The coupling mechanism between key resources acquisition capabilities and technologies innovation capabilities under open innovation pattern

Junshu Du, Yi Guo*

School of Business, East China University of Science and Technology, Shanghai, China, 200237

Received 1 December 2014, www.cmnt.lv

Abstract

This research investigates the mechanism of coupling relationship between enterprise key resources acquisition capabilities (*KRACs*) and technological innovation capabilities (*TICs*) in open innovation pattern. An evaluation model of coupling relations is set up by means of synergistic theory, which including efficiency function, coupling degree function, coupling degree index system, as well as coupling coordination function. Then, by taking SY corporation as a case, the study employs the evaluation model to evaluate the coupling degree of *KRACs* and *TICs*. The results show that the two factors of SY company both are in the state of middle coupling degree and coordination degree. The paper, on the one hand, fills the gap about the theory research between business *KRACs* and *TICs* in open innovation. On the other hand, this present provides a theoretical basis and practical guidance for enterprises to evaluate properly and monitor the coupling coordinated development between *KRACs* and *TICs*.

Keywords: Open Innovation; Coupling; Key Resources Acquisition Capabilities; Technological Innovation Capabilities

1 Introduction

Corporate innovation activities are traditionally viewed as taking place mostly within a single firm and set in a vertically integrated model. Since the early work [1], open innovation has attracted an ever increasing amount of interest, and has been proposed as a new paradigm for the management of innovation [1]. According to [2], open innovation is defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively". More and more enterprises are realizing that cooperation will increasingly strengthen their firms' incentives to increase their reliance on external knowledge or resource for innovation, and firms should be open to outside innovation [3]. Academia has also become increasingly aware of the importance of open innovation [2,4], and consequently researches on open innovation have also made a lot of achievements. However, previous studies on open innovation have primarily focused on case illustrations [5], identification of open innovation's dimensions, external technology acquisition and external technology exploitation [6], and their impacts on innovation performance [7,8], as well as intermediate variables (such as mediators or moderators) between them, and also the effects of different levels on innovation performance in open innovation [9].

In spite of an increasing amount of attention paid to open innovation research and some achievements obtained, there are still many unanswered questions regarding open innovation research, and many areas where further investigations are needed in theoretical and empirical research [2]. Open innovation breakthroughs, resource constraints due to enterprise boundaries in closed innovation, emphasizing innovation resources not only from the enterprise interior but also the outside, and the innovation activities are open which allows the resources of the innovation to expand. The key resources of technology and the market accessed play a significant role in promoting their own technological innovation in products and processes.

However, how the interaction of enterprises' abilities to access external key resources for innovation and their own technological innovation capabilities (TICs) is one of important issues that need to be explored in depth in open innovation. Regrettably, there are few studies about the relationship between key resource acquisition capability (KRACs) and TICs at present, and literature from the viewpoint of coupling effect to study and evaluate them is also lacking. According to [4], one of the areas that require consideration in open innovation activities is that of coupled mode. Therefore, this paper addresses the above mentioned limitations of extant research on coupling relationship in open innovation. To our knowledge, this study is the first to investigate the dyadic coupling interaction of KRACs and TICs. In doing so, we will analyse the synergistic coupling relationship between KRACs and TICs, and build an evaluation model of coupling relations so as to examine the state of their coupling, which will provide a reference

* Corresponding author's Email: yiguo@ecust.edu.cn

for enterprises and as a result accelerate technological innovation activities.

The remainder of the paper is structured as follows. Section 2 discusses the coupling relationship between KRACs and TICs as to shed light on their interaction mechanism. Next, we develop an evaluation model of coupling relations of KRACs and TICs, which including their efficiency function, coupling degree function, coupling degree index system, as well as coupling coordination function. Section 4 is to perform a case study with SY company. Finally, Section 5 concludes and discusses the implications and limitations of our work.

2 Coupling relationship between KRACs and TICs

In the 1970s, professor Harken proposed firstly the concept of “coupling” [10], and believed there was a wide variety of different time and space span systems with vastly different structures in nature. In spite of their different properties, systems affect and cooperate with each other, and also exist as a series of unstable and stable conversion in their environments. Coupling, which refers to a phenomenon in which two or more systems influence each other through various interactions as to join ultimately, originates from physics. The phenomenon reflects the dynamic relationship, including interdependence, coordination and promotion under the benign interaction between the subsystems [11]. Extended to the field of social sciences, coupling refers to the interactions of objective things that are combined to play a role under certain conditions in social phenomena. Similarly, in this research the phenomenon that the two sub-systems of KRACs and TICs interact with each other through their interacting elements, is defined as the key resources - technical innovation coupling.

Innovation activities within a firm are an interactive process characterized by technological interrelatedness between various sub-systems or sub-processes [12]. These sub-processes include those of concept generation, product development, production, technology acquisition, leadership, resource provision, and system and tool provision. An enterprise’s KRACs and TICs as the two abilities sub-system within technology innovation system, will yield synergistic effects through interaction with each other, thus we think there is a synergistic coupling relationship between them. According to the resource-based view (RBV), a firm’s competitive advantage stems from its unique assets and distinctive capabilities [13]. Not all resources, however, are likely to be of equal importance in creating competitive advantage. Advantage-generating resources are considered to be those that possess the combined traits of enabling the provision of competitively superior value to customers [13]; resisting duplication by competitors [14]; and whose value can be appropriated by the organization [15]. Various tangible and intangible resources in firms can be transformed into a unique ability, and the synergic effect of complementary resources can effectively enhance the performance of the enterprise and obtain sustainable competitive advantage [13]. As Drucker [16] pointed out, marketing and innovation were only two basic functions for enterprise. Marketing and innovation are used to generate revenue; the rest can be considered as costs. Technological innovation is a process that involves the interaction of many different resources. Marketing resources and technical resources are the key drivers of new product development in innovation activities [17], which are the point for supporting the core competitive advantage [12]. Based on the above, this study chooses marketing and technical resources as a business’ key resources within resource acquisition.

Marketing resources referring to a resource to create value in the market with the collective knowledge, skills and resources to satisfy customer needs, is called “focus on market resources”, and can be divided into three dimensions, organizational culture, marketing assets and marketing capabilities [18]. From the perspective of key resources, the promotion of TICs needs to obtain kinds of new resources, with companies constantly update and improve existing internal resources. Thus, marketing resources provide market sources for enterprise technological innovation. Teece [12] considered that, the key to success of commercialization of new products depends on the support of a series of marketing resources, such as market research, advertising, distribution, and post-service, which affected the TICs of enterprises and finally the commercialization of a product. Within marketing resources, a company’s sales forecasting, distribution, promotion, and marketing integration have positive effect on new product development as well as innovation capability through some marketing skills and related marketing activities [19]. In fact, it reflects the company’s marketing capability, which is an ability used in the public sphere to sell products on the basis of understanding consumer needs, the competitive environment, costs and benefits, and also the acceptance of the innovation [20]. The stronger a corporation’s marketing capability, the more it has the ability to grasp the existing and potential needs of customers, furthermore the firm’s responses to market changes and technical updates are will be much faster, and are bound to promote an enterprise’s R&D [21]. Therefore, the investment in R&D will be much more than before; subsequently the R&D capability will be improved, leading to better guidance for manufacturing and a reinforcement in manufacturing and organizing capabilities. Thus, the TICs of enterprises get a promotion overall.

Technical resources refer to assets and capabilities of new technologies created endogenously ultimately through making choices about technologies, improving existing technologies and products by an organization, independently, including R&D resources, manufacturing skills, production technology, process innovation ability and forecasting in technology changes [17,21]. The usage of technical resources is beneficial in improving the technological properties of new products and in gaining market value by providing customers with excellent quality products. The market value reflects the market advantage and super-profits, behind which is the integration and effective use of the technical resources. Limited to own technical resources, an enterprise's innovative activities are difficult to complete independently, and there is a need to constantly communicate with the outside to search for new technical resources, so as to find new opportunities and future dominant paradigm of technologies. In the process of obtaining technical resources, learning capabilities, R&D capabilities, production and management capabilities provide firms with a base of abilities for open innovation, and have played an important role in the course of absorption in improving the overall technological innovation capabilities. Therefore, the abilities to obtain technical resources become an important factor that are transformed into TICs of a corporation, and affect the strength of TICs ultimately. As pointed out by research [19], technical resources acquisition capacities could predict the technological changes responded to external business environment by enterprises, and enhance the TICs in arising performance of the new product development.

From the perspective of TICs, according to [22], TICs were defined as a comprehensive set of characteristics of an organization that facilitates and supports its technological innovation strategies. TICs are a kind of special assets or resources which include technology, product, process, knowledge, experience and organization. They are tacit and could not be codified normally. In general, a wide variety of assets, resources, and capabilities are required for the success of an innovation. Therefore, TICs should be defined in different scopes and levels in order to cope with the requirements of company strategy and accommodate special conditions and competition environment. A firm with greater innovation capabilities will be more successful in responding to its external environment and developing new knowledge about how to improve existing products and processes or create new ones [23]. Within technological innovation activities, TICs, reversely, could enhance the marketing resources acquisition capability and technical resources acquisition capability, with providing various critical scarce resources for innovation [24]. Thus understanding an enterprise' TICs will be beneficial illuminating the customer requirements and preferences, to perceive the competition environment, and implement good sales strategies. In addition, with the promotion of TICs, an enterprise has a more profound understanding of the R&D of new products and technologies, production processes for manufacturing, technology changes, and so on. Thus, the ability to obtain technical resources will be raised in the process of constant learning and accumulating.

In the cycle between KRACs and TICs, the two capabilities of a firm are improved in spiral form as well as the core competitiveness of innovation. Based on the analysis above, there is an interaction coupling relationship between KRACs and TICs, which is dynamic and coordinated when they interact with each other through their respective coupling elements.

3 Coupling model for KRACs and TICs

In this paper, the degree of coupling is employed to reflect the coupling relationship model between KRACs and TICs, and describe the extent of interaction of the systems or elements [25]. From the synergy theory, coupling effect and the extent of coordination determine the system's orientation and structure when they reach a critical area, or determine the trend in development for system from disorder to order. The key mechanism for system from disorder to order is that the synergies among order parameters within the system, which determine the characteristics and law of the system in phase transition, and then the degree of coupling is the right measure for synergy. Thus, the phenomenon of interaction and influence between KRACs and TICs through their respective coupling elements is defined as key resources-technical innovation coupling, and reflects the strength and extent of contribution to technological innovation.

Although coupled systems in various disciplines have been researched for quite some time, there has still not been an agreement regarding the calculation on the degree of coupling. Researches related to this issue are relatively lacking at present, however one of major studies is Rosenbrock's Diagonal Dominance [26]. In spite of adjustable function, it is difficult to reflect the degree of coupling systems. Another is the Relative Amplification Coefficient method [27], which demonstrates that the condition of non-coupling effect on $[X_i, U_j]$ is λ_{ij} =1 in theoretically, and the greater of deviation distance to 1, the greater impact on the match of $[X_i, U_j]$ by other factors. However, the fact is that when the value of λ_{ij} is negative, the coupling effect is far more than the impact of λ_{ij} (>1). As a measure of the degree of coupling system, this approach has some drawbacks [28].

The degree of coupling between KRACs and TICs is computed drawing on the capacity coupling function, which reflects the interaction of two sub-systems elements' contribution to technological innovation in a firm. Based on analysis above, we have constructed a coupling assessment model between KRACs and TICs, involving efficacy function, function of coupling degree and coupling coordination function [29].

3.1 EFFICACY FUNCTION

Efficacy function reflects the extent of contribution to the orderly development of coupling system by KRACs and TICs. Variable U_i (i = 1,2,3, ... m) is set as the order parameter of coupling system between KRACs and TICs, and U_{ij} reflects the extent of contribution to coupling system by the indicator j^{th} (j = 1,2, ... n) in the i^{th} order parameter, and its value is X_{ij}, a, b are the upper and low thresholds of order parameters when the coupling system is in steady status. Then, the u_{ij} as the coefficients of efficacy function of KRACs and TICs for orderly system is calculated in formulas (1) and (2):

Positive coefficient: $u_{ij} = (x_{ij} - b_{ij}) / (a_{ij} - b_{ij})$ (1)

Negative coefficient: $u_{ij} = (x_{ij} - b_{ij}) / (a_{ij} - b_{ij})$ (2)

where u_{ij} represents the extent of X_{ij} ' contribution to the coupling system of KRACs and TICs, which reflects the level of satisfaction of indicators to the target. Specifically, it is the most satisfactory if u_{ij} approaching 1, as well as most dissatisfactory when u_{ij} tending to 0, thus the u_{ij} index value will be ranged in [0,1].

Then, u_i as the comprehensive contribution of each order parameter within sub-systems could be calculated using information entropy method. The concept of information entropy was first proposed by Shannon in 1948. When applied in the social system, information entropy is a measure of the uncertainty for the system status. Generally, if the value of information entropy is higher, the structure of the system is more balanced and the variation is less; otherwise, if the value of information entropy is lower, the structure of the system is more unbalanced and the variation is greater. Therefore, the weight of the indicators, i.e. the degree of variation of the indicators, can be calculated by the value of information entropy [30]. Entropy assigning method can determine the indicators weight by analysing correlation degree and information among indicators, and avoid bias caused by subjective influence to a certain extent. The steps are as follows (formulas (3)—(7)):

The proportion of the indicator j in order parameter i :

$$f_{ij} = u_{ij} / \sum_{i=1}^{n} u_{ij} \quad (3)$$

Information entropy of the indicator:

$$e_j = -\frac{1}{\text{In}\, m} \sum_{i=1}^{m} f_{ij} \times \text{In}\, f_{ij} \quad (0 \le e_j \le 1) \quad (4)$$

Entropy redundancy: $d_j = 1 - e_j$ (5)

Weight of the indicator: $w_j = d_j / \sum_{j=1}^{n} d_j$ (6)

Comprehensive level in order parameter i:

$$P_i = \sum_{j=1}^{n} w_j \times u_{ij} \quad (7)$$

Where n is the number of indicators, and m is the number of order parameter.

3.2 COUPLING DEGREE FUNCTION

According to [29], the coupling degree could be learned from capacitive coupling in physics and be computed as the following:

$$C_m = \left\{ (u_1 \times u_2 \times ... u_m) / \left[\prod (u_i + u_j) \right] \right\}^{1/m} \quad (8)$$

Due to coupling relationship between KRACs and TICs, the value of m is 2. Therefore, the coupling degree function of KRAC and TIC is:

$$C = \left\{ (u_1 \times u_2) / \left[(u_1 + u_2) \times (u_1 + u_2) \right] \right\}^{1/2} \quad (9)$$

Based on formulas (9), C as the coupling degree value is ranged in $[0,1]$. As mentioned above, when $c = 1$, the value of coupling degree is the maximum, indicating that the interaction of two capacities sub-systems reaches a benign resonant coupling, and technological innovation system will tend to a new orderly structure. Whereas, when $c = 0$, the value of coupling degree is the minimum, indicating none of coupling between the two capacities sub-systems, with disorder development for technological innovation system. Based on the division of coupling phase in physics, the paper divides the coupling status of KRACs and TICs into three stages, as shown in Table 1.

3.3 COUPLING COORDINATION FUNCTION

As an important indicator reflecting the coupling relationship between KRACs and TICs, the degree of coupling could distinguish the strength of the coupling effect of KRACs and TICs, as well as its timing interval. However, it is difficult for the degree of coupling to reflect the overall effectiveness and synergies in some cases, especially with the inconsistent methods in calculating the threshold of low and upper.

TABLE 1. Stage and Status of Coupling Between KRACs and TICs.

Stage	Status	Explanation
0<c≤0.3	Low level of coupling	A firm pays more attention to improve TICs and ignore the importance of the KRACs, resulting in much lower level of KRACs than TICs, which, to a certain extent, limits the space for improvement for technological innovation.
0.3<c≤0.7	Medium level of coupling	KRACs and TICs are both improved, and their level of interaction is not optimum, indicating that there is a room for improvement for finding a matching degree between them
0.3<c≤1.0	High level of coupling	KRACs and TICs are both greater, and the developments of KRACs and TICs are complementary and they promote each other. The technology innovation system gradually achieves optimal effectiveness.

For example, when doing a satisfaction survey on indicators, we can choose 5-point Likert scale, 7-point Likert scale or 9-point Likert scale for score without a unified measure, as may be misleading if we rely only on the coupling degree. Thus, the coupling coordination degree model (CCDM) is set up between KRACs and TICs, so as to assess the extent of the coupling coordination to different KRACs and TICs, and the formulas (10)—(11) are expressed as following:

$$D=\sqrt{C\times T} \tag{10}$$

$$T=\alpha U_1+\beta U_2 \tag{11}$$

Where C represents the degree of coupling, U_1 is the level of KRACs sub-system and U_2 is the level of TICs sub-system. D is the degree of coupling coordination, and T is the comprehensive harmonic index, reflecting the overall effect or level of KRACs and TICs. The values of D and T are range from 0 to 1. α and β are the weights, representing the contribution of KRACs and TICs, respectively.

Based on the analysis about division of the coupling above, CCDM could be roughly divided in this way: when $0<D\le 0.4$, represents low level of coupling coordination; $0.4<D\le 0.6$, represents medium level of coupling coordination; $0.6<D\le 0.8$, represents high level of coupling coordination; when $0.8<D<1$, represents extreme high level of coupling coordination. Meanwhile, to evaluate accurately the relationship between KRACs and TICs, this study draws on the relevant research results when setting up the comprehensive evaluation index system, as shown in Table 2. It particularly addresses the actual situation manufacturing enterprises face in China and constructs the evaluation index system based on objective scientific principles.

TABLE 2. Index system used for evaluation of the relationship between KRACs and TICs.

Order Parameter	Evaluation Index	Description	Reference
Key Resources Acquisition Capabilities	Marketing Resources Acquisition Capability	In open innovation, comparing to your major competitors:	[19], [20]
		an ability to capture the quality of the firm's customer service	
		an ability to promote and advertise effectively	
		an ability to subdivide and penetrate the market	
		an ability to obtain strength of distribution networks	
		an ability to obtain the power of product pricing	
	Technical Resources Acquisition Capability	In open innovation, comparing to your major competitors:	[17],[19],[21]
		an ability to develop new technology	
		an ability to develop new product	
		an ability to develop manufacturing processes	
		an ability to grasp and forecast technological change	
Technological Innovation Capabilities	Learning Capability	an ability to identify, assimilate, and exploit knowledge from the external environment	[22],[24]
	R&D Capability	an ability to integrate R&D strategy, project implementation, project portfolio management, and R&D expenditure	
	Resource Allocation Capability	an ability to acquire and to allocate appropriately capital, expertise and technology in the innovation process	
	Manufacturing Capability	an ability to transform R&D results into products, which meet market needs, accord with design request and can be manufactured	
	Marketing Capability	an ability to publicize and sell products on the basis of understanding consumer needs, competition position, cost and benefit, and acceptance of innovation	
	Organization Capability	an ability in securing organizational mechanism and harmony, cultivating organization culture, and adopting good management practices	
	Strategic Planning Capability	an ability to understand all kinds of external relations and to acclimatize to external environment.	

4 Case Study

4.1 SAMPLE AND DATA

Given the representative and typical data in case study, this paper used the company SY as a research sample for analysis. SY is a large-scale engineering machinery manufacturing oriented private enterprise in China, whose main products include concrete machinery, mining machinery, lifting machinery, port machinery and so on. Over two decades of development, SY experienced a process ranging from closed to open innovation in technology R&D, and has subsequently become a leader in China's engineering machinery industry. The mode of technology innovation of SY reflects the situation in the machinery manufacturing industry, to some extent, especially the development course of private enterprises in China. Therefore, empirical analysis of this present on coupling coordination degree evaluation about KRACs and TICs is not only conducive to finding problems in innovation activities, but also to provide references and enlightenments for other companies on their way to independent innovation.

With a random stratified sampling method, we conduct research questionnaires to SY company's senior technical and management personnel. The survey was conducted in March 2014 and 52 valid responses were obtained out of 70 questionnaires, achieving a final response rate of 74.29%.

4.2 RESULT ANALYSIS

The weights of each order parameter and evaluation index are calculated by the information entropy approach according to the formulas (3) to (6). SY's order parameters and the weights of evaluation indicators are shown in Table 3.

According to the evaluation index system of coupling degree, the satisfaction survey table of each index is designed with 5-point Likert scale, ranging from "strongly disagree (=1)" to "strongly agree (=5)".

TABLE 3. Order Parameters and Weights of Evaluation Indicators.

Order Parameter	Weight	Evaluation Index	Weight
Key Resource Acquisition Capabilities	0.4624	Marketing Resources Acquisition Capability	0.4552
		Technical Resources Acquisition Capability	0.5448
Technological Innovation Capabilities	0.5376	Learning Capability	0.1395
		R&D Capability	0.1726
		Resource Allocation Capability	0.1489
		Manufacturing Capability	0.1436
		Marketing Capability	0.1277
		Organization Capability	0.1302
		Strategic Planning Capability	0.1375

The maximum and minimum values of threshold of order parameter are 5 and 1, respectively, so $a_{ij}=5$ and $b_{ij}=1$. Based on the actual data obtained from the survey questionnaire and formula (1), the value of u_{ij} could be calculated.

According to Table (3), the value of u_{ij} and formula (3)—(7), the values of order parameters (KRACs and TICs) are 0.371 and 0.634, respectively. Also, we got the value of coupling degree based on u_1, u_2 and formula (9), which is C=0.482. According to the weights of KRACs and TICs in Table 3, α and β are respectively 0.4624, 0.5376, and together with u_1, u_2 and formula (10)—(11),

then the values of D and T are 0.497 and 0.512, respectively. The results are represented in Table 4 below.

According to the data above, analytical results are as follows:

(1). the value of order parameter TICs is 0.634, indicating that there are relatively large contribution of TICs to technology innovation system. While, the value of order parameter KRACs is 0.371, less than TICs in comparison, demonstrating that TICs has a greater role in promoting technological innovation system than KRACs at present.

(2). According to the coupling function, the value of coupling degree for SY company is $C_m=0.483$, within (0.3, 0.7), which indicates that the coupling system of KRACs and TICs is in the medium level of coupling and not in the optimum status, also the degree of match between the two sub-systems remains to be further improved.

TABLE 4. The Coupling Degree of KRACs and TICs of SY Corporation.

Coupling Variable	Value
Order parameter of KRACs	0.371
Order parameter of TICs	0.634
Coupling degree	0.483
Comprehensive harmonic index	0.512
Degree of coupling coordination	0.497

(2). According to the coupling function, the value of coupling degree for SY company is $C_m=0.483$, within (0.3, 0.7), which indicates that the coupling system of KRACs and TICs is in the medium level of coupling and not in the optimum status, also the degree of match between the two sub-systems remains to be further improved.

(3). The value of coupling coordination degree is $D = 0.479$, within (0.4, 0.6), as demonstrates that the coupling system of KARCs and TICs is in the moderate level of coordination coupling. The goal congruence of KRACs and TICs is poor and the extent of coordination needs to be further strengthened.

6 Conclusion

This study contributes to the growing interest in integrating the resource-based view and synergy theory approaches in studying the coupling relationship between KARCs and TICs in open innovation patterns, a subject that has not yet been fully investigated in prior literature on empirical studies. The research has built a coupling degree model and proposed a comprehensive index system for the assessment of KARCs and TICs, it then took SY company as an example for empirical analysis, which reached the following conclusions. We find that there is an interaction coupling relationship between KARCs and TICs, and the two capabilities are within the enterprise technological innovation system, together. As two major sub-systems, the extent of their coupling synergy is a key to successful innovation. The model of coupling degree was used to analyse the coupling status of KARCs and TICs in the engineering company SY. The results showed that the order parameter value of KARCs was low, and the values of coupling degree and coupling coordination degree between KARCs and TICs are not high. The findings demonstrated that, the development of KARCs is lagged behind TICs, and the interaction of the two capabilities is in the medium level of coupling coordination stage, and still has much room for improvement. There is need a need for the SY corporation to coordinate the development of KARCs and TICs, and also pay more attention to improve the KARCs when promoting the TICs. In addition, by emphasizing coordinated development of capabilities, this paper also corresponds to other scholars' interests in coupled mode for enterprises in open innovation [4].

Although the results of this study complements the extant study about the dyadic coupling interaction of KRACs and TICs, and provides suggestions for technological innovation activities, the present research has limitations that provide set boundaries during interpretations of various findings and scope for future research.

For one thing, subject to the difficulty in availability and time lag, this study takes only SY company as the representative sample, and conducts the quantitative evaluation in-depth based on coupling evaluation model of KRACs and TICs. However, private enterprises in China generally face innovative resource-constrained situations, and how to get the key innovation resources to breakthrough constraint of innovation resource is the focus of attention for private firms in innovation activities. We believe that this model is relevant not only to specific enterprises such as the private companies. Compared to state-owned corporations with financial and policies support by the state, and foreign companies with experienced management and advanced technology, it is not easy for corporations like SY, as only one representative in private enterprise, to reach the medium level of coupling between KRACs and TICs. Therefore， the validity and generalization of this research's findings to other types of enterprises are still limited. Future research could expand the industry and type of business, and applying this model to study the relationship between KRACs and TICs in other areas will be critical for a more comprehensive understanding of the varied patterns and coupling relationship. This could also be meaningful and help to explain differences in coupling relationship between KRACs and TICs.

From a methodological perspective, on the other hand, this paper underscores the promising aspects of employing an evaluation model, which is used to explain the coupling relationship between KRACs and TICs from a static point. However, the development of enterprise capabilities is progressive and dynamic. Next a study based on the evolution analysis techniques, could use the dynamic coupling model to explore the relationship between KRACs and TICs, by conducting longitudinal studies or other appropriate tracking studies from an evolutionary perspective.

Acknowledgements

This research is supported by the project of humanities and social sciences of Chinese Ministry of Education (Grant No.13YJCZH295). Additionally, the authors are sincerely grateful for the anonymous reviewers' valuable comments and suggestions that have greatly helped improving the quality of the paper.

References

[1] Chesbrough H W 2003 *Open innovation: The new imperative for creating and profiting from technology* Harvard Business Press: Boston
[2] Chesbrough H, Vanhaverbeke and West J 2006 *Open innovation: Researching a new paradigm* Oxford University Press: New York
[3] Christensen J F, Olesen M H and Kjær J S 2005 The industrial dynamics of Open Innovation: Evidence from the transformation of consumer electronics *Research Policy* **34**(10) 1533-1549
[4] West J, Salter A, Vanhaverbeke W and Chesbrough H 2014 Open innovation: The next decade *Research Policy* **43**(5) 805-811
[5] Dodgson M, Gann D and Salter A 2006 The role of technology in the shift towards open innovation: The case of Procter & Gamble *R&D Management* **36**(3) 333-346
[6] Hsuan J, Mahnke V 2011 Outsourcing R&D: A review, model, and research agenda *R&D Management* **41**(1) 1-7
[7] Sisodiya S R, Johnson J L and Grégoire Y 2013 Inbound open innovation for enhanced performance: enablers and opportunities *Industrial Marketing Management* **42**(5) 836-849
[8] Hung K P, Chou C 2013 The impact of open innovation on firm performance: The moderating effects of internal R&D and environmental turbulence *Technovation* **33**(10-11) 368-380
[9] Lichtenthaler U 2011 Open innovation: Past research, current debates, and future directions *The Academy of Management Perspectives* **25**(1) 75-93
[10] Haken H 1983 *Synergetics: An introduction 3nd edition* Spring-Verlag: Berlin

[11] Zhou H 2003 *Modern Chinese Dictionary* Guangming Daily Press: Beijing

[12] Teece D J 1986 Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy *Research Policy* **15**(6) 285-305

[13] Barney J B 2001 Resource-based theories of competitive advantage: A ten-year retrospective on the resource-based view *Journal of Management* **27**(6), 643-650

[14] Dierickx I, Cool K 1989 Asset stock accumulation and sustainability of competitive advantage *Management Science* **35**(12)1504-1551

[15] Collis D J, Montgomery C A 1995 Montgomery competing on resources: strategy in the 1990s *Harvard Business Review* **73**(4) 118-128

[16] Drucker P F 2007 Innovation and entrepreneurship: Practice and principles *Routledge*

[17] DeSarbo W S, Di Benedetto C A and Song M 2007 A heterogeneous resource based view for exploring relationships between firm performance and capabilities *Journal of Modelling in Management* **2**(2) 103-130

[18] Hooley G J, Greenleya G E, Cadogana J W and Fahy J 2005 The performance impact of marketing resources *Journal of Business Research* **58**(1) 18-27

[19] Song M, Droge C, Hanvanich S and Calantone R 2005 Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts *Strategic Management Journal* **26**(3) 259-276

[20] Weerawardena J 2003 The role of marketing capability in innovation-based competitive strategy *Journal of Strategic Marketing* **11**(1) 15-35

[21] Jung J, Mah J S 2013 R&D Policies of Korea and Their Implications for Developing Countries *Science Technology and Society* **18**(2) 165-188.

[22] Cooper R G 1983 A process model for industrial new product development *Engineering Management, IEEE Transactions on* (1), 2-11

[23] Burgelman R, Maidique M A and Wheelwright S C 2004 *Strategic Management of Technology and Innovation* McGraw-Hill: New York

[24] Hurley R F, Hult G T M 1998 Innovation, market orientation, and organizational learning: An integration and empirical examination *The Journal of Marketing* **62**(3) 42-54

[25] Yam R, Lo W, Tang E P Y and Lau A K 2011 Analysis of sources of innovation, technological innovation capabilities, and performance: An empirical study of Hong Kong manufacturing industries *Research Policy* **40**(3) 391-402

[26] Conner K R, Prahalad C K 1996 A resource-based theory of the firm: Knowledge versus opportunism *Organization Science* **7**(5) 477–501

[27] Rosenbrock H H 1974 *Computer-Aided Control System Design* Academic Press Inc. Ltd: London

[28] Bristol E 1966 On a new measure of interaction for multivariable process control *Automatic Control, IEEE Transactions* **11**(1) 133-134

[29] Ailon A 1991 Decoupling of square singular systems via proportional state feedback *Automatic Control, IEEE Transactions on* **36**(1) 95-102

[30] Li Y, Li Y, Zhou Y and Zhu X 2012 Investigation of a coupling model of coordination between urbanization and the environment *Journal of Environmental Management* **98**(15 May) 127-133

[31] Shannon C E 2001 A mathematical theory of communication *ACM SIGMOBILE Mobile Computing and Communications Review* **5**(1) 3-55

Authors

Du Junshu , 1985.1, School of Business, East China University of Science and Technology, Shanghai, P.R. China

Current position, grades: the Doctor of College of School of Business, Chongqing University ,China.
University studies: received his BEng in College of Mechanical Engineering from Yancheng Institute of Technology in China. He received his ME Project Management. from Jiangxi University of Science and Technology in China.
Scientific interest: His research interest fields include Computer Model in Management and Technological Innovation
Publications: 7 papers published in various journals.
Experience: He has completed four scientific research projects.

Guo Yi , 1955.5, School of Business, East China University of Science and Technology, Shanghai, P.R. China

Current position, grades: the Professor of School of Business, East China University of Science and Technology ,China.
University studies: received his BEng from Fudan University in China. He received his M.E. from Fudan University in China.
Scientific interest: His research interest fields include Organization Management and Innovation
Publications: 45 papers published in various journals.
Experience: He has completed 22 scientific research projects.