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The Coevolutionary Relationship of Technology, Market and Government Regulation in Telecommunications

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The Coevolutionary Relationship of Technology, Market and Government Regulation in Telecommunications

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Abstract

The technical change in telecommunications industry is tremendous, and it is exactly the continuous technological progress in telecommunications that brings sustained prosperity and development of the telecommunications industry. In this paper, the interplay between technology, market and government in telecommunications is discussed briefly in the first place, and then we introduce technology and government into the traditional SCP paradigm as essential factors which have economic meanings to construct a new industry analysis framework called TGM (SCP). Based on this framework, we propose the spiral coevolution model of telecommunications industry which elaborates on the interaction mechanism between technological innovation, government regulation and market evolution in telecommunications. Our study indicates that the evolution of the telecommunications industry is the result of technological innovation, government regulation and market competition, and among the three, technological innovation is the fundamental driving force. Compared to the “invisible hand”—market and “visible hand”—government, we believe that technology is the “third hand” in telecommunications industry. The policy implications regarding these findings are given at the end of this paper.

Keywords: technological innovation; government regulation; telecommunications; industry analysis.

1. Introduction

Neoclassical economics believe that supply and demand in a free market will naturally reach equilibrium under the effect of the “invisible hand”—market price mechanism. Obviously, price mechanism cannot deal with all problems in the market, the existence of market failure requires “visible hand”—government to intervene and regulate markets in order to correct those market failures (Greenwald and Stiglitz, 1986, Stiglitz, 2010). However, from the perspective of the development history of the telecommunications sector, relying solely on the “invisible hand” and “visible hand” cannot achieve the effective allocation of resources (Hausman and Taylor, 2016, Stiglitz, 2010). There may exist market failure and government failure in the telecommunications simultaneously, so what factor on earth leads to the fast growing of this industry in the case where market and government may fail at the same time? In the analysis of the historical development and techno-economic characteristics of the telecommunications industry, we argue that in addition to market and government, there exists the “third hand” in telecommunications: technology.

Advancements in telecommunications technology, especially mobile technology, have radically changed people’s lives (Gupta and Jain, 2016). Technological innovation is the most core feature in telecommunications service industry, and the speed of technical change and industrial development in this industry far exceed that in other natural monopoly industries, which is the most significant difference of telecom industry relative to other industries. In the light of the development history of world telecom industry, the birth and development of analog technology, digital technology, optical fiber technology and other telecommunications technologies, have played a critical role in the formation of fixed-line telephone market, mobile telephone market and broadband market, and the

tremendous advances in emerging telecom technologies have significantly changed the industry boundaries and industrial structure of the telecommunications industry (Huurdeeman, 2003). It can be said that every time the great development of the telecommunications industry are inseparable from the emergence and operation of new technologies, it is exactly the continuous technological progress in telecommunications that brings sustained prosperity and development of the telecommunications industry. Radical technological innovations in telecom technology can change the original techno-economic characteristics of the telecom industry, and then affect market structure, market conduct, market performance and regulation policy in this industry. That is, it is technical change that shaped the industry and changed telecommunications regulation (Laffont and Tirole, 2001, Hausman and Taylor, 2016, Neu et al., 1987). Therefore, we argue that the evolution of the telecommunications industry is the result of technological innovation, government regulation and market competition, and among the three, technological innovation is the fundamental driving force.

A group of previous literatures studied the relationship between technological innovation and market competition or regulation in telecommunications (Madden and Savage, 1999, Van Cuilenburg and Slaa, 1995, Li, 2008, Bauer and Shim, 2012, Vogelsang, 2016, Bourreau and Doğan, 2001, Ai and Sappington, 2002, Bauer, 2010, Bourreau et al., 2012, Ehrlich et al., 2010), but there is no literature focusing on the coevolutionary relationship of technology, market and government regulation in the telecommunications from the perspective of industry evolution. So we intend to bridge this gap by examining the general rules and interaction mechanism between technology, government and market in the evolution of the telecommunications industry, and putting forward several relevant policy proposals. In this study, what we need to solve is how to introduce technological innovation and government regulation into traditional industry analysis framework as elements which have economic meanings, so that we can discuss the interaction relations between technology, market and regulation. Specifically, first of all, through the analysis of the classic case and industry characteristics of the telecommunications, we briefly discuss the relationship between technology, market and government in the telecommunications industry. Then, based on the classical SCP (Structure – Conduct – Performance) industry analysis framework which was built by Harvard School, we propose a new industry analysis framework which is suitable for analyzing the telecom industry —TGM (SCP) , that is, Technology – Government – Market (Structure – Conduct – Performance). Traditional industrial organization theory does not make a specific analysis on the issue that market structure is determined by what factors, but just attribute those factors to external conditions or basic conditions. This study accurately discovers and demonstrates the decisive role of the techno-economic characteristics of the telecom industry and the regulatory factors on the structure of the telecom market, thus obtaining a new industry analysis framework. Next, based on the proposed TGM (SCP) framework and the characteristics of the telecommunications industry, we deploy the theorizing method of inductive reasoning to construct the spiral coevolution framework model which elaborates on the interaction mechanisms among technological innovation, market and regulation in the telecom service industry. Finally, according to the research findings of this study, we put forward some ideas and policy proposals about what role the government should play in promoting the technological innovation in telecommunications.

This study makes three possible contributions to the literature. First, for the first time, we propose that technology is the “third hand” in telecommunications service industry, which emphasizes explicitly the critical role of technology in the evolution of the telecommunications industry. Second, based on the classical SCP paradigm proposed by the traditional structuralist school of the industrial economics, this paper establishes a new industry analysis framework that is Technology – Government – Market (Structure – Conduct – Performance), expecting to further promote the development of industrial organization theory. Third, this paper discusses the general rules among technological innovation, government regulation and market evolution in the telecom industry under

the proposed framework model, extending studies on the evolutionary theory of the telecommunications industry.

