

Motivation factors of technological innovation in China's telecommunications industry

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Abstract. As one of the basic industries in the digital era, the telecommunications industry not only holds the lifeblood of the national communications career, but also closely affects the way and the quality of people's life. The innovations of telecom technologies can affect every aspect of the telecom industry chain and jointly promote the development of the entire industry. However, statistical data indicate that compared with other countries over the world, the current level of technological innovation in China's telecommunications industry remains to be improved. Based on the theory of technological innovation, this paper identifies and analyses the main contributory factors which affect technological innovation in China's telecommunications industry. Specifically, we establish a dynamic system of technological innovation for the telecom industry and deploy the method of econometrics to verify its internal mechanism. The empirical results show that there is a significant positive correlation between the technological innovation outputs and the factors including government investment, market competition intensity, R&D investment of enterprises, enterprise learning ability and linkage strength of industry innovation chain.

Key words. Technological innovation, telecommunications, motivation.

1. Introduction

In the era of economic globalization and rapid development of information, science and technology have become the core competencies between countries, Social progress, economic take-off, improvement in people's lives depends on the improvement of technical level. The history of human society shows that the country which

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is actively innovating, can seize the opportunities, and get the rapid development, and the other country which is conservative can only miss the opportunity. As a source of national prosperity, technological innovation has been concerned and studied by economists such as Schumpeter, and gradually summed up a set of scientific and technological innovation theory for future generations to learn and use [1]. Although the theory of technological innovation has been studied and improved by a lot of scholars since Schumpeter, but the theory of the combination of technological innovation and industry or enterprise is not mature enough, few scholars focus on a particular industry or the enterprise in it to conduct comprehensive and systematic analysis of technological innovation power. As the main point of technological innovation, the enterprises are obliged to the commercial applications and the proliferation of the new technology. The technological innovation power of the enterprise not only affect its' own technological innovation activities, will also affect the technological development process of the whole industry and society [2, 3]. And enterprises need theoretical support and guidance to adjust and enhance their own innovation. Therefore, it is necessary to improve the theory of technological innovation for enterprises.

As an important part of the information industry, telecom industry mastered the lifeblood of information and communication in the internet era. The development of the telecommunications industry not only significantly affected the economic development and social progress, but also closely related to people's lives [4, 5]. With the enhancing of economic and science strength and the improvement of national income, the scale of China's telecommunications industry is also continuing to expand. In 2016, the number of national telephone users increased by 26.17 million net, totaling 1.53 billion. Among them, the number of mobile phone users increased by 50.55 million, totaling 1.32 billion. The popularizing rate of mobile phone users is 96.2 / 100 people. The number of 4G users got explosive growth, it increase by 340 million in this year, totaling 770 million, the penetration rate of mobile phone users is 58.2%. In the same year, the number of the fixed Internet broadband access users of the three basic telecommunications enterprises increased by 37.77 million, a total of 297 million. With the internet broadband city construction continues to advance, fiber access quickly spread, the number of FTTH / O users increase by 7.94 million net, a total of 228 million [6]. The data is depicted in Figure 1. The industry data show that China is already the world's largest telecommunications market. The telecom industry has the characteristics of high-tech industry, technological innovation is the core of its development strategy. With the advent of 3G and 4G times, the competition in the telecommunications industry is becoming more and more intense, and the new technology and new business in the field of telecommunications emerge endlessly. Technological innovation is increasingly becoming the key to sustainable development of telecom enterprises. However, China's telecommunications industry's latest technological level in the world ranking has yet to be improved, in 2016, China's ICT development index (IDI), which measures the development of information and communication technology (ICT), ranked 81, with IDI of 5.19 (global average of 4.94), fixed broadband penetration of only 18.6% and global ranking of 55. In China's telecommunications industry, the level of technological

innovation does not match the size of the telecommunications market. Consumers get poor technology and services at higher prices. As the largest telecommunications market in the world, consumers in China do not enjoy the profit brought by scale economy and network externality. China's telecom industry carries the important task of information and communication development. Technological innovation as an important driving force for the development of the telecommunications industry, will directly affect the business changes, market expansion and the improvement of economic benefits [7, 8]. However, there are still a variety of problem in technical innovation in current Chinese telecommunications industry, and the technological level also need to be improved, So the study of technological innovation in China's telecommunications industry is very meaningful.

