The Mechanism of Patent Cooperation Networks Influence Technology-based Small and Mid-sized Enterprises Growth

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***Abstract*--With the rapid technological reform and increasingly fierce competition in the global market, the quantity and quality of patents has become the key to the survival and growth of enterprises. However, technology-based small and mid-sized enterprises(TSMEs) have a lack of innovation resources and its innovation capacity are always weak, only by choosing and embedding themselves to patent cooperation networks(PCNs) that suit their growth can TSMEs truly improve their innovation performance. So what model and characteristics do TSMEs' PCNs have? And which model are benefit to their innovation performance improving? How to dynamically adjust the PCNs evolution models to promote the continuous improvement of TSMEs' innovation performance? All of them are the key issues to be solved during the study of using PCNs to promote TSMEs' growth. Breaking away from the paradigm of studying the network as a whole in previous studies, this research starts from the structure of self-centered enterprise PCNs, and based on breadth and depth of the patent cooperation，carries out dual structure classification and multi-model construction of the network, explores and analyzes its characteristics，evolution law and the impact mechanism of the co-regulation of absorptive capacity and network capacity on the TSMEs' growth performance.**

I. INTRODUCTION

Technology-based small and mid-sized enterprises (TSMEs) are important medium to speed up cultivating and developing strategic emerging industries such as biomedicine. They are also of extremely important and profound significance to the national economic growth and social progress. But a lack of innovation resources and weak innovation capacity has always been the bottleneck in their growth. In a world of open innovation and Internet survival, a large number of TSMEs, by means of collaborative patent application, purchase, transfer, licensing, and alliance, are gradually establishing patent cooperation networks to acquire innovation resources and improve innovation capacity. Patent cooperation has become an important form of cooperative innovation, and is showing a steady rise in terms of scale, strength, coverage and density[1][2]. Against the background of a surge of patent cooperation, the management and development of patent cooperation networks (PCNs) resources has become one of the important ways to break through the growth bottleneck for TSMEs. Patent cooperation between TSMEs and multiple innovation subjects is gradually spreading to relation proximity with social network as medium. The extent and closeness of cooperation between innovation subjects will affect the enterprise in their innovation resources acquisition and innovation ability enhancement. In reality, there is no lack of hollow-out enterprises due to excessive dependence on external technology from extensive cooperation; there are also enterprises trapped in dilemma of technological rigidity due to repeat cooperation[3][4]. Obviously, only by choosing and embedding themselves to PCNs that suit their growth can TSMEs truly improve their innovation performance. However, existing research is not deep enough on the enterprises' active construction and selection of different models of PCNs, as well as setting up in them of a coordination mechanism based on collaborative partnership to upgrade their innovation performance[5]-[7]. Therefore, we need to use more objective patent cooperation data to construct visualized network structure and carry out longitudinal study in network dynamic evolvement. It will make an important entry point to learn how to improve TSMEs' innovation performance in a network context.

II. THE RESEARCH REVIEW OF PATENT COOPERATION NETWORKS

A. The Definition and Construction of Pantent Cooperation Networks(PCNs)

With worldwide increasingly perfection of the patent database and the development of the related analysis software, a network innovation model has gradually become a domestic and international research hot spot. The model is based on patentee cooperation information, inventor cooperation information, patent citations and reference information, relationship with patentees etc. From a network perspective, it adopts complex network theory[8][9] and social network analysis tools (such as UCINET,NETDRAW,PAJEK) to study the patent cooperation between enterprises and other organizations. From the Web of Science(SCI,SSCI) database, the researcher carried out literature retrieval on "Patent Network" from January 1994 to January 2015, focusing on the field of social science and economic management. A total of 273 articles turn up. Judging from number of publications in recent 20 years (Figure 2) as well as the number of citations each year (Figure 1), we can see that the patent networks research has been a hot subject in last five years. Our study made further retrieval on the " Patent Cooperation Network ", and found that related research has been concentrated in last 10 years, and has been a hot topic for the last three years (see Figure 3 and Figure 4). Our study also makes classification analysis on the literature retrieval of the " Patent Cooperation Network ". Related literature mainly center on research fields like innovation networks, R&D

networks, patent cooperation, knowledge transfer, industry clustering, industry-university-research cooperation, technology forecasting, etc. Among them, those using patent data or social networks analysis account for 85%. The researcher not only pays attention to the relevant information analysis of patent cooperation applicants, but also uses such multi-dimensional data like citations to analyze the PCNs and its impact on innovation performance. The researcher follows related research on the self-centric networks based on enterprises' perspective, including, TSMEs' networks role[10], the impact of the patent cooperation on enterprise competition relations[11]-[13], and R&D cooperation networks structure[14]-[16]. The object of study is not confined to cooperation networks between enterprises and universities, but also involves those between enterprises, and between enterprises and public organizations. By means of multidimensional exploration of patent cooperation application and patent citation data, the researcher further studies the networks effects on knowledge spillover and knowledge interactions[17][18]. It is clear that the study of "PCNs" is moving towards a direction based on enterprises' perspective and is exploring the inner mechanism and promotional factors of multi-dimensional networks structure's impact on innovation performance. To sum up from the above analysis, the research defines "PCNs" as a multi-dimensional complex networks formed in the process of a TMSE R & D cooperation, industry-university-research cooperation or technology transfer, during which the TSME, by means of cooperation, applies for, purchases, and transfers or cross-licenses patents.

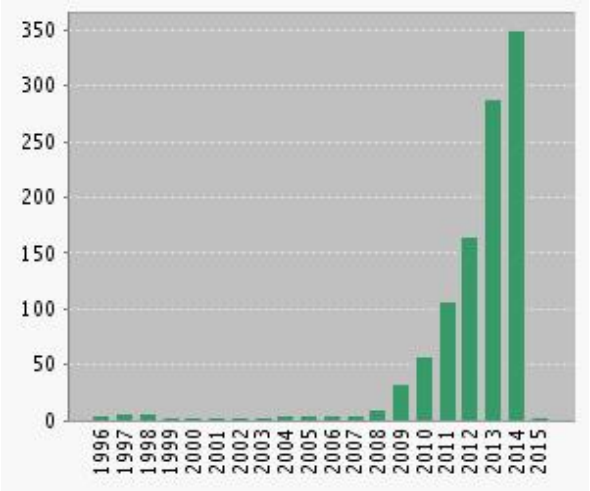

Figure 1"Patent Network" the number of citations in recent 20 years

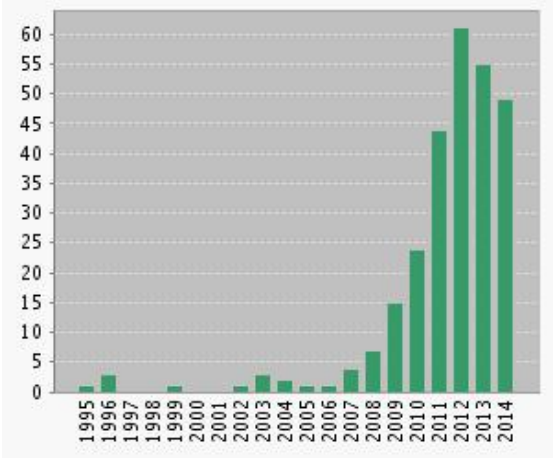

Figure 2 "Patent Network" the number of publications in recent 20 years

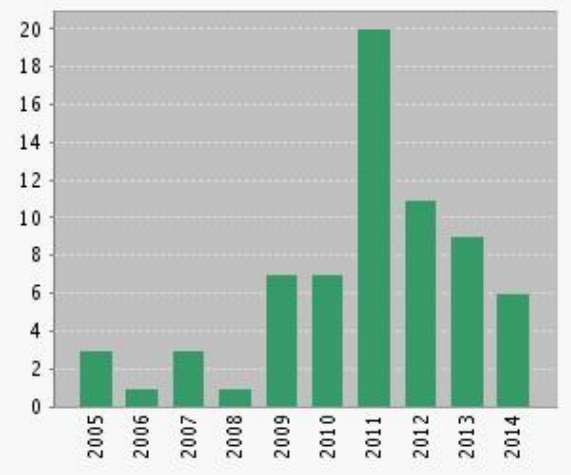

Figure 3 "Patent Cooperation Network" the number of publications in recent 20 years

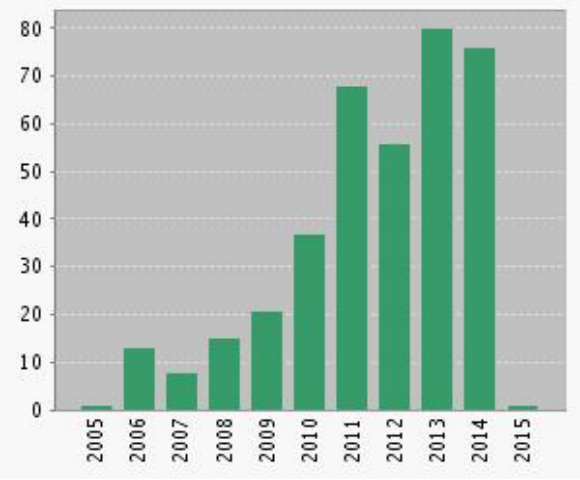

Figure 4 "Patent Cooperation Network" the number of citations in recent 20 years

Geographical, technological or social proximity is mainly relied on to differentiate and construct PCNs. Their specific classifications are shown in Table 1.