The rest of the paper is structured as follows. Section 2 briefly discusses the relationship between technology, market and government in telecommunications. Section 3 proposes the new TGM(SCP) industry analysis framework, based on the analysis framework, the spiral coevolution model which elaborates on the interaction mechanisms among technological innovation, market and regulation in the telecommunications industry is constructed. Section 4 provides some relevant policy proposals according to the research findings of this study. Section 5 concludes and provides a summary.

2. Technology, market and government in telecommunications

In Robert. M. Solow's pioneering study in 1957, he indicated that about 80% of the growth in gross output value for each working hour in the United States from 1909 to 1949 was attributed to technological progress (Solow, 1957). Although later studies yielded a lower estimated value (Denison, 2011), Solow's conclusions about the importance of technological progress have not been changed. In the monograph wrote by Schumpeter, *Business Cycle*, the case studies of the emergence and development of new technologies and new industries clearly demonstrate the important role of technological innovation in promoting resource allocation and institutional change (Nelson and Winter, 2009, Schumpeter, 1939). The emergence of telecommunications industry is due to the information and communication technology, technological innovation even more plays a critical role in the fast growing telecommunications industry. Several empirical results have shown that the technical change almost exclusively contributed to productivity improvements in the telecommunications industry (Banker et al., 2010, Hisali and Yawe, 2011, Madden and Savage, 1999, Nemoto and Asai, 2002). Therefore, compared to the “invisible hand”—market and “visible hand”—government, we believe that technology is the “third hand” which coordinates the development of the telecom industry. In this paper, what relationships between the “third hand” technology, telecommunications market and government regulation is the issue that we are going to discuss.

The basic relationships between technology, market and government in telecommunications are shown in Figure 1.

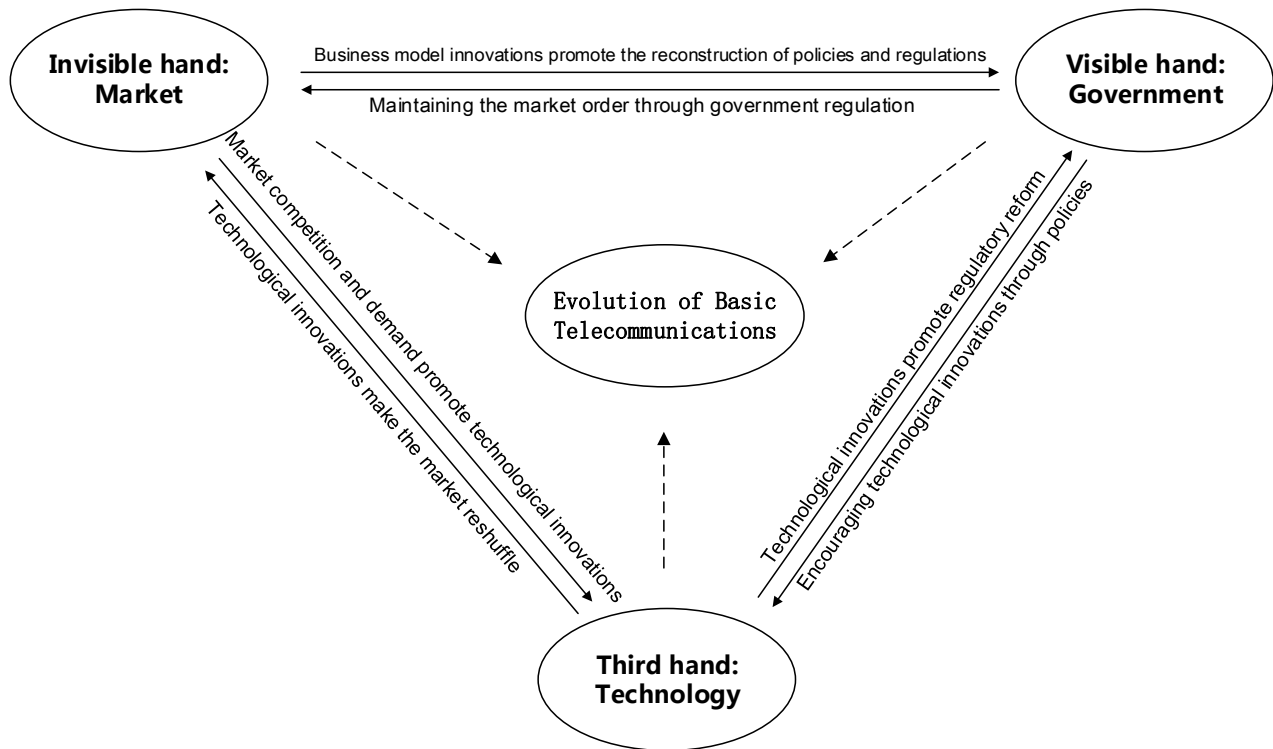


Figure 1 The relationships between technology, market and government in telecommunications

2.1 Technology and market

Technological innovation is the main driving factor of market evolution as well as the direct embodiment of market performance improvement, which means that technological innovation and market is influenced and promoted by one another.

