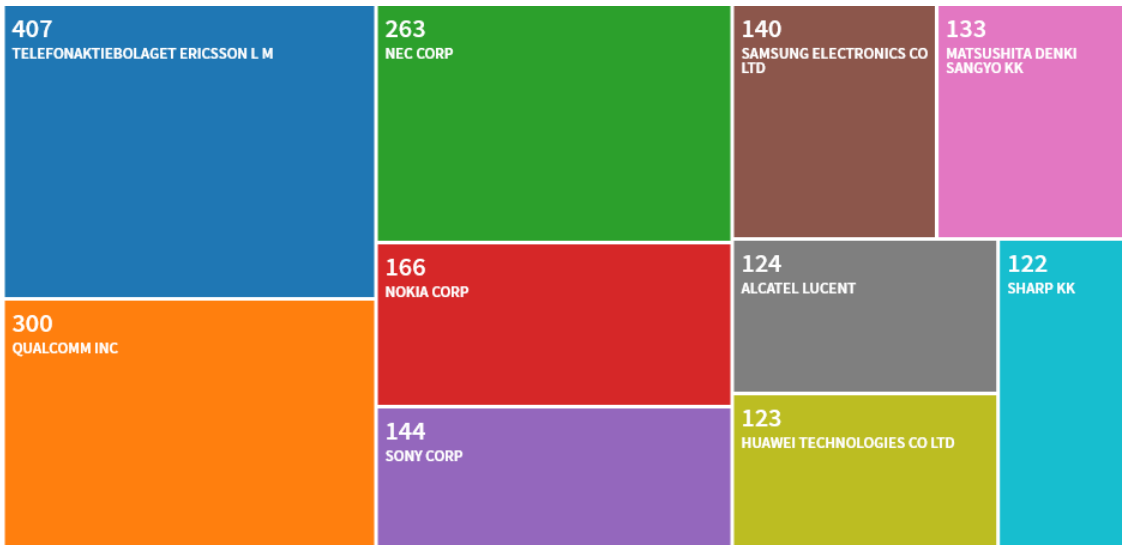
The first tier, China’s SOEs technological transformation were done through government plan and financial support like low-interest loans and tariff exception in the 1990s. It took to three years to complete, and it was a large-scale acquisition exercise. Second-tier technology transformations were done through MNCs. Protective border measures force MNCs to invest in factories in China to penetrate China's domestic market. China exercises a policy: “bring in technology, and then you can sell in China.”

The mandatory export ratio is variable according to a particular criterion. The third tier is private enterprises. Only in the third tier that entrepreneurship drives technical upgrading and innovation. In this way, entrepreneurship is the key driver for the economy and market. The first tier did not perform well compared to the second and third-tier because leaders in SOEs were not pure entrepreneurs. Their fates did not rest in the enterprises they were assigned in. Their future was controlled in the hands of ‘organization departments’ in the party. They have fewer incentives to initiate technology transformation for their successor unless the government asked them.