TABLE 1 THE CONSTRUCTION CLASSIFICATION OF PCNS

Index Classification	Index Difference	Construction Classification	Reference
Geographical Proximity	Regional Difference	Crossing-border PCNs Inter-regional PCNs Inter-enterprises PCNs	Lei, Xiao-Ping et al(2013)[19];Paier et al(2011)[20];Xiang Xiyao et al (2010)[21];Liu Xiaoyan et al(2013)[22];Ye Chunxia et al（2013）[23]
Technological Proximity	The Difference of Technical Cooperation Model	Patent Cooperation Application Networks Patent Technology Transfer Networks	Beaudry et al(2011) [24];Murphy et al (2013) [25];Si Changqi et al (2010) [26]
	The Difference of Technology Application Model	Patent Alliance Patent Pool	Phelps C C.(2010) [27]; Pek-hool Soh(2010) [28] et al
Social Proximity	Cooperative Object Difference	Industry-University-Research Patent Cooperation Networks Scientific Research Cooperation Networks Inventor Cooperation Networks	Arza et al (2011) [29]; Bertrand-Cloodt et al(2011) [30]; Luan Chunjuan (2008) [31]; Ma Yanyan et al（2011）[32];Liu Fengchao et al（2013）[33]

It has been common for researches to focus on those of crossing-border, inter-regional and inter-enterprises in nature. They tend to identify a network's overall layout on basis of geographic space. Studies focusing on networks of industry-university-research cooperation and of inventor cooperation are normally constructed in accordance with the dissimilarities in cooperation objects. Regardless whether it is constructed by geographical distribution, or the differences between the cooperation objects, the PCNs is mainly dependent on patent cooperation application or patent citations to build a relationship, thus falls into the realm of research of patent application networks. Only a small proportion of research is geared to patent technology transfer networks. A technology alliance or a patent pool is one that PCNs established on the basis of contractual relationship, epitomizes the type of complicated networks formed by a combination of relationships of patent cooperation application and patent technology transfer. In fact, research on PCNs model can draw on the related research on cooperative innovation and expand further. For instance, Rothaermel based on the different objectives of the three parties i.e. enterprise, supplier and customer in cooperative innovation, divided it into exploratory cooperative innovation and applied cooperative innovation, each exerting different influence on enterprise's innovation performance[34]. Lam adopted case study methodology to attributed the cooperation innovation networks of American multinationals to centralized networks, and but classified the Japanese multinational innovation networks as decentralized networks[35]. Corsaro, having interviewed 46 high-tech companies from a same entrepreneuring networks, found that three different networks allocation models, namely, skeptical, exploratory, and trusting type, can coexist in the same innovation networks, and exert influence upon each other through the cross-border activities[36]. The above studies provide positive insight to exploring the formation of enterprise-centered PCNs. By differentiating patent cooperation purposes, breadth and depth, and networks resources allocation, we can make in-depth analysis of the formation of patent cooperation subnet, so as to generate more scientific validation in studying the impact on enterprise growth from networks self-correlation, common subject characteristics and networks endogenous factors.

B. The Influence of PCNs on the Enterprise Growth

Although scholars explore enterprise growth mechanism from different perspectives, fundamental factors that affect an enterprise's growth lie in the quality of its own resources, the interactivity with external environment, customer market adaptability and advancement of technological innovation. The dynamic evolution of the PCNs brings changes in the growth of enterprises embedded in it. Therefore, how to dynamically and effectively build, optimize and adjust PCNs to realize sustained corporate growth has increasingly become a hot research topic. But the impact on enterprise's innovation performance from PCNs remains controversial. Research documents record the following three major points of view (view comparison shown in Table 2).

TABLE2 COMPARISON OF DIFFERENT VIEWS ON THE IMPACT OF PCNS ON INNOVATION PERFORMANCE

View	Main Idea	Reference
Resource Based View	Patent Cooperation is Beneficial to Integrating Heterogeneous Resources, Enhancing the Ability of the Partners and Exerts a Positive Effect on Innovation Performance Growth	Chen Zifeng et al (2009); Ozbugday et al(2012)
Evolutionary View	The Impact of Patent Cooperation on Innovation Performance Appears in an Inverted U. Networks with too Close or Lack of Cooperation Show Lower Innovation Performance than Those with Average Cooperation Intensity, with Repeat Cooperation even Exerting Negative Impact	Bertrand-Cloodt et al (2011); Broekel Tom et al(2012);Liu Xiaoyan et al (2013)
Ability View	Only by an Interactive Integration of the Enterprise's Ability with the External Networks Resources, can the Enterprise Expect Real Innovation Development	Dovin et al(2008);Holger Graf et al(2011);Zhang Hua et al(2013)

Scholars holding resource based view believe that patent cooperation is beneficial to integrating heterogeneous resources, and exerts a positive effect on innovation performance growth. For instance, Chen Zifeng and Guan Jiancheng analyzed the Small-world properties of 9 innovative country and regional R&D cooperation networks, and point out that their shorter average path length and stronger Small World properties tend to lead to more innovative output. Study by Ozbugda yet al of Dutch manufacturing factors affecting industrial innovation between 1993 and 2007 indicates the increase of patent applications among enterprises has significant impact on industrial innovation performance growth. Scholars with resource based view pay more attention to the impact on innovation performance by static PCNs, and neglect impact by such network's dynamic evolution features.

Scholars holding evolutionary view point out that the impact of patent cooperation on innovation performance appears in an inverted U shaped. Networks with too close or lack of cooperation show lower innovation performance than those with average cooperation intensity, with repeat cooperation even exerting negative impact. For instance, study by Beaudry et al of Canada's invention cooperation in nanotechnology reveals that repeat cooperation exerts a negative impact on patent output. Tom Broekel use patent cooperation application data to analyze the 270 service areas in German electrical and electronic industry. The result shows that intensity of regional cooperation has an inverted U shaped impact on regional innovation performance, and regions of average cooperation intensity score higher in innovation performance than those of too close or lack of cooperation[37]. Research by Liu Xiaoyan, Yuan Pingnan and Tong Tong [22] in the PCN's knowledge diffusion factor of integrated circuit industry reveals that the enterprise's network's density is in negative correlation with the knowledge diffusion. Although scholars with evolution views pay close attention to the impact of the dynamic PCNs on innovation performance, they have not, however, revealed internal process mechanism through which the evolution of PCNs influences innovation performance.

Scholars with ability view stress that only by an interactive integration of the enterprise's ability with the external networks resources, can the enterprise expect real innovation development. Dovin pointed out that networks capability is inseparable from the improvement of enterprise performance[38]. Research by Holger Graf of German and French regional organizational innovation networks indicates the networks gatekeeper's role is subjected to the influence of organizational absorptive capacity[39]. Zhang Hua and Lang Chun gang carried out a theoretical study on the inventor cooperation networks[40]. The study points out that the difference resulted from different levels of self-monitoring in networks construction and the utilization opportunity will lead to the development of different knowledge innovation [30]. Scholars holding ability view highlight the indirect impact of PCNs on innovation performance. They point out that in order to achieve a more comprehensive understanding of the PCN's impact on enterprise innovation growth mechanism, a dynamical monitoring of the interaction of embedded networks diversity and the enterprise behavior can is required.

The above-mentioned views fully demonstrate the limitation of the direct impact from PCNs upon the enterprise growth. Those scholars holding the view of networks resources pay attention to effect of the vital role of networks capability and internal resources integration on the performance of enterprise innovation and the constant interaction between the enterprises[34]-[36].The scholars with networks evolution views believe that factors like networks selection mechanism and networks proximity all affect networks evolution and its breakthrough from networks inertia[37]-[40].The scholars of networks capacity hold that PCNs effects on enterprise innovation performance are subjected to influence and regulations from factors like the enterprise networks capability and absorptive capacity. Some scholars state that there are differences in absorb ability of the external knowledge. Precisely these differences generate different growth and innovation performance. Still there are other scholars who point out that if the enterprise possesses strong networks capability, it can achieve rapid improvement in technological power through external networks. But in the existing studies, enterprise behavior, an important characteristic variable, has yet been incorporated satisfactorily into the networks study model. On the one hand, enterprises of different categories, size and growth stage tend to have drastic different behavior and are affected by a multitude of factors. There is a lack of consistent and feasible analysis framework; On the other hand, the existing social and economic complex networks model based on individual selection is mainly WS model of Watts and BA of Barabasi's, and they fail to well explain the corresponding relationship between networks growth rules and individual behavior choices. However, the PCNs does not limit itself to a collection of enterprises and institutions that contact with each other in specific areas and share geographical proximity. It is more of a cooperation relationship among enterprise-centered outward expanding multiple subjects affected by technology- and social- proximity. Therefore, the enterprise's cognition and choice of networks resources play a significant role in PCN's influence upon innovation performance. Research on the enterprise's growth should pay particular attention to the indirect impact mechanism by diversified PCNs' co-evolution on innovation performance. Focusing on the differentiation and initiatives of enterprise behavior will be the next research hot spot in the relationship between PCNs and enterprise growth.

III. THE ANALYSE OF MECHANISM ABOUT PCNs' INFLUENCE ON TSMEs GROWTH

The very essence of PCNs lies in the interactive innovation process of social network-based knowledge flow

and resource integration, and especially in the knowledge increase in the cooperation networks, which in turn can result in management upgrading and provide the opportunity to uncover untapped resources. Therefore the research on PCNs' influence on enterprise development can lead to a deeper understanding of the enterprise growth mechanism in a social networks context. Breaking away from the paradigm of studying the networks as a whole in previous studies, this research proceeds from the self-centered PCNs, examines structural differences of PCNs affecting the breadth and depth of the enterprise's access to resources, analyzes the inherent driving factor of key ability in PCNs' impact upon enterprise growth, and offers TSMEs a breakthrough path and growth plan along "relying on PCNs-cultivating enterprise ability-promoting enterprise growth".

A. The Construction of PCNs' Model

Different from the past research which mostly proceeded from the entire networks and categorized it on the basis of geographical, technological or social proximity, this research starts from the structure of self-centered enterprise PCNs, and based on breadth and depth of the of the patent cooperation, carries out dual structure classification and multi-model construction of the networks, explores and analyzes its characteristics (diagram as shown in figure 5). For PCNs model constructing, reference has been made to the research of Corsaro research[36]. From a perspective of interaction between self-centered networks and enterprise's behavior and ability, we divide TSMEs PCNs into two models of "exploratory" and "utilitarian". We plan to use characterizations like networks scale, density and diversity to represent patent cooperation breadth, and use networsk relation intensity, node distance, and centricity to indicate patent cooperation depth. Attempts will be made by enhancing the patent cooperation breadth to build networks resources of high heterogeneity, with the aim to define the networks that acquires broad new external knowledge source as "exploratory PCNs"; Efforts will also be spent by enhancing the patent cooperation depth to build networks resources of low heterogeneity, with the aim to define the networks that makes deeper use of existing new external knowledge source as "utilitarian PCNs". The PCNs with different breadth and depth combinations exert different effect on the growth of TSMEs. Based on the above analysis, this study puts forward the following propositions:

Proposition 1: PCNs' Model be Divided into Exploratory and Utilitarian.

B. The Mechanism of PCN's Influence on TSMEs Growth

Enterprise growth theory has been subjected to the influence from classical economics, new classical economics, new institutional economics, Post-Keynesianism and Penrose's Theory of the Growth of the Firm. These researches cover wide an area, including basic connotations like enterprise behavior, growth, organizational structure and management, etc. As a result, a what is known as "Jungle Phenomenon" emerges in enterprise growth theory[41]from which not a unified theory system has formed this far. This study attempts to look at the enterprise growth from the perspective of the integration of its internal ability and external network resources, and proposes that it is a process under constant influence and intervention from the enterprise's internal ability, one of its constant exploring, integrating and utilizing external resources, improving internal capacity, and finally attaining sustainable growth. For the TSMEs' growth mechanism there are numerous expositions, and scholars have tried to study the diversifying factors of influence from different perspectives. To sum up, the followings eleven are the most prominent: entrepreneurs (including management ability and entrepreneurship), governance structure, manpower, finance and accounting, production operations, product and market, R&D, corporate culture, internal and external information exchange, clustering and incubation, external competitive environment.

In conclusion, the key factors influencing TSME growth are in essence reflected in the quality of their own resources, interaction with external environment, customer market adaptability and advancement of technology innovation. Fruit of technological creation and invention, patent is closely linked to the enterprise's technological innovation ability, and is an important indicator of its innovation ability. Construction of PCNs is not only conducive to improving the quantity and quality of the enterprise's patent, but also offers the opportunities and pathways to find new resources. Therefore, facing an open network competition environment,

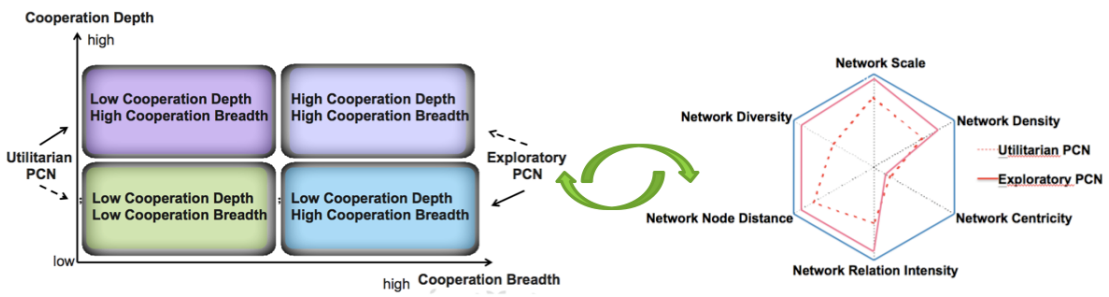

Figure 5 The Model of PCNs and its Characteristics

dynamic and effective building, optimizing and adjusting PCNs to realize the sustained growth of TSMEs are undoubtedly to become a hot research topic. Based on the above analysis, this study puts forward the following proposition:

Proposition 2: Both Exploratory and Utilitarian PCNs Exert Significant Impact on TSME Growth.

There have been related researches attempting to reveal the "black box" in growth process of SMEs from different perspectives like ecological niche, strategic alliance and self-organization, etc. Miguelez analyze the cross-regional inventor cooperation network from patent data of six years in 269 areas of Europe, point out that the regional innovation performance is not only affected by the regional innovation input, but also by stock of knowledge acquired from cross-regional cooperation[42]. In the study of SME growth mechanism, most researchers agree that the change in knowledge capital stock is the most vital embodiment of a firm's growth ability, with absorptive capacity particularly important for its knowledge innovation maturity. Scholars stressing on the enterprise's internal ability point out that network theory school overemphasizes the impact of external exchange on enterprise innovation, but ignores the series of processes through which the enterprise acquires, digests, transforms and makes application of knowledge. They hold that enterprises differ in their ability to absorb external knowledge. And such differences result in differences in the enterprise's innovation performance [43]. The enterprise's absorbing ability involves the four aspects of acquisition, digestion, transformation and application [44]. Fan Jun and Wang Jinwei hold that the implicit knowledge acquisition has a significant positive effect on growth performance of a startup business, and network allocation and seat-occupation ability, by affecting implicit knowledge acquisition, exerts indirect positive effect on the growth performance of a new firm[45]. Some scholars further point out that absorptive capacity plays an intermediary role between enterprise network structure and innovation performance [46]. The above research fully demonstrates the vital role played by knowledge absorption in determining the impact of PCNs on enterprise innovation performance, lays foundation for the absorptive capacity-based research to explore the process mechanism of PCN's influence on enterprise growth. Based on the above analysis, this study puts forward the following assumption:

Proposition 3: Absorption Capacity Plays an Intermediary Role in Determining the Influence by PCNs on the Growth of TSMEs.

The dynamic evolution of PCNs leads to changes in growth of the embedding enterprise. Study by Zhao Chi and Zhou Qin of the self-organizational structure model of TSME growth suggests that with deepening of knowledge innovation and the loss of competitive advantage, enterprises will be gradually motivated to search for new technologies, eventually restrain themselves to a mutative growth path in alternation of the old and new paradigms[47]. This requires the enterprise to possess new capabilities to match the organizational change. Among them, the networking capability is the kind with which an enterprise develops and manages external network, seeks and uses network resources to gain competitive advantage. So it plays an active role in promoting innovation. The connotation of the network capability covers competence in network strategy, operations, relationship, seat-occupation, core management, portfolio management and role management, etc [48]-[50]. The concept of network capability pushes the study of innovation network from the network dimension to micro level of the enterprise, in exploring how enterprises manage and utilize innovation network to satisfy their needs of innovation, improve innovation performance, gain the sustainable competitive advantage, so as to provide the microeconomic foundation for innovation network to function. Lamin et al. point out that it is hard for start-up businesses to improve the technical ability in the short term by internal accumulation[51]. If the enterprise has strong network capability, it can accomplish the goal via external network. The empirical study by Fang Gang shows that network capability has significant positive influence on the enterprise innovation performance, and knowledge transfer plays a partial intermediary role in the process, implicating the mechanism by which the enterprise actively manages the external network and implements value acquisition management[52]. In addition to direct or indirect influence mechanism of network capability on the innovation performance, the current research has also paid attention to its adjusting effect. The empirical study by Ren Shenggang, Wu Juan and Wang Longwei shows that network capability generates positive adjustment effect on the relationship between innovation performance and embedding relationship intensity, relationship quality, network location and innovation performance, but no such influence on the relationship of network size, density and innovative performance[53]. The empirical study by Yun Jiang, Ma Wenjia and Chen Li finds that network strategy capability and the average openness of relationship capability show significant positive interaction effect on innovation performance[54]. Yu Xiaoyu points out that the sub-dimensions of network capability plays two-way adjustment role between technical ability and international business performance[55]. Based on the above analysis, this study advances the following assumption:

Proposition 4: network capacity plays an adjustment role in PCNs influence on TSME growth.

By analyzing and reflecting upon the theory and the related literature, this study probes into PCNs model and its inner mechanism of influencing TSME growth in an increasingly competitive market environ, and is of the opinion that the network plays an intermediary role affecting absorptive capacity of TSMEs in their growth, and network capability plays an adjustment role. From there, four research proposals are deduced, whose conceptual model is shown in Figure 6.

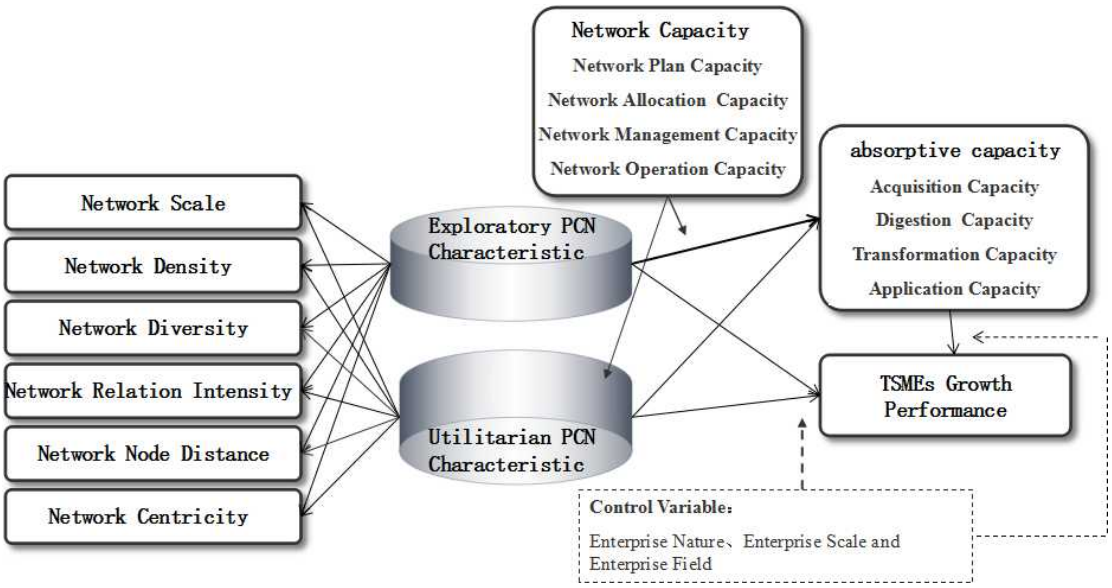

Figure 6 The Mechanism of PCNs' Influence on TSMEs Growth

C. The Balance Mechanism of the Impact of PCNs Evolution Based Capacity Regulation on TSMEs Growth

Model construction of PCNs based on different combinations of innovation breadth and depth does not only help TSMEs in their accurate assessment of the existing patent cooperation resources and their utilization potentiality, assist them to identify excessive dependence on external technology either due to extensive cooperation, or technological path rigidity resulted from repeat cooperation or growth bottlenecks from business cooperation resource deficiency; but also, through the association of patentees and inventors of patent technologies in a PCNs, explore the untapped patent cooperation resources, search for ways and possibilities to acquire resources, develop for TSMEs "blue ocean" of cooperation resources, and thus is of positive practice for knowledge creation and diffusion in the future.

It is hard for TSMEs to raise their technological ability in the short period through internal accumulation. With network capability, they can achieve the goal via external resources [51]. But enterprises within the same network structure exhibit differences in innovation performance. And the differences of absorptive capacity lead to difference in their innovation performance [56]-[58]. For TSMEs in growth bottleneck stage, cultivating network capability and absorptive capacity to achieve selective embedding in and dynamic adjustment to different models of PCNs to re-integrate external resources has become a possible growth pathway to breakthrough innovation capability trap. In their utilization of PCNs to push forward growth, TSMEs are not to overlook the series of process of knowledge acquisition, digestion, transformation and application. We need to maintain a dynamic control of the context and border conditions of the role of PCNs, uncover model building rules and characteristics of different PCNs based on different embedding models and cooperation depths, validate the impact of absorptive capacity and network capability on different PCNs models, and in turn, their impact upon enterprise's growth mechanism, and provide positive clues for TSMEs to cultivate key ability for growth.

IV. DISCUSSION

Building PCNs is conducive for TSMEs to make use of external network resources to share patent technology advantage, reduce the risk of R & D, and is of far-reaching significance for all collaborating parties to attain their strategic objectives, and join hands in technological and market development. It can avoid the waste of resources and capacities in the rivalry competitions, so as to accomplish corporate growth together. Therefore, the construction and use of PCNs is one of the key contents of enterprise patent strategy. PCNs model building and application not only can give a maximized play of patent strategy, but also provide the enterprise with a set of scientific and rational visible tools, offer real and dynamic decision-making reference for the enterprise's patent R & D investment, technology transfer and commercialization strategies, and open vast practice space and bring rich theoretical source in implementing the differentiation strategy design in IPR competition.

A. Define and Construct Multiple PCNs From the Perspective of Network Behavior

How to define and construct the different models of PCNs is the key issue this research needs to solve. Most of existing researches are based on the overall network characteristics and identify and acquire PCNs from cooperative partners and regions, rarely has any research based itself on self-centered network and proceeded from a perspective of corporate

behavior. An enterprise might tend to carry on in-depth cooperation with existing patent cooperation subjects or it might choose different ones for extensive cooperation. Either case will affect the resource allocation of cooperation network and the adjustment of enterprise corresponding ability, thus impacting the firm growth. This study starts from the dual structure of breadth and depth of patent cooperation, and divides the originally whole cooperation network into different sub-networks based on purposes of cooperation and resource allocations, and makes in-depth analysis of these subnets and the inner mechanism through which their interaction and synergy affecting enterprise growth, so as to reveal the "black box" of firm growth process.

B. Study and Explore Visualization of Different PCNs Models

The current questionnaire surveys show significant limitation in analyzing network dynamic evolution and coordination, and qualitative research and case study based on complex network theories can only reveal the general law of network dynamic evolution and coordination, but the gap between simulative and real life network cannot be overlooked. Using social network analysis and patent measurement analysis to conduct visualization research of the actual PCNs of TSMEs will not only reveal the possible different PCNs models, but also make quantitative analysis of their dynamic evolution laws, reveal the possible inherent laws of co-evolution among them, and lay foundation for the research to analyze the effect of PCNs on enterprise growth mechanism.

C. The Influence of Different PCN Models on TSME Growth Mechanism

This paper conducts quantitative research on the direct impact of multiple PCNs on TSME growth via patent measurement and social network analysis, explore show different types of PCNs influence firm growth curve, and studies, through the different time nodes in PCNs dynamic evolution, the interactive effect between the synergy of multiple networks on enterprise growth. Furthermore, on the basis of identifying typical enterprise's multiple PCNs through qualitative research and case study, the paper supplements and improves the impact research on firm growth curve from different types of PCNs. (4) Study the relationship between capability interaction and different PCNs model evolution from a dynamic perspective.

D. Study the Relationship Between Capability Interaction and Different PCNs model Evolution From a Dynamic Perspective

The key factor for TSMEs to breakthrough growth bottleneck lies in the acquisition and transfer of the external resources. But the curve effect of the PCNs on firm growth performance shows that the enterprise must balance the dynamic evolution between multiple networks through management and integration of network resources, and realize the sustainable upgrading of enterprise performance through the dynamic transition. While network capability, which includes network planning, seat-occupation, management and utilization, plays a critical role of adjustment in the co-evolution of multiple PCNs. But both the planned-to-be-introduced intermediary variables of absorptive capacity and adjusting variables of network capability are non-continuous variables, so the study of the indirect effect mechanism can only be one of cross-section. However, cross-section study at least provides two inner mechanisms of the role of the two capabilities, lays foundation for the subsequent simulation research on construct feedback mechanism. The paper makes further concentrated study, through a dynamic balance process mechanism analysis of different PCNs models, of the level change of two kinds of capabilities in different time nodes and synergy relationship with the network evolution. In this way, the study serves to construct the growth pathway of different models of PCNs co-evolution based on the network capability and absorption ability cultivation with positive feedback and self-organization effect. Furthermore it offers for TSMEs the growth plan "of relying on PCNs-cultivating enterprise ability- promoting enterprise growth".

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