Technological innovation can reduce the entry barrier of telecom industry and change the competition pattern in telecom market. Due to the uncertainty of innovation activities, the existence of sunken cost and the difference of organizational structure, technology leaders may fail to react to major mutations in technology while the latecomers could carry on leapfrogging development and surpass former technology leaders. The discontinuity of technology may change the entry barrier of telecom industry and reduce market concentration (Gruber, 1995, Gruber, 1992). Viewing from the development course of telecommunication industry we can see that telecom industry used to be part of electronics industry and that the emergence of electronic computer tremendously reduced the operation cost of telecom industry. In the 1980s, chip-based microprocessors were 30,000 times cheaper than early computers while the computing ability improved by over 200 times; the cost of optical cables has been decreasing over the past few decades, from 10\$ per meter in 1980 to 1.75\$ per meter in 1980, then to 0.1 \$ per meter in 1990 (Wenders, 1987). The development of telecommunication technology has immensely reduced the cost of telecom operation. Therefore, by dramatically changing technology economy characteristics of telecom industry, subversive technology innovation helps reduce the degree of natural monopoly in telecom industry, making it possible for other competitors to enter the industry, as a result of which the competitive relationship in telecom market is altered over time.

On the other hand, it is obvious that a relatively reasonable market structure helps boost the technological innovation of industry. Ever since Schumpeter proposed innovation theory, the problem

that what kind of market structure is conducive to innovation has been widely concerned by academia (Schumpeter, 1942) (Schumpeter, 1934, Schumpeter, 1939). Many scholars have conducted empirical and theoretical researches on the influence of market structure on technological innovation. Some claim that monopoly which is known as high concentration market is beneficial to technological innovation (Caves and Uekusa, 1976, Goel, 1990), Some hold the opinion that competition is conducive to technological innovation (Arrow, 1962, Geroski, 1990), While others think that competition of moderate level contributes to technological innovation, between market structure and innovation exists inverted U-type relationship (Dubey and Wu, 2002, Aghion et al., 2005). Admittedly, these three viewpoints have theoretical basis and realistic basis, but there are also limitations. Currently, the prevailing view claims that the relationship between technological innovation and market structure varies by industry owing to various technical economic characteristics and regulatory environment facing each industry (Baldwin and Scott, 2013, Scherer, 1965, Adams, 1970). Cuilenburg & Slaa (1995) conducted empirical test, utilizing data from 24 OCED member states, to verify whether the relationship between innovation and competition in the telecommunications industry is linear or inverted-U type, while from the perspective of empirical validity, it was impossible to determine which hypothesis is more accurate (Van Cuilenburg and Slaa, 1995). Utilizing telecom industry data of 74 countries from 1991 to 1994, Madden & Savage (1999) conducted an empirical study in the telecom industry, hoping to test the influence of market scale and market concentration on innovation activities. The findings supported the assumption that the market scale of telecom industry has a positive effect on innovation, but did not support the assumption that market concentration is conducive to innovation. Meanwhile, the empirical result also demonstrated that increase in private capital ownership of telecom carriers contributes to innovation activities (Madden and Savage, 1999). This indicates that in telecommunications, competition tends to accelerate the pace of innovation under the premise that there were not many carriers participating in the competition, which was basically consistent with the assumption proposed by Schumpeter that large enterprises are conducive to innovation.

2.2 Technology and government regulation

The techno-economical characteristic, regulatory policy as well as current development situation of the market jointly determine the development trend of telecom industry. And technical factors and regulatory policies also have reciprocal effect with one another.

For one thing, regulatory policies of the government directly affect the innovation incentive of enterprises. In general, regulation affects innovation activities in two ways. Firstly, price regulation, specifically regulations on network interconnection fee and retail price, changes the profits of enterprises and then influence the incentive to innovation (Bourreau and Doğan, 2001). Secondly, price regulations and market access regulations jointly alter the entering conditions for new entrants, thus affecting the innovation decision-making of incumbents and potential entrants. Besides, due to the difference in regulatory efficiency, the regulatory regime (such as whether the regulatory bodies are independent or not) also affect the transaction cost and profit of the enterprises during regulation, and then indirectly influence enterprise's incentive to technological innovation (Cubbin and Stern, 2004, Kennedy, 2006). Therefore, government regulatory factors significantly affect the pace of technological innovation.

For another, due to the fact that the development of regulatory policy needs to adapt to the characteristics of technology, technological progress will also boost regulatory reform (David and Shurmer, 1996). The development of telecom industry in recent years proved the fact that the market

tends to achieve favorable performance when regulatory policies conform to technological development. And failures in regulatory policies often comes with policy makers' being unable to recognize the characteristics and development trend of technological progress. In the early 2000s, China's government failed to recognize and conform to the trend of rapid development of mobile communication industry and didn't issue mobile licenses for fixed-line operators in time. Fixed-line carriers push the limit by using out-dated PHS technology to enter the mobile market, which led to enormous waste of investment. According to Xu Fuxin, who is widely recognized as the father of PHS, the total investment on PHS was nearly 100 billion RMB (XinHuaNet, 2008), all of which caused inefficient repetitive construction and vicious competitions. In March 2009, Ministry of Industry and Information Technology (MIIT) posted requirement urging China Telecom and China Unicom to withdraw PHS from the market by the end of 2011, which made the two operators pay tremendous exit costs. In these 10 years, PHS was firstly put on and then completely withdrawn from the market. a large amount of money was wasted and the competitive order in mobile communication market was severely deteriorated. To a certain extent, PHS delayed the development of mobile communication technology and telecom market. Thus, it is evident that the grasp of technological progress is increasingly becoming an important factor influencing the effectiveness of regulatory policy.