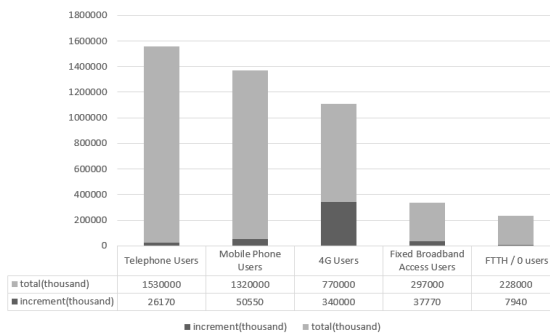


Fig. 1. The scale of China's telecommunications industry in 2016

In summary, this paper combines the existing technological innovation theory, establishes a technical innovation power system for China's telecommunications industry, and deeply discuss the characteristics of the motive force and the impact of the technological innovation on telecommunications companies. These studies fill the theoretical gap between the theory of technological innovation and the specific industry or business. At the same time, we use the regression method to test the motive force, and analyze the effect of different motive force. This research method analyzes and evaluates the motive situation of technological innovation in the telecommunication industry scientifically and effectively. It not only conforms to the trend of social development, but also laid a solid foundation for the comprehensive and systematic study of technological innovation power theory in the further. Therefore, it is of great theoretical significance to study the motive force of technological innovation.

2. Technological Innovation Power System in China's Telecom Industry

Enterprise technology innovation is often affected by many factors, different motive force will affect and depend on each other, and jointly promote the technological innovation process of the enterprise and the industry as a whole. So we can give the following definition of the technological innovation power system: An organic

whole with a specific function, which is combined by the technological innovation motivational elements that affect and depend on each other. The telecom enterprises plays a major role in the process of technological innovation in the China's telecom industry. In order to study the motivation factors of technological innovation in China's telecommunications industry, we can start from the research of the telecommunications enterprises. There is no enterprise can be independent of the external environment and other related businesses. Its production, management and technological innovation will inevitably be affected by many factors. The impact of external environment on enterprise technological innovation is mainly reflected in the policy, market and new technology. The cooperation alliance with related business and the interaction in the industry chain will also bring a steady stream of power to the technological innovation of the enterprises. Of course, the enterprise's technological innovation is also largely dependent on the internal organization. In addition, a positive corporate culture, the innovative atmosphere, the effective incentive mechanism, the regulatory system, and the adequate R&D investment and construction will promote the innovation and development of enterprises. In summary, the source of technological innovation in China's telecom industry can be divided into three aspects like external environment, within the enterprise, internal cooperation between the enterprises.

External environmental factors include government incentives, market demand, market competition and technology promotion [9]. As an industry deeply affected by government regulation, the technological innovation process of China's telecom industry is largely related to government incentives [10]. The types of government incentives are varied, including material support, intellectual property protection, and spiritual incentives. The driving force of market demand mainly includes product demand situation, new product profit space and so on. Market competition as another market factor also has an impact on the technological innovation of the telecommunications industry. The influencing factors include market competition intensity and fairness of market competition. Moreover, because of the characteristics of high technology, the business changes and product updates of the telecom industry need a steady stream of scientific and technical support, so the continuous supply of new technologies is also a key driving force to promote innovation in the industry. The driving forces of technology promotion include the supply of scientific and technological achievements and the spread of science and technology.