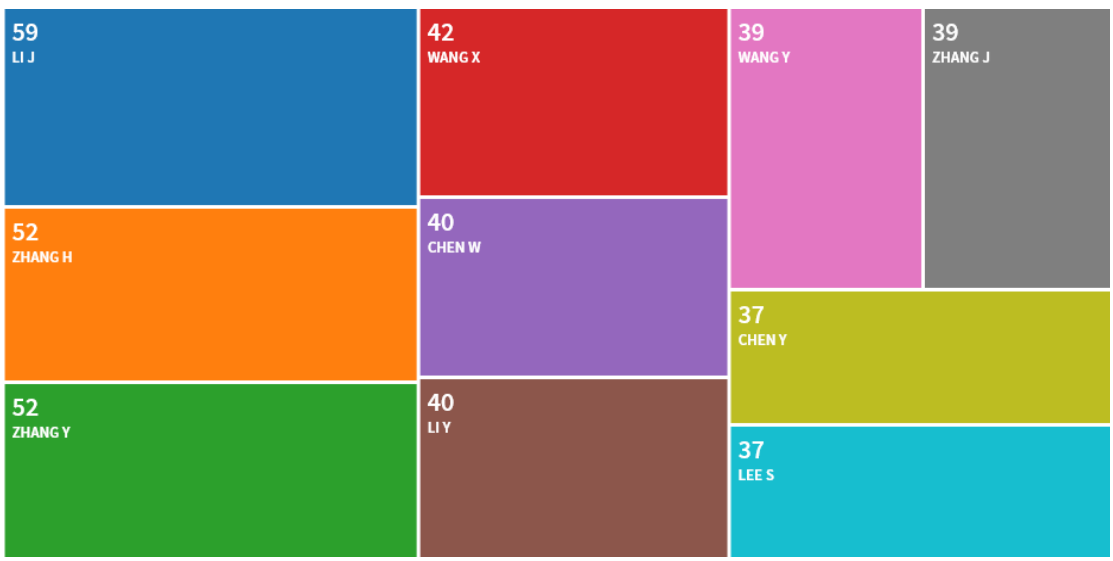
In this case, China is changing its technological capabilities by implementing the triple helix innovation model. This model refers to the collaboration between government, industry, and academia (universities), which aims to promote social and economic development with the concept of a knowledge society and economy. The model is manifested in China's intellectual property. As a form of compliance with ministerial regulations and commissions on technology transfer, universities currently usually have IPs from research funded by the government. Universities and companies in China are starting to realize that the next generation of telecommunications equipment inventors has the opportunity to set the de facto global standard. They can determine who will license it after patenting the technology globaly. The effect will be seen years later as the technology matures. Types of high-tech products such as telecommunications are estimated to take about five years (Atun, Harvey, & Wild, 2007).

Based on data patent retrieval of telecommunication equipment and processing using the WoS and CKCEST patent analysis, 8,343 total patent data results were found for 35 years (1985-2020). In the exports and imports related to international trade, this result is categorized under HS Code 8517.

(a)



(b)



(c)

Figure 14. Visualization treemap of telecommunications equipment patent based on (a) subject areas, (b) assignee name, and (c) inventor (Source: Data Processed)

Based on observations of patent trends over the past few decades, it was known that the number of world patents applications of telecommunications equipment fluctuates.

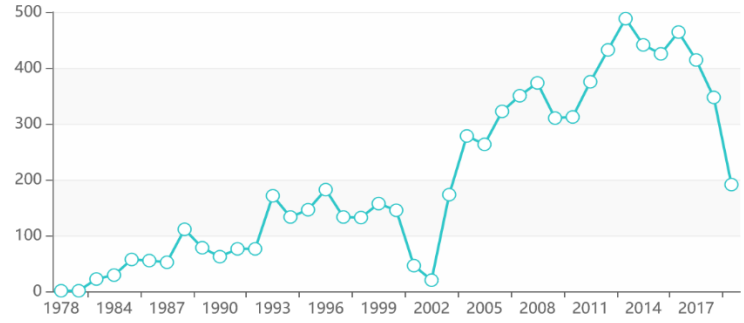


Figure 15. Global patent annual trends in 1978-2019 (Sources: Data Processed)

From 1978 to 1987, patent applications grew slowly. Telecommunications equipment was in the early stages of development. From 2002 to 2013, patent applications grew fast. It was the telecom equipment expansion stage. It reached it's peak in 2013 with 488 patents. After that, it fluctuated and plummeted to 191 patents in 2019. The general trend was on the rise, telecom equipment technology development trend is good.

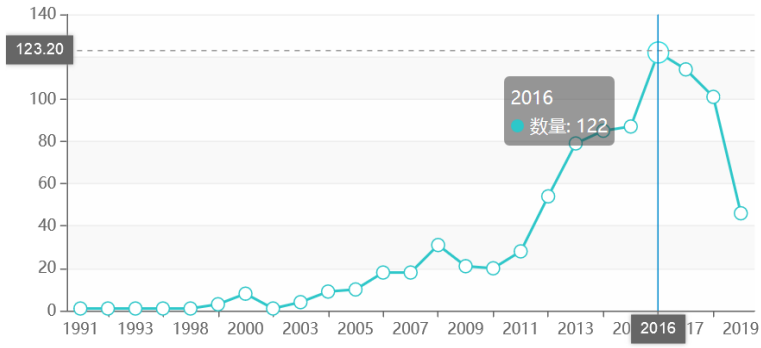


Figure 16. China patent annual trends in 1991-2019 (Source: Data Processed)

As for China, we can infer based on Figure 16 that the first patent was in 1991 and reached its peak in 2016 with 122 patents and plummet to 46 patents in 2019. However, the general trend is on the rise, and the trend is good. If we compare with Figure 17 below, we can see clearly that the progress of China patent applications from 1991-2019 has been accelerating. China has held the four position of the highest number of patent applications.

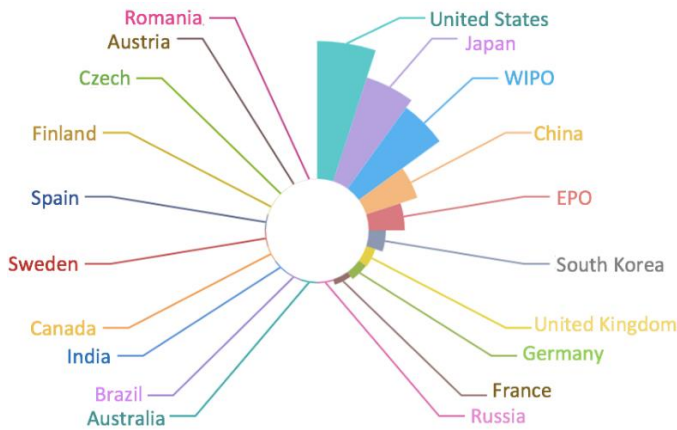


Figure 17. Analysis of patent application by countries (Source: Data Processed)

If we analyze the five countries with the highest number of patent applications, it is found that the United States ranks at the top of the highest number of patent applications for telecommunications equipment with 2,204 patents (28.3%), followed by Japan with 1,749 patents (22.45%), World Intellectual Property Organization (WIPO) with 1,603 patent (20.58%), China with 864 patents (11.09%), dan Exclusive Provider

Organization (EPO) with 579 (7.43%). USA patent applications accounted for 28.3% of the total, which shows that the USA attaches great importance to telecom equip. At the moment, China is catching up with 864 patents.

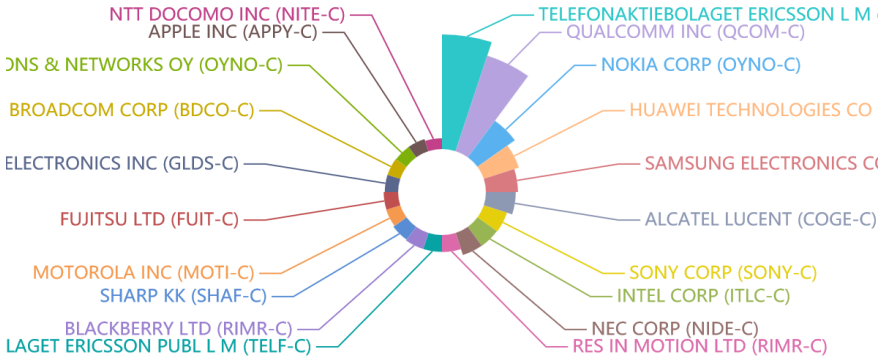
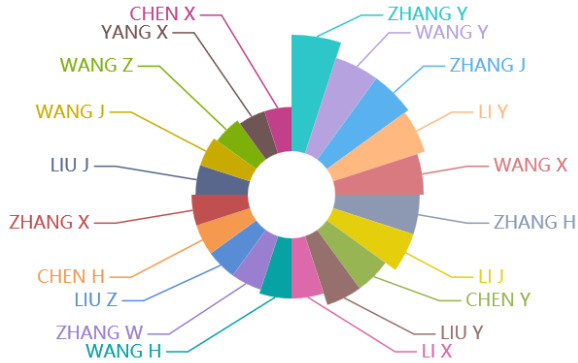
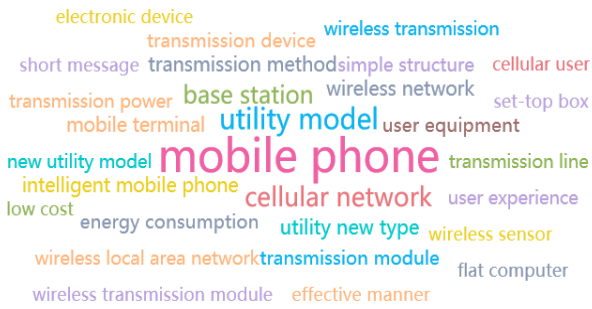