2.3 Government regulation and market

One of the main purposes of government regulation is to make the market evolve towards a self-sustaining competitive market structure, where enterprises compete with each other and total social surplus rises thanks to lower price, higher quality and more selection of production(Bourreau and Doğan, 2001). Therefore, many scholars hold the opinion that the government only needs to intervene when market failures occur (Arrow, 1952, Hayek, 1964). However, deregulation is not a easy choice especially in some basic industries such as telecom industry, power industry, energy industry, transportation industry and so on, where still remain a state of natural monopoly in many country. For these industries, the fixed cost of infrastructure is extremely high, and the social costs will be too high if multiple infrastructures are repeatedly constructed to stimulate competition (Laffont and Tirole, 2001). In addition, the government regulates the industry in order to achieve specific social and political objectives, such as promoting universal service and safeguarding national security and so on (Cave and Crowther, 1996). Especially for the high-tech industry like telecom industry, policymakers are realizing the increasingly importance of technology in national security (David and Steinmueller, 1994, Kshetri, 2004). Therefore, governments needs to regulate the telecommunications industry and play a vital role in the development of telecommunication industry.

Telecom regulators rely mainly on two control measures to regulate the industry, structural controls and behavioral controls. Structural control mainly refers to the splitting and restructuring of telecom operators, the introduction of competition and the promotion of property rights reform, which help to form a desirable market structure and then influence the competitive relationship of enterprises in the market. Behavioral control refers to the control of market behavior, such as price control, advertising restriction and acceptable quality level. At present, the telecommunications regulators in most countries use these two types of control alternately. The regulatory regimes influence the business strategy and investment behavior of enterprises, and then affect the market structure and the action mechanism of market forces, leading to different market performance.

On the other hand, the innovation of market business model also promotes the reform of regulatory policy. Business model innovation refers to an unprecedented and more appropriate way

to provide customers with products and services, it is the adjustment of existing value chain(Mitchell and Coles, 2003, Magretta, 2002). When an unprecedented business model appears in the market, the existing regulatory regime may not be able to accommodate the needs of the changing market, or perhaps there is no regulatory mechanism to regulate these new business models, that's when regulatory policy should be adjusted accordingly to cope with the changes in the market business model.

2.4 Conclusion

From the analysis above, we can see that the in telecommunications, technology, market and government factors are mutually interacting and promoting, these three factors evolve together to promote the development of telecommunications industry. We need to find a proper way to introduce technical innovation and government regulation to traditional industrial analysis framework as an element with economic implication, and discuss the mechanism of action among technology innovation, market and regulation in telecom industry.

3. An analysis framework model for the telecommunications industry based on TGM(SCP)

3.1 Traditional analysis framework SCP

The relationship between market structure, market behavior and market performance is the most basic relation of industrial theory (Tirole, 1988). Through analyzing the relationship between market structure, market behavior and market performance and the conduction effect, the American scholars of Harvard School, Mason, Joe S. Bain, Scherer et al. established the classic industry analysis framework, "Structure-Conduct-Performance" (SCP). The basic meaning of the SCP paradigm is that in the whole, market structure has the most basic role in the industry analysis. Market structure determines the conducts of the enterprises in the market, and enterprise conducts determine market performance, while market conduct and market performance react to market structure in turn(Weiss, 1979, Scherer and Ross, 1990). The standard representation of the traditional SCP paradigm is shown in Fig 2.

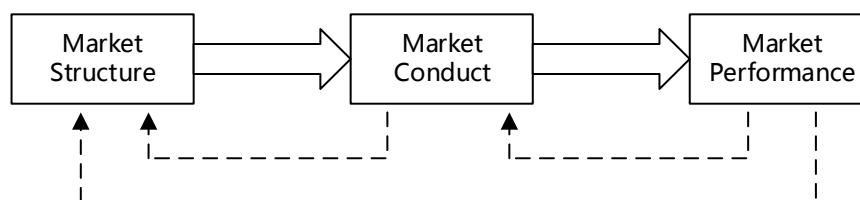


Figure 2 The traditional SCP paradigm

The most important significance of the establishment of the SCP paradigm is that, for the first time, the industrial organization theory has a complete set of basic concepts and core contents, which has become the most extensive tool for the industry to analyze the industry. Its basic framework system and experience study method still guide the direction of industrial economics research. Although the paradigm lacks a rigorous theoretical derivation process in its establishment, it has an irreplaceable role in empirical analysis, especially if it does not depend on detailed research assumptions and therefore has nice robustness. Therefore, we can carry on the analysis on the basis of SCP paradigm, and construct the framework of this study by introducing technology factors and government factors to expand the SCP paradigm, in order to discuss the relationship between technological innovation , market evolution and government regulation.

3.2 Extension of SCP analysis paradigm -- TGM (SCP)

SCP paradigm only focuses on the interrelationship of structure, conduct and performance within the market, and lacks discussion of the basic conditions outside the market. In the framework of

industry analysis, we should introduce the analysis of the determinants of market structure. From the analysis of the telecommunications industry in the previous section, technology factors and government factors play an important role in the development of the telecommunications market. Technological progress has affected the inherent attributes of the industry and the operational form of enterprises, and it will also urge policy makers to understand the changes in industrial properties and market demand in order to facilitate the reform of its own regulatory regime. The telecom industry has the unique property of natural monopoly, economies of scale and networking, which is quite different from other industries, so governments in all regime, need to implement sector-specific regulation in this industry, and adjust their own regulatory policies with the dynamic changes of natural monopoly in telecommunications. Moreover, since the telecommunications industry is belong to strategically sensitive industry which involves national security, it has been remained state-owned so far in some countries.

Based on this, this study introduce the technology and government factors into the traditional industry analysis framework to construct a new industry analysis framework called TGM(SCP). As is shown in Figure 3, we intend to discuss telecommunications industry issues from the relationship of three levels, technical level, governmental level and market level.