The internal motivation of the organization means the power generated by the telecom enterprise to promote technological innovation. As the core member of the technological innovation in the industry, the telecom enterprise is the foundation and the source to promote technological innovation of telecom industry. Internal organizational factors include corporate culture, resources and competencies, entrepreneurial spirit and organizational systems. Enterprise culture is the spiritual civilization foundation of technological innovation in telecom industry. It embodies the value of advocating technological innovation in telecommunications companies. When the innovative corporate culture is effectively accepted by all members, it will inspire and promote the staff consciously immerse into the technical innovation work, so as to create an innovational atmosphere and stimulate the overall effort.

Resources and competencies means the resources and learning skills that enterprises have in terms of technology. Entrepreneurship can often affect the culture and management style of the whole enterprise. Negative and conservative entrepreneurial spirit will lead to the stagnation of the whole enterprise. Positive and aggressive entrepreneurial spirit can lead the enterprise to achieve the rapid development of technological innovation.

Inter-firm factors include cooperative alliances and innovative chains. The alliance between telecom companies can reduce the risks and uncertainties of the innovation process, reduce transaction costs, achieve economies of scale and accelerate the commercialization of new technologies. Compared to the technical cooperation alliance, the innovation chain emphasizes an open cooperation across the enterprise boundary and the industrial sector. In this innovative industry chain, each link has a focus, but also linked to each other. Universities and research institutions provide technology, technical intermediaries committed to the matching and commercialization of technology, enterprises committed to research and provide product and service, the Government give policy guidance and support. The cooperation between these organizations is conducive to the establishment of a scientific and orderly coordination mechanism and promote the continuous development of technological innovation. In summary, the external environment factors, internal organization factors and the inter-firm factors affect the motivation and the implementation of innovation jointly, and ultimately affect the innovation performance of enterprise.

As discussed above, there are many factors can motivate the technological innovation. However, because of the characteristics of natural monopoly, highly regulated, technical dependence in China's telecom industry, these factors are in obvious particular order of importance. Combined with the characteristics of China's telecommunications industry, we have selected the key drivers of technological innovation, and establish a more targeted dynamic system model for the follow-up regression analysis. The model is depicted in Figure 2.

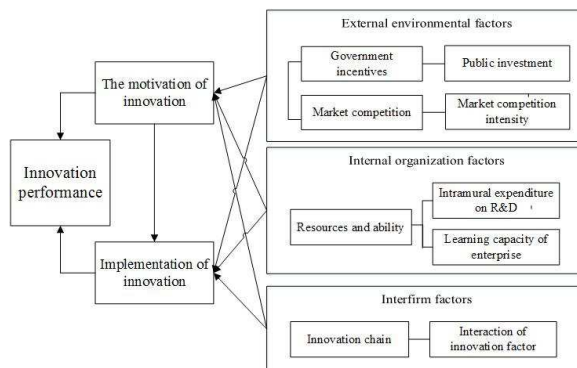


Fig. 2. Power system of technology innovation in China's telecomindustry

3. Regression model and data

3.1. Regression model

By definition, technological innovation is the commercialization and extension of new technologies, and create the actual profit. The motive factors affect the motivation and the implementation of innovation jointly, and ultimately affect the innovation performance of enterprise. Therefore, we can test the effectiveness of the technological innovation system in China's telecom industry through the regression analysis of the motive factors and innovative performance. If the relationship between the motive factors and the innovation performance is significant, then it can be considered that the technological innovation system is effective. We choose the core motive factors such as the public investment, the competition in product market, intramural expenditure on R&D, the learning capacity of enterprise and the interaction of innovation factors as the independent variable, and choose the innovation performance of telecom industry as the dependent variable, and establish the following regression equation:

$$IPTI = C + \beta_1 PI + \beta_2 CPM + \beta_3 IERD + \beta_4 LCE + \beta_5 IIF \quad (1)$$

Based on the time series data of China's telecom industry, we can make the empirical test about the impetus of technological innovation in telecom industry. The definitions and measures of the variables in the regression equation are as follows:

1. IPTI(Innovation Performance of Telecom Industry). It means the output of the industry's technological innovation. We can use the new products sales of China's telecom industry to measure it. New products refer to the products that use new technical methods or new design ideas. Or the products that have significant improvement in the structure, material or process than the old products and significantly improve the product performance or expand the function. The research and development of new products represent the commercial application and popularization of new technologies, which reflects the technological innovation of enterprises. The new products sales is the innovation income of enterprises.
2. PI(Public Investment). It means the material support of the government to help the technological innovation of telecommunications enterprises, we can use the government fund on the R&D area to measure it.
3. CPM(Competition in Product Market). It means the intensity of market competition. We can use the number of the enterprises that have scientific research institutions in telecommunications equipment manufacturing industry to measure it. First of all, the telecommunications equipment manufacturing industry is the core member of the technological innovation in telecommunications industry. There is huge innovation space in its business and products, so it can provide a steady stream of innovation products for other aspects of the telecommunications industry. Secondly, there are more equipment manufac-

turing enterprises, so the market competition factors more likely to have a significant impact on its technological innovation. The establishment of internal scientific research institutions reflect their full attention to technological innovation. The more enterprises committed to technological innovation, the greater the intensity of competition can be, so that the speed of new technology and new product development and change can be faster. Finally, the technological innovation process of the entire telecom industry will move forward.

4. IERD(Intramural Expenditure on R&D). It means the internal R&D investment in the enterprises, we can use the self-raised funds by enterprises to measure it.
5. LCE(Learning Capacity of Enterprise). We can use the number of scientific researchers in the telecom enterprises to measure it. The more researchers in the enterprise, the stronger the learning and practical capacity can be, and then the technological innovation process can be promoted.
6. IIF(Interaction of Innovation Factors). It means the strength of the linkage of the elements in the innovation chain. We can use the number of the R&D project in the college to measure it. The innovation chain of the telecommunication industry includes R&D institutions, universities, technology intermediaries and telecom enterprises. The intensity of the interaction between these organizations reflects the linkage strength of the industry innovation chain. In the upper reaches of the innovation chain, universities and R&D institutions play the role of technology source, while enterprises in the lower reaches play the role of technology practitioners and promoters. The stronger the interaction between the enterprises, universities and R&D institutions is, the easier the implementation of technology can be. In view of the procurability of the data, we selected the number of related subjects in the colleges and universities to measure it. The more subjects there are, the more technical and theoretical support can be available. So it can indirectly reflect the linkage strength of the innovation chain of the telecom.

3.2. Data

The data source of this paper is *China Statistical Yearbook on Science and Technology (1996-2015)*. We intercepted the time series data across 20 years which is related to the communications industry. The data includes some information of large and medium-sized enterprises in the communications industry, such as the patent applications, the new product development projects, the sales revenue of new products, the government investment in R&D funds, self-raised funds by enterprises, R&D personnel, the number of product users, the number of enterprises having R&D institutions, New product development funds, the investment to the research institutions and universities, the number of the related subject in colleges and universities, expenditure for acquisition and renovation of foreign technology. The data can closely fit the technological innovation condition, and support the model. Table

1 shows the basic descriptive statistical results of the core data on the technological innovation of the communications industry from 1996 to 2015.

Table 1. Descriptive statistical results

Descriptive statistics	New products sales revenue (10 million yuan)	Public investment (10 thousand yuan)	Number of enterprises having R&D institutions (unit)	Self-raised Funds by Enterprises (10 million yuan)	R&D Personnel (person)	Project of College (unit)
Mean	124024	304935	1397	6832661	264336	15123
Median	105952	297685	779	5879025	226595	17109
Maximum	306577	695795	4108	15114290	518675	24125
Minimum	24997	53846	339	1723065	75691	186
Std. Dev.	83726	186731	1265	4158460	151136	7649
Skewness	0.75	0.32	0.91	0.62	0.41	-0.68
Kurtosis	2.43	2.11	2.39	2.26	1.72	2.38

4. Empirical results

We use the regression equation to verify the power system of technology innovation in China's telecom industry. Table 2 shows the empirical results.