Figure 18. Analysis of patent applications by assignees (Source: Data Processed)

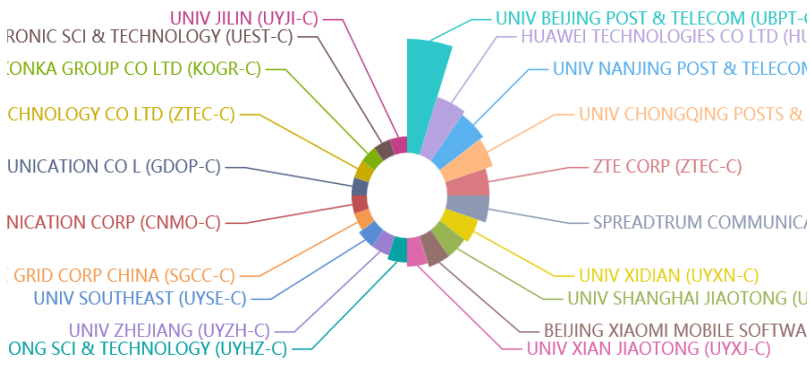
From Figure 18, we can know which organization has the highest patent applications and the strongest technical strength. The top five companies with the most patent applications are Telefonaktiebolaget Ericsson (647 patents or about 19.58%), Qualcomm (567 patents, 17.16%), Nokia (255 patents, 7.72%), Huawei (204 patents, 6,17%), and Samsung (177 patents, 5.36%), nearly accounted for 60% of all.



(a)



(b)



(c)

Figure 19. Analysis of patent applications by (a) assignees in China, (b) word cloud, and (c) its agencies (Sources: Data Processed)

If we break down China's patent applications for telecommunications equipment, we found that it is mostly on mobile phones (217 patents), followed by utility model (88 patents) and cellular network (73 patents). In China, universities are major sources of invention patenting. The top 5 are University Beijing Post & Telecom (28 patents or about 16.67%), Huawei Technologies (15 patents, 8.93%), University Nanjing Post & Telecom (14 patents, 8.33%), University Chongqing Posts & Telecom (13 patents, 7.74%), and ZTE Corp (11 patents, 6.55%).

These five institutions have amounted to 48.22% of Chinese telecommunications equipment patents. SOE accounted for only about 5%, represented by State Grid Corp China (4 patents, 2.38%) and China Mobile Communication Corp (4 patents, 2.38%).

These results indicate that China has implemented the triple helix model. Innovation for development is carried out by industry and academia (universities), and the government. These three roles join hands in the production, transfer, and application of knowledge. Innovation in China arises within each of the three spheres and links each other: university, industry, and government.

Figure 20. Analysis of telecommunications equipment by word cloud (Sources: Data Processed)

From the word cloud of telecommunications equipment, we can see the keywords that appear most frequently are "base station" (786 patents), next is "cellular network (742 patents)," and "user equipment (720 patents)", it shows that patents have the most connection with "telecom equip."