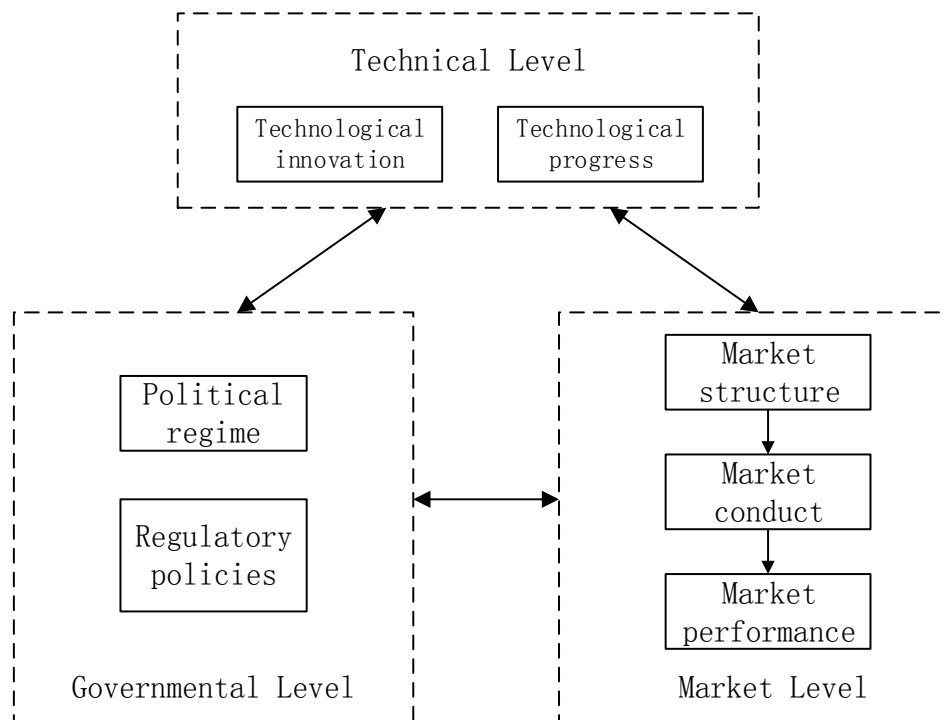


Figure 3 TGM(SCP) industry analysis framework

3.3 Spiral coevolution model

From the perspective of the development of telecom industry, the emergence of this industry is due to the development of contemporary information technology, every time the great development of the telecommunications industry are inseparable from the emergence and operation of new technologies, but telecom regulation is kind of an institutional arrangement that emerged at time when the telecommunication industry developed to a certain stage. Hence, technological innovation is the logical starting point in the evolution of telecom industry.

The traditional telecom industry is a typical natural monopoly industry. However, due to the factors such as telecommunications technology and cost structure condition, the natural monopoly of

the telecom industry has the characteristics of hierarchy and dynamism. Hierarchy mainly refers to there are businesses that have different degree of natural monopoly in this industry, that is, there are strong natural monopoly business, weak natural monopoly business, and even competitive business existing in the telecom industry at the same time. For example, in the traditional telecommunications, local fixed-line services are often considered to be strong natural monopolies, while long-distance telephone markets are considered relatively weakly natural monopolies (Laffont and Tirole, 2001, Hausman and Taylor, 2016). Dynamism refers to the fact that the boundary of the telecom industry is evolving dynamically, the property of natural monopoly of the industry can will change with the emergence of new technologies. The natural monopoly property of the telecom industry is essentially determined by the techno-economic characteristics of the telecommunication industry. During the divestiture of AT&T in the 1980s, telecom experts expected to utilize the microwave technology with a low rate of return on scale to support the formation of a competitive long-distance telephone market. However, this technology was replaced by fiber technology which has high fixed costs and low marginal costs in a short time, so soon experts emphasized that there was a need to make long-distance telephone market become a natural monopoly market, suggesting that repeated construction of a complete fiber network was a waste of money (Laffont and Tirole, 2001). In addition, the reason why the natural monopoly of the local fixed-line market is considered to be stronger than that of the long-distance fixed-line market, which is also essentially due to technical reasons, that is, class-4 tandem switches dealt with inter-city traffic and class-5 local switches served end-user customers. Improvements in digital switching technology and the advent of optical-fiber transport eliminated cost differences between local and long-distance calls (Hausman and Kohlberg, 1989). Therefore, when a new technology emerges, if the economic characteristics of this new technology are significantly different from the prior one, the techno-economic characteristics and cost structure of the telecom industry will change, and the property of the industry (the degree of natural monopoly) will also change accordingly.

Changes in the natural monopoly of the telecommunications industry will change the structural barriers to entry, which provides possibility for the entry of new enterprises and creates the preconditions for the adjustment of industrial boundary and the evolution of market structure. First of all, technological innovations significantly reduce the sinking costs and production costs of telecom enterprises, optimizing the cost structure. For example, fiber, wireless, satellite and other large-capacity transmission technology make the unit costs of long-distance voice, high-definition video, large-capacity data transmission reduce significantly. Secondly, Technological innovation weakens the economies of scale of the telecom industry. The fundamental reasons of the existing of economies of scale in traditional telecommunication market is because of the “whole network” feature of the traditional telecom services, but the leaping development of switching transmission technology makes the optimal level of economic scale reduce, the level in which enterprises achieve breakeven. Besides, the new product market resulting from technological innovations will also change the market structure of the old product market. For example, the emergence of cellular mobile technology has significantly changed the market structure of traditional fixed-line market. As of 2015, 96.6% of U.S. households had telephone services, but households that had only wireless service accounted for about 47%, far exceeding the number of wireline-only households (8%) (Blumberg and Luke, 2016). Thus traditional telephone companies’ local-access market share has fallen from about 97 percent in the past to about 29 percent of U.S. households in 2015 (Hausman and Taylor, 2016).

Once technological progress has changed the intrinsic properties of the industry and business forms of enterprises, the existing telecommunications regulation will no longer contribute to the efficient development of the industry and protection of social welfare, lagging regulation can cause the increase of transaction costs (García-Murillo, 2005). As such, in order to maximize the social welfare under the new industrial property, the regulator will reform its own regulatory system according to the changes in the industry, including industrial property and market demand. On the one hand, regulatory agencies examine whether the current market structure is reasonable or not through analyzing the current techno-economic characteristics of all telecommunications services, if the market structure is considered unfavorable, telecom operators are split and restructured through administrative procedures in order to adjust the market structure and promote industrial competition. In 1982, the issue of “Modified Final Judgment”(MFJ) led to the divestiture of AT&T, the regulated local telephone companies is separated from AT&T to reorganize into seven Bell Operating Companies (BOCs), US administrative departments expect to make the long-distance telephone market become a competitive market through divestitures and reforms (Hausman and Taylor, 2016). China's regulatory agencies also carried out three large-scale acquisitions and divestitures reforms in its telecommunications industry in 1999, 2002 and 2008 (Xia, 2016). On the other hand, the regulatory agencies regulate the conducts of telecom operators through regulatory policies such as price regulation and interconnection regulation, preventing incumbent enterprises from using their own market powers to carry on unfair competition. Through the above analysis, we can find that the techno-economic characteristics and regulatory factors of the telecom industry jointly determine the evolution of the market structure, and the changes in the nature of the natural monopoly caused by technological innovations will change the awareness of regulators in terms of the telecommunications industry and promote the reform of government regulation. Hence, technological innovation is the fundamental factor in promoting the development of the telecommunications market.

Next, reformed government regulation system also constitutes the institutional environment of a new round of technological innovation. The motivation for enterprises carrying on technological innovations lies in recognizing the existence of potential profits, and the price regulation and access regulation can affect the potential profits of enterprises, thus having an influence on the innovation incentives for enterprises. Besides, governments in all regimes have some power to shape telecommunications innovation and implementation outcomes to suit policy objectives (Stewart et al., 2011). On the other hand, under the joint actions of industrial techno-economic characteristics and government regulation, the telecommunications industry evolve into a certain market structure, which determines the conducts of enterprises (that are also subject to government regulation) and market performance. Improvements in market performance will generate incentives for the next round of innovation investment decision and have a positive impact on enterprises' development and application ability of technological innovation, thus affecting the effect of the next round of technological innovation. As such, the regulatory systems after reform and market performance work together to affect the next round of technological innovation.

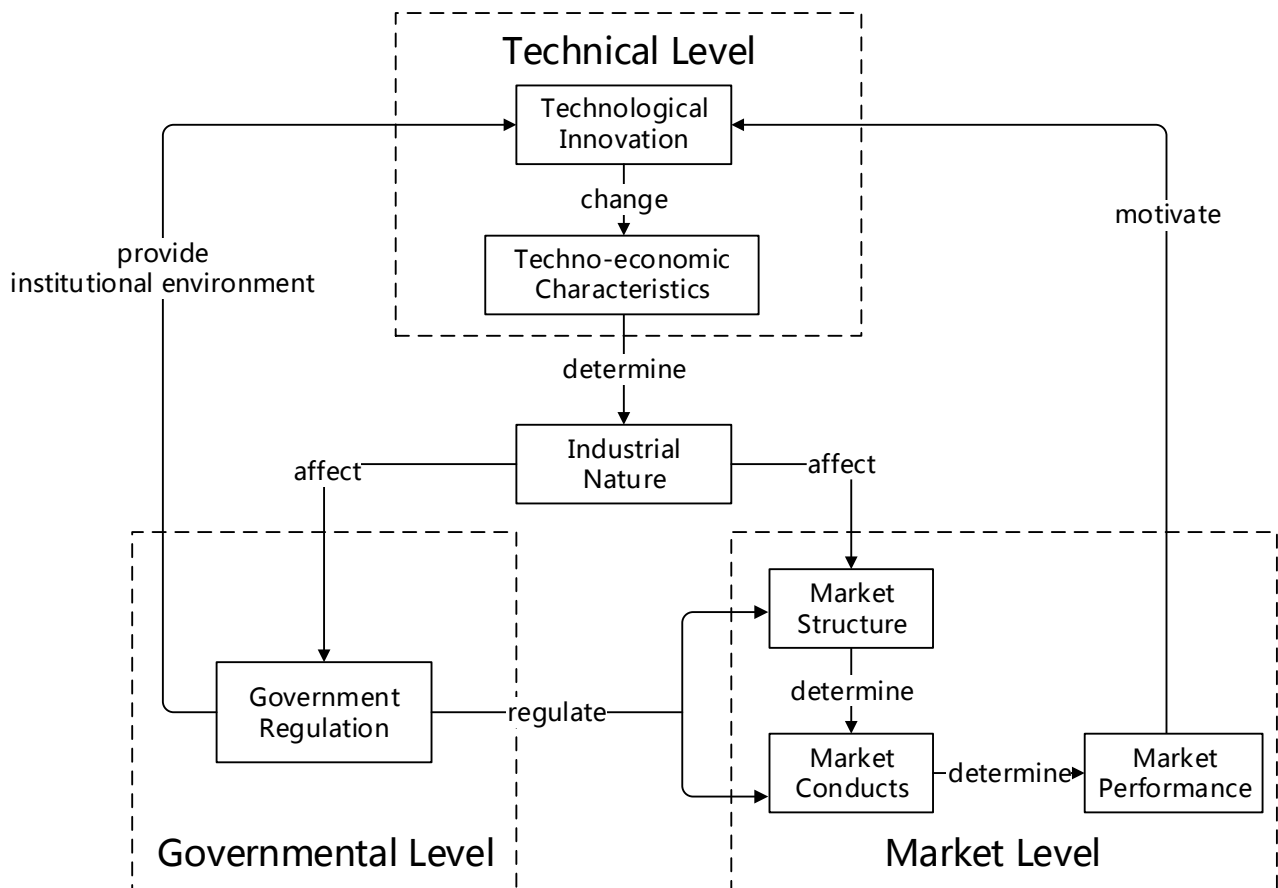


Figure 4 Spiral coevolution model of telecommunications based on TGM(SCP)

Through the discussion of the evolution mechanism of the telecommunications industry above, and based on the TGM(SCP) industry analysis framework we proposed, the spiral coevolution model which describes the interaction mechanism of technology, market and government in telecommunications is proposed. As is shown in Figure 4, technological innovation is the logical starting point in the evolution of telecom industry¹, telecom technological innovations change the techno-economic characteristics of the telecom industry, which determine the natural monopoly, economy of scale and net externality of this industry. Transformations in the nature of the telecom industry promote the reform of telecom regulation, and the new telecom regulation provides the institutional environment for the next round of technological innovation. On the other hand, technological innovations reduce the operating cost of service providers, and exert influence not only on the competitions among incumbents but also on potential entrants' decisions, thereby affecting the competition relations among enterprises and leading to the alteration of market structure and market performance. And also, the alteration of market structure in telecom industry has an impact on the incentive of technological innovation in the next round. As such, technological innovation, telecom market and government regulation, these three affect each other and coevolve to promote the development of the telecom industry. Technological innovations in the first stage determines the techno-economic characteristics of the industry and industrial nature in the first stage, thereby affecting the market competition and regulation in this stage, and the outcome of market competitions and the changes in regulatory environment will have an impact on the technological innovations in the second stage. Technological innovations in the second stage will also affect the market

¹ Here "technological innovation" does not refer to a single technological innovation, but an innovation cluster marked by a radical innovation.

competition and regulation content in this stage, thus affecting technological innovations in the second stage. The coevolution path of technology, market and government regulation is similar to a kind of upward spiral relations, so it is named spiral coevolution model.

4. Policy implications

Judge from the results of inductive reasoning and the development history of the telecom industry, telecom regulators need to continually examine the significant changes in the industry brought by technological changes, so that they can carry out the corresponding reforms for telecommunications regulatory system and adjust regulatory measures and policies to adapt to the characteristics of technological changes (David and Shurmer, 1996). Market entry barriers can be divided into structural barriers, institutional barriers and strategic barriers. Structural barriers refer to economic entry barriers caused by factors including scale economy, the absolute cost advantage of the incumbents and product differentiation (Bain, 1956), institutional barriers refer to the barriers that arise due to the government regulation of industry (Demsetz, 1982, Stigler, 1968), strategic barriers refer to the strategic deterrence behaviors of incumbents which is used to hinder potential entrants (Salop, 1979). Technological innovation can help to break through the original structural entry barriers by reducing product cost and improving production efficiency, but the telecommunications sector is strictly regulated by the government in most countries, so it need government, the “visible hand”, to break the institutional barriers caused by its original institutions and the strategic barriers caused by incumbents’ acts of unfair competition. However, due to the existence of regulatory neutrality issue, government regulation itself tends to curb the massive changes brought by disruptive technological innovations (Vogelsang, 2016, Bauer and Shim, 2012). This phenomenon is what institutionalists call “ritual locking” (Ayres, 1946, Bush, 1987). Telecom regulators need to realize that technological progress is a necessary and inevitable trend of the development of telecommunication industry, they need to be courageous to break the institutional barriers that hinder technological innovation as well as eliminate the institutional factors that hinder the realization of technological innovation, and then promote the sustainable development of telecom industry.

Meanwhile, our antitrust policies need to identify whether the market powers of enterprises are achieved in a favorable manner. Market power in the short run is the incentive that drives investment in research and development (Hausman and Taylor, 2016). Penalizing market power which is a result of innovative efforts rather than anticompetitive practices can be inefficient, especially in the long run. The inefficiency stems not only from the unrealized innovation in the current period due to fear of regulation *ex post*, but also from reduced capacity for further development and application of innovation (Bourreau and Doğan, 2001, Hausman and Taylor, 2016). This effect is particularly pronounced in a dynamic telecommunications industry in which cumulative innovation is vital, and externalities apply to the entire economy (Correa, 2006, Datta* and Agarwal, 2004, Dutta, 2001, Ding and Haynes, 2006, Cronin et al., 1991). The development history of telecom industry shows that the only way that market power truly disappears is through technical change and disruptive new services and technologies, In the same way, market power in the buggy-whip industry would likely have been erased by the automobile industry rather than by the courts or the regulator (Hausman and Taylor, 2016).

Owing to the fact that technological innovation is a fundamental factor of telecom industry evolution, regulators not only need to adjust the regulatory system in time to adapt to the characteristics of technological change when the technological innovations are exogenous, but also need to make technological progress initiatively, that is, employ incentive regulation that can promote

technological innovations of telecommunication enterprises to propel the sustainable development of telecommunication industry. Even if efficient and creative in matching supply and demand, market is usually incapable of organizing the risky, long-term and complex R&D processes needed for creating radical technological innovations (Chesbrough and Teece, 1996). Market is inherently flawed in stimulating technological innovation for the following reasons: 1) Market uses strong methods to force enterprise to promote innovation, and the high profits induce enterprises to innovate despite the high risk. However, market fails to address the problems of innovation risk and innovation incentive fundamentally, and companies may not be willing to develop and use emerging technologies which may damage their existing business (Henderson, 1993). 2) Market itself may not be able to create a market structure that is most conducive to innovation. 3) Market itself cannot create an external environment conducive to innovation, such as laws related to innovation, tariffs, policies etc. More importantly, technological innovations in IT industry, especially the technological innovations in telecommunications, are activities with high economic externalities, which can strongly promote the development of other industries and help produce huge externalities to the overall productivity (Quinn and Baily, 1994, Correa, 2006, Datta* and Agarwal, 2004). From this standpoint, the government should create an environment that is conducive to innovation and adopt regulatory policies that stimulates innovation. Telecom regulators need to realize that technology innovation is the essential way to reduce cost and improve the service quality of telecommunications services, in the condition where technical level is not mature enough, relying solely on structural control to restructure the telecom industry and promote competition, or using price regulation to influence the competitive relationship and profitability of telecom operators cannot help to promote the efficient development of telecom industry.

In addition, governments play a vital role in the development of radical telecom technologies and the setting of telecommunications standard. Some previous studies indicated radical technological innovation is more driven by the development of science and technology (Dosi, 1988, Nemet, 2009). Due the huge risk and externality of R&D of science and technology, governments need to build a national innovation system that is suitable for its domestic economic development and act as a facilitator and monitor in the innovation system (Freeman, 1995, Nelson, 1993). The analysis on innovations in telecommunications shows that due to the complexity of telecommunications technology and the need for standardization, it is difficult to achieve radical innovations in terms of a single enterprise or even a single country. Innovation regimes, which was proposed by Godoe (1995), have provided a capability of coordination, direction and leadership in the creation of many of the radical technological innovations that have emerged in the sector (Godoe, 1995). That is to say, radical innovations in telecommunications can be achieved by setting strategy goals, they are rational outcomes of the innovation regime, and the government plays an important role in the formation and maintenance of the innovation regime (Godoe, 2000).

Technical standardization plays a basic and strategic role in the development of the telecommunications industry (Rosenberg, 1994, Hawkins, 1996, Ernst et al., 2014, Yoo et al., 2005, Lyytinen and King, 2002), the owner of technical standards can dominate the direction of technological progress in the future (Steinmueller, 2005). Although standards development organizations (SDOs), such as ITU, set most of the technical standards in telecommunications (David and Shurmer, 1996), SDOs do not have the legal authority to implement a technical standard. It is government that plays a significant role in the development and adoption of technical standards (David and Shurmer, 1996, Montealegre, 1999, Funk and Methe, 2001, Hanseth and Monteiro, 1997).

The cooperation network of different technical organizations and market players is of vital importance to the successful development and diffusion of a standard (Teece, 1986), and the government can create such a cooperation network, government in the standardization process can act as a project founder, risk undertaker, interest moderator, collaboration facilitator, and process monitor (Gao et al., 2014). The fierce competition of European companies on GSM demonstrates the importance of government support, and the relatively weak position of CDMA indicates the negative impact of the market-based standard setting method (Funk, 1998, Funk and Methe, 2001). Chinese government played a critical role in the development and implementation of its domestic 3G standard TD-SCDMA (Kshetri et al., 2011, Gao et al., 2014, Zhan and Tan, 2010). In 2000, with the support of the Chinese government, eight companies established the TD-SCDMA Technology Forum², which provides a venue for sharing relevant information and promoting the development and commercialization of TD-SCDMA. In order to promote the industrialization of TD-SCDMA, in October 2002, the Ministry of Information Industry (MII) established the TD-SCDMA Industry Alliance (TDIA) to promote efficient cooperation between firms (Tsai and Wang, 2011). In February 2004, the National Development and Reform Commission (NDRC), the Ministry of Science and Technology (MOST) and MII jointly launched the TD-SCDMA R&D and Industrialization Project (TRIP) to provide subsidization for firms to investment in the TD-SCDMA technology (Gao et al., 2014). Chinese policymakers regard TD-SCDMA as a way to leapfrog in the global technology contest (Zhan and Tan, 2010). The outcome of TD has been a mixed one thus far, however, the successful development of TD-SCDMA shows that Chinese firms have become the core participants in the standardization of complex technology systems, it helps Chinese firms to win the discursive power and accumulate technological capabilities in the setting of TD-LTE and forthcoming 5G standard, meanwhile promote the national positive image of China internationally (Kshetri et al., 2011).

5. Conclusions

In this study, we propose a new industrial organization research framework TGM (SCP), based on which the spiral coevolution model of the telecommunication industry is constructed to explore the coevolution relationship between technological innovation, government regulation and market evolution in telecommunications. Our study indicates that the evolution of the telecommunications industry is the result of technological innovation, government regulation and market competition, and among the three, technological innovation is the fundamental driving force. Compared to the “invisible hand”—market and “visible hand”—government, we believe that technology is the “third hand” in telecommunications industry, it is exactly the continuous technological progress in telecommunications that brings sustained prosperity and development of the telecommunications industry

The spiral coevolution model we proposed outlines the development pattern of the world telecommunications industry, which has a guiding significance for governments around the world to deal with the relationship between technology, regulation and market in telecommunications. As government regulation is the institutional condition of technological innovation, and technological innovation is the fundamental driving force for the development of the telecommunications industry. Thus, government should play its own important role in promoting technological innovation and technical standardization in the telecommunications industry, eliminating factors that may hinder the pace of technology progress and establishing incentive systems that are conducive to technological innovation in an effort to promote the continuous development of telecommunications technology.

² In January 2009, TD-SCDMA Technology Forum changed its name to TD Technology Forum.

As such, the overall development level of the telecommunications service industry can be improved constantly.

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