Table 2. Regression analysis results of technology innovation power factors in China's telecom industry

Dependent Variable: IPTI				
Included observations: 16 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9460.264	7017.025	-1.348187	0.2073
PI	0.145390	0.034804	4.177381	0.0019
CPM	0.129955	5.84563	2.22311	0.0504
IERD	0.015734	0.003177	4.952798	0.0006
LCE	0.253208	0.071698	3.531611	0.0054
IIF	0.267781	0.795911	3.364465	0.0072
R-squared	0.994435	F-statistic	357.3689	

It can be seen from Table 1 that the coefficients of public investment, intramural expenditure on R&D, learning capacity of enterprise and interaction of innovation factors are significant at 1% significance level. The P-value of the competition in

product market is about 0.05, which shows that the coefficient is significant at 5% significance level. From the R-square, the five independent variables on the interpretation of the dependent variable reached 99.4%. According to the value of R square, the explanation of independent variables on the dependent variable reaches 99.4%. The probability of F-statistic is 0, indicating that the whole equation is very significant. On the whole, the regression equation perfectly fits the function relationship between the innovation performance and the innovation power elements, and fully demonstrates the internal law of the power system of China's telecom industry. From the regression equation, when the other variables remain the same: 1) The government's R&D investment in China's telecom industry increase by 1% can lead to 0.145% increase in the technology innovation performance of the industry; 2) The intensity of competition in telecom technology market achieve each additional 1%, the technological innovation performance will increase by 0.13%; 3) The intramural expenditure on R&D in telecom enterprises achieve each additional 1%, the technological innovation performance increased by 0.016%; 4) The average learning capacity of telecom enterprises increase by 1% can lead to 0.253% increase in the technological innovation performance of the whole industry; 5) The intensity of the linkage between the elements of innovation chain achieve each additional 1%, the innovation performance will increase by 0.268%. The empirical results show that these dynamic factors do promote the increase of the technological innovation output of the Chinese telecom industry, and thus promote the technological innovation process. So it fully proves the scientificity and rationality of the dynamic system of technological innovation in China's telecom industry.

5. Conclusions

According to the theory of technological innovation, this paper established a set of technological innovation power system for China's telecom industry, and established a regression equation based on the system. Then we use the data in *China Statistical Yearbook on Science and Technology (1996-2015)* to fit the regression equation and obtained a very significant empirical result. From the empirical results, the technological innovation performance in China's telecom industry is closely related to the factors such as public investment, market competition intensity, intramural expenditure on R&D, learning ability of enterprises and linkage strength of industry innovation chain, which proves that the technical innovation power system is reasonable.

From the results of this study, we can draw the following conclusions:

1. The motivation of technological innovation in China's telecom industry is relatively complex, it can't be summarized by single factor. From the traditional cognitive, the telecom enterprise's technological innovation performance is often influenced by its R&D investment. However, through the empirical tests we can know that technological innovation can be affect by government, market, internal management and industrial innovation chain, etc. In the study of technological innovation in China's telecommunications industry, we should avoid

- a single narrow thought, but should use a comprehensive, network perspective to look at the problem. Thus we can correctly understand the industry's internal innovation mechanism, and make an accurate judgment on the innovation situation.
2. The technological innovation in China's telecommunications industry is influenced greatly by government. The public investment can determine the enterprises' enthusiasm of innovation and the innovation output. In addition, loan concessions and tax breaks can also indirectly reduce the financial pressure of enterprise, thus encourage enterprises to promote innovation. In addition to financial support, policy protection can mobilize the power of the whole industry to support the technological innovation of enterprises. Such as the protection of intellectual property, the tendency of regulate standards, encourage the technological innovation of universities and institutions, and lead the establishment of demonstrative industry clusters.
 3. As the core member of technological innovation, telecom enterprises should be clearly aware of the relationship between the technological innovation output and the motivation factors, and fully mobilize the various factors, such as the R&D investment, the corporate culture, the entrepreneurial spirit, the supervision system and incentive mechanism, thus improve the technological innovation capability scientifically and efficiently and promote the technological innovation process.

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