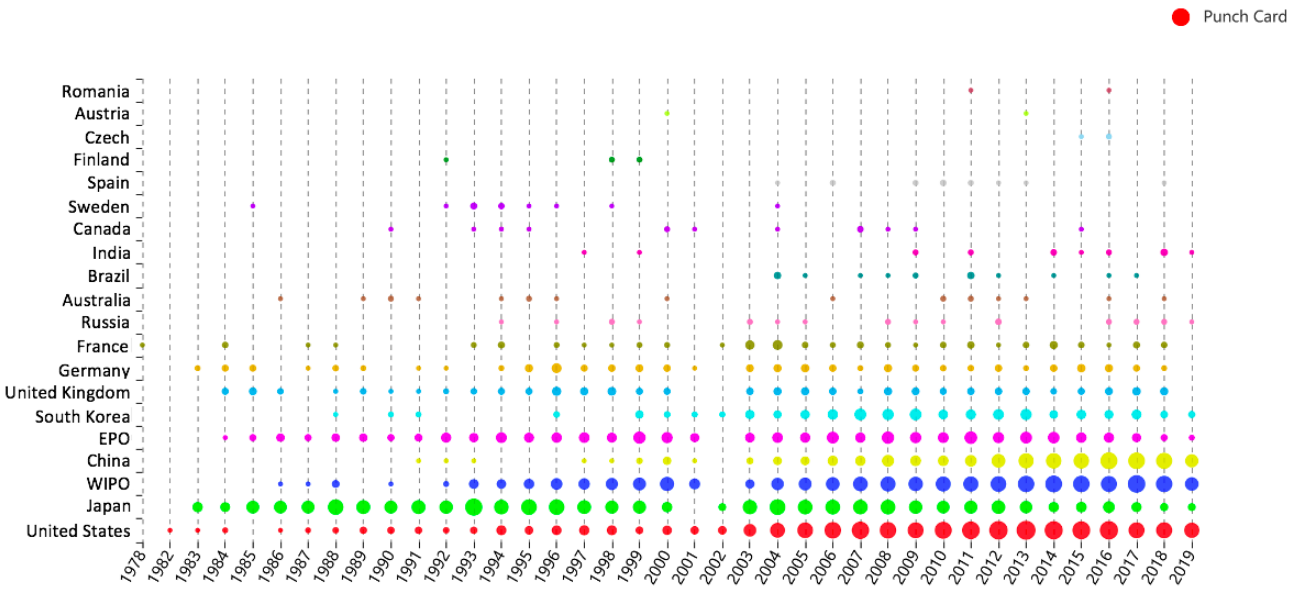


Figure 21. Application time-application country analysis (Sources: Data Processed)

From application time-application country 2-dimensional analysis, we can see that the first country to apply for telecommunications equipment patent was France in 1978 (1 patent), the next is USA (1982, 1 patent) and Japan (1983, 18 patents) and Germany (1983, 2 patents). The first Chinese patent for telecommunications equipment was filed in 1991 in switching equipment (base station controller). Although China started late, it has developed rapidly.

Even though France was the pioneer in telecom equipment, it is not lagging, though still at top-10 countries who filled the most international patent applications in telecom equipment. China is ranked third in telecommunications equipment patent applications because WIPO and EPO international and multilateral organizations have 193 member states and 38 contracting states.

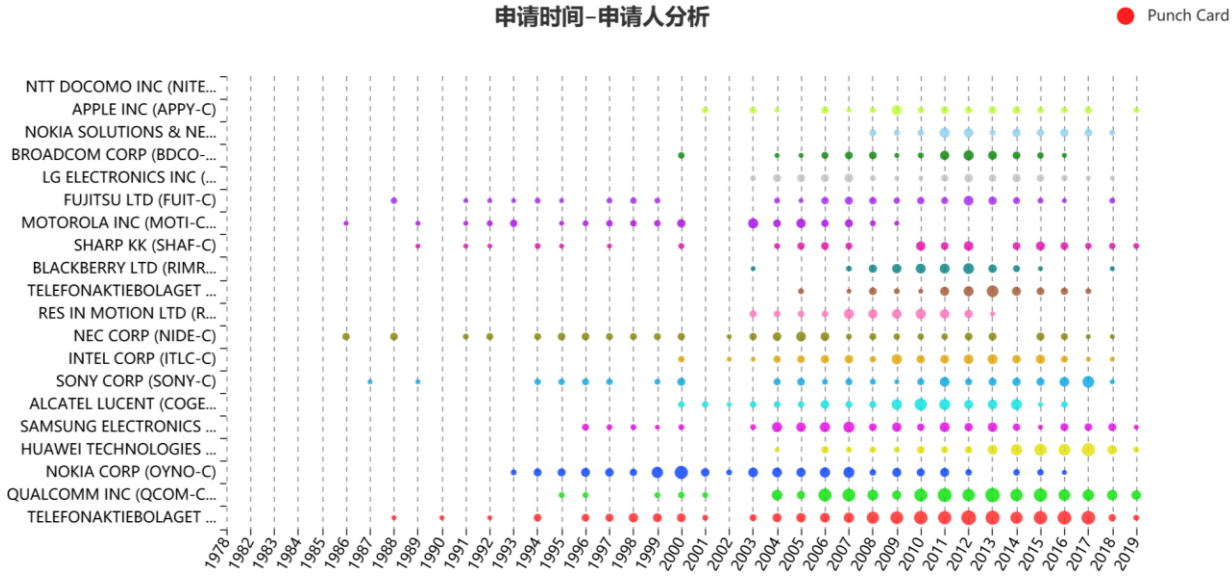


Figure 22. Two-dimensional analysis based on assignees (Sources: Data Processed)

Figure 22 is a 2-dimensional analysis based on assignees. The three top players are Telefonaktiebolaget LM Ericsson, followed by Qualcomm, Nokia, Huawei, and Samsung. The first movers are NEC (Japan) and Motorola (USA). The first Chinese patent for telecommunications equipment was filed in 2004 by Huawei. From that year, China as a latecomer, succeed in catch-up and move towards the top 5 technological leaders in telecom equip. It has to be related with imitation to innovation strategy conducted by China for late movers' catch-up strategy.

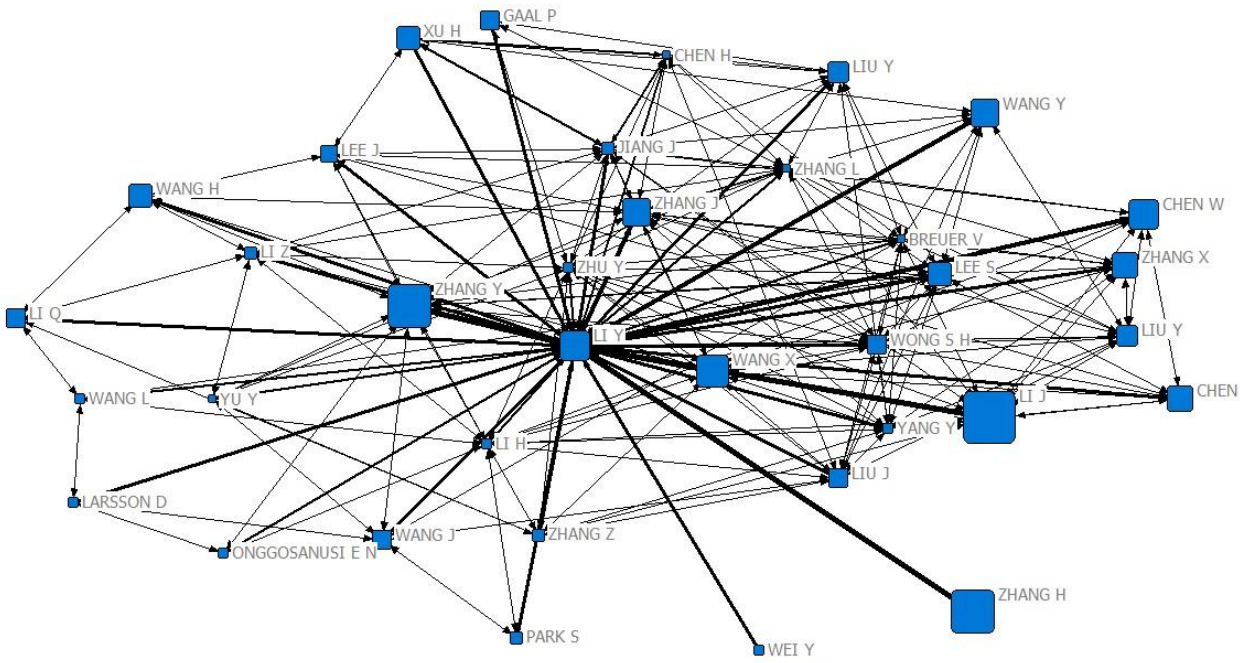


Figure 23. Network analysis of telecommunications equipment patent retrieval (Sources: Data Processed)

Based on Figure 23, it can be concluded some points:

a. Zhang Y, Li Y, and Wang X are from the same country (China) with a thick network and work more closely together.

b. It implies that telecommunications equipment involves many inventors that research it as a whole system in a high complexity and interdependent from study item and working item.
c. These inventors have their patents based on their ideas and proposals and discuss them together for their complexity and performance. Their patent applications basically protect their ideas or proposals. This process takes quite a long and ends with a feature that is decided together.
d. This network analysis shows us that patents in telecommunications equipment development are basically synthesized from many proposals acknowledged as competitive. It also tells that seldom there is a single proposal from an inventor or enterprise that has been adopted as it is (without modification). The decision is taken by consensus (consents process).
e. These kinds of patents are one of many ways to implement telecommunications equipment development.
f. There is an Indonesian inventor named Eko Onggosanusi who worked as Research Director in Samsung Research America.

5. Conclusion

Based on the results and analysis obtained, it can be concluded that several factors contribute to the rapid technology transformation in China are government technology policy, human resource development and education, foreign technology adoption and adaptation, and indigenous R & D efforts. In this process, the government does not work alone but also collaborates with SOE and entrepreneurship. Thanks to the government's encouragement, SOEs can innovate. It also encourages the growth of domestic entrepreneurship spread throughout China.

Indonesia and China telecommunications equipment industries differ mainly in a number of unique institutional and cultural characteristics, such as the enduring role of relational management between firms and institutions. Indonesia tends to depend on oligarchs to sustain innovation. These oligarchs that acted as business magnates are getting privileges from the government based on their close and mutual relations, while for China, it is based on meritocracy and single leadership. Ass the most powerful actor in Indonesia, Oligarchy is lethargic to innovate and be comfortable with the import-oriented strategy to fill the technology gap. While, it is precisely the opposite with China not only to fill the technology gap but bound to leap to become leaders, not followers.

Indonesia can learn from China in terms of developing its telecommunications equipment industry. Currently, the domestic industry in Indonesia is still unable to keep up with the telecommunications equipment industry at the global level. Therefore, several recommendations that can be given based on the results obtained in this study are more directed towards the development of the telecommunications equipment industry in Indonesia.

Based on our study we provide concrete suggestion for Indonesian policy makers or stakeholders to have five strategic policies to spur innovation, especially in the telecommunications equipment. Frist, implementing a technology transfer strategy that is profitable for Indonesia to encourage increased innovation. Second, implementing a mentoring system by presenting technology experts or foreign scientists for HR development to strengthen competitiveness and increase innovation capabilities. Third, strengthening cooperation and collaboration with foreign technology companies, for example, in the form of joint ventures but with periodic performance evaluations to provide significant benefits for increasing the competitiveness of the domestic industry. Fourth, increasing the R & D budget to encourage innovation. Fifth, the government supports domestic industry and researchers to increase production and innovation, for example, by providing tax incentives or subsidies for patents. Sixth, activating the role of SOEs as agents of change in the latest technology.

This study has potential limitations. The effect estimates in the model and our data are based on multiple forms of quantitative data and probably lack open-ended qualitative data. Therefore, our estimates may be conservative and underestimate the non-SOEs in shaping the telecommunications equipment industry in China.

6. Acknowledgments

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