An Analysis on Effects of Science Communication on Regional Technological Innovation in SECI Model

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***Abstract*--From the perspective of knowledge, the foundation of technological innovation is knowledge-based innovation. Knowledge-based technological innovation is a dynamic process of creation, communication and application of new knowledge. Knowledge flow between technology innovators and technology followers within a region is an important factor of promoting regional innovation capability. This paper constructs technological innovation cycle under the perspective of knowledge to study knowledge creation, flow and transformation in the technological innovation cycle and analyzes the effects of science communication in the process of knowledge transformation. Finally, the effects of science communication on regional technological innovation are gained under the perspective of knowledge.**

I. TECHNOLOGICAL INNOVATION IN SECI MODEL

A. SECI model

After Ikujiro Nonaka made an in-depth study of knowledge innovation experience of Japanese enterprises in 1970s-1980s, he systematically put forward four basic models of knowledge transformation for the first time – socialization, externalization, combination and internalization, i.e. famous SECI model. Such model has become a classical basic theory for knowledge management research [1]. Ikujiro Nonaka connected the performance of Japanese companies and the ability to create new knowledge and applied it to produce successful products and techniques for the first time, and contributed the success of Japanese companies to their ability to create knowledge [2]. The essential preconditions of this theoretical system are as follows: ① knowledge includes explicit knowledge and tacit knowledge [3]; ② in innovation activities, explicit knowledge and tacit knowledge will transform mutually; ③ knowledge transformation and creation can occur among individuals, between individuals and the organization and among organizations. These four models continuously interact and transform mutually. Finally, knowledge creation and transformation can be achieved.

① Socialization process from tacit knowledge to tacit knowledge is a sharing knowledge process. Tacit knowledge is highly individualized. Its composition is characterized by complex background and the difficulty in formulation. Thus, tacit knowledge flow has preconditions and is thus not easy to be directly utilized by the subject.

② Externalization process from tacit knowledge to explicit knowledge is the process of clearly expressing tacit knowledge as explicit knowledge. Externalization is a key link of knowledge creation. Only when tacit knowledge forms clear explicit knowledge through flow, absorption and application can knowledge become concrete and have the conditions for sharing. Tacit knowledge is the core for a generation of new knowledge and occupies a large proportion in individual knowledge hierarchy composition. Thus, it has very important position in knowledge creation and is thus called the most valuable knowledge. In the process of transforming tacit knowledge to explicit knowledge, a way which can be expressed is sought for the things which cannot be expressed to make tacit knowledge understood and systematized to explicit knowledge so as to make its value exerted to the largest extent.

③ Combination process from explicit knowledge to explicit knowledge aims to set up a common knowledge platform. Explicit knowledge is flowing knowledge which can be easily expressed and usually exists in the form of specification, document and system.

④ Internalization process form explicit knowledge to tacit knowledge is a process of individuals absorbing explicit knowledge and transforming it to tacit knowledge. The transformation from explicit knowledge to tacit knowledge is the internalization process of explicit knowledge, absorbs explicit knowledge, and makes it implicit. As a result, tacit knowledge gains innovation and improvement.

These four transformations depend on each other, associate with each other, and presents spiral upward. They jointly promote knowledge transformation and communication so as to lay a solid foundation for knowledge innovation. The process of science communication is similar to mutual transformation of explicit knowledge and tacit knowledge.

B. The knowledge flow in technological innovation

Knowledge alternately transforms and spirals during interactions between explicit knowledge and tacit knowledge. The spread and accumulation of knowledge, is the process of technology innovation. Knowledge subjects absorb knowledge, deliver knowledge, and realize knowledge flow and circular spiral. Tacit knowledge is implied knowledge and is not easy to be shared. Tacit knowledge flow is one-way and two-way flow among different subjects. In the flow process, effective integration of knowledge element is realized through transformation. Tacit knowledge flow includes the flow from tacit knowledge to explicit knowledge and the flow from tacit knowledge to tacit knowledge. The former externalizes tacit knowledge so as to make the exchange effects more shared, which is beneficial to knowledge flow. The latter refers to the process in which both exchange parties interact and construct new tacit knowledge through observation, experience and imitation, as shown in Fig.1.

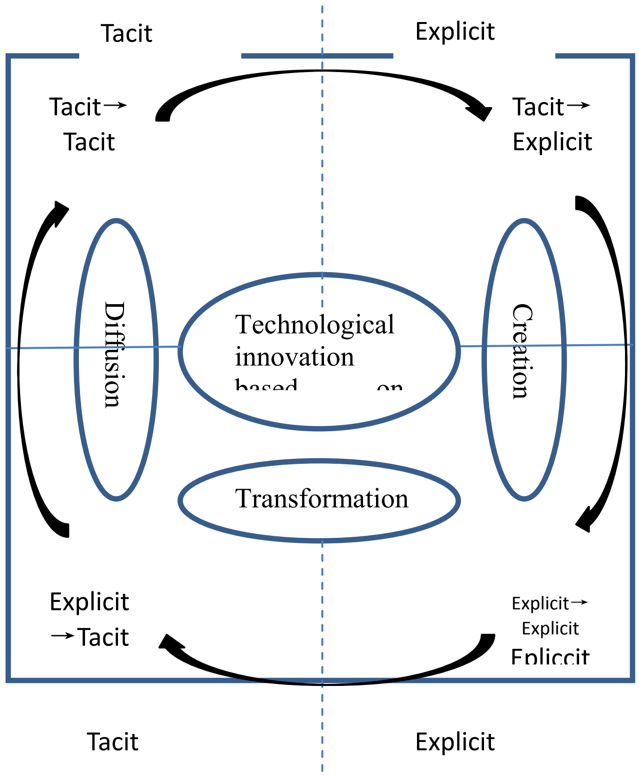

Fig.1 Technological innovation in knowledge transformation process

In the communication and transformation process of tacit knowledge, a part of tacit knowledge is transformed to explicit knowledge, which increases the possibility of knowledge communication. Knowledge subjects at each level improve knowledge ability and individual learning ability through socialization and externalization process of tacit knowledge and promote knowledge as basic technological innovation. Regional incentive system, cultural environment and value orientation may restrict tacit knowledge flow and transformation. In an open system, knowledge flow is beneficial to keeping knowledge and information exchange with the outside. This is similar to the function of science communication.

C. Regional technological innovation under knowledge perspective

In the process of technological innovation, from the perspective of flow range, knowledge flow can be occurred among companies, individuals and between individuals and companies. In terms of the form of knowledge flow, there is tacit knowledge flow and explicit knowledge flow. In the aspect of science communication, there is public knowledge flow and proprietary knowledge flow. Effective knowledge flow refers to commercialization from generation of new ideas to innovative development in the process of technological innovation to ensure continuous knowledge flow. Effective knowledge flow contributes to improving technological innovative ability. Knowledge flow aims to pursue the possibility of knowledge sharing and realize the maximization of technological innovation benefit.

A.K Gupta considers that knowledge flow among transnational corporation departments, global leaders and technological innovators is an important approach of technological innovation and technological diffusion [4]. From regional perspective, knowledge flow between regional technological innovators and technology followers is the source of regional technological innovation. It can be seen from Fig. 2 that technological innovators are main exporters of knowledge and knowledge creators. As knowledge “processing factory” and knowledge creators, they are characterized by knowledge low inflow and high outflow. Technology followers are the main exporters of knowledge and knowledge integrators, characterized by low inflow and low outflow. The researches of Bruce et al. show higher implicitness degree of knowledge means larger possibility of regional transfer; higher explicitness degree of knowledge means larger possibility of technology spillover. In a region, various enterprises integrate the knowledge they gain with their own knowledge to create new knowledge and form innovation ability. These knowledge and abilities are recycled in the region to transform tacit knowledge to explicit knowledge, drive and maintain the advantage of regional technological innovation.

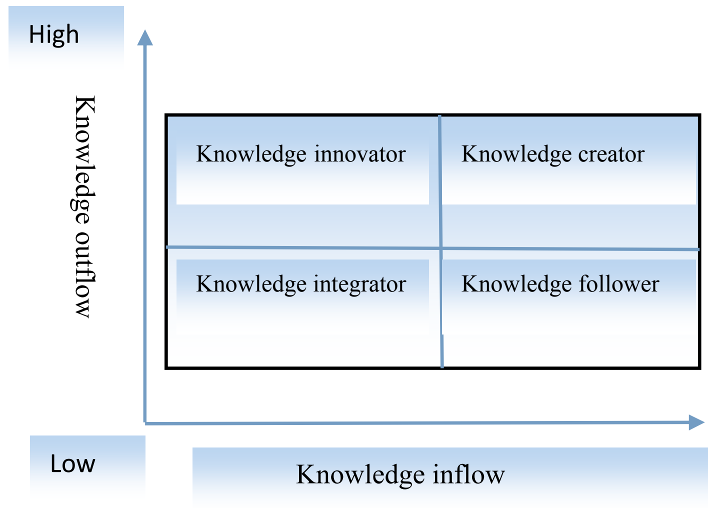

Fig.2 Regional knowledge flow chart

Knowledge flow in technological innovation generates four results: realize technological innovation, change company value chain, change value allocation and competition situation change. Knowledge flow in regional technological innovation is not one-way, it includes the following elements: absorbing knowledge from technological innovation by technology followers; knowledge flow caused by technological diffusion, transfer and overflow in technological innovation process of technological innovators. The process and result of knowledge flow break original knowledge structure of technology innovators and followers, adjust the competition environment in the market, realize the objective of regional technological innovation, the increase in regional knowledge and form virtuous circle of technological innovation.

II. EFFECTS OF SCIENCE COMMUNICATION ON TECHNOLOGICAL INNOVATION

A. Technological innovation cycle under knowledge perspective

Innovation cycles through the history. Technological innovation often has certain cyclic periods. Technological innovation cycle changes existing and well-known knowledge storage to new knowledge and connects individuals and the society. Traditional ideas consider that technological innovation process is a linear process of new knowledge creation, communication and application. But, that the new knowledge appears from nowhere is out of the question. It must be formed by an innovative individual on the basis of existing knowledge. After technological innovation and diffusion, the knowledge is known and accepted by the public, thus becomes existing knowledge and is blended into public knowledge library. The introduction of existing knowledge in traditional linear technological innovation process can make linear technological innovation process become a cyclic process of technological innovation. This idea is consistent with the idea of Australian Technological Science and Engineering Research Institute. They consider that innovation can be regarded as a cyclic process [5]. In conclusion, technological innovation process is as follows: innovative individuals generate knowledge on the basis of existing knowledge stock; as new knowledge communicates and diffuses, it will become knowledge stock again known to the public.

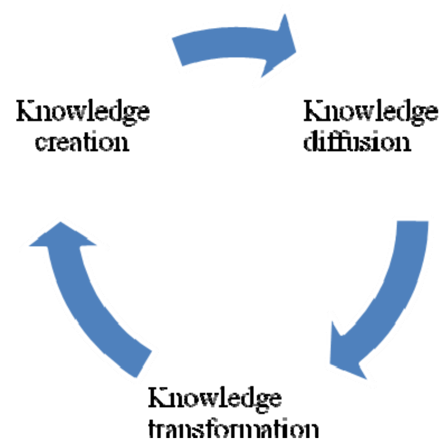

Fig.3 Technological innovation cycle diagram in knowledge transformation process

Technological innovation cycle has three stages. The behaviors in each stage have a subject. Stage I - knowledge creation stage: it is a process of forming new knowledge on the basis of existing knowledge; the subjects are innovative individuals. Stage II - knowledge diffusion: it is a process of communicating and diffusing new knowledge; the subjects are communicators. Stage III - knowledge transformation stage: it is a process where new knowledge is known and accepted by the public and becomes knowledge stock; the subjects are the public.

B. Effects of science communication on technological innovation

Under knowledge perspective, science communication in technological innovation cycle is mainly reflected in the following context:

① Knowledge creation process

Knowledge is a dynamic production process. Knowledge identification, development, research, acquisition, decomposition, use, sharing and existence repeat themselves in the whole process. Through these processes, knowledge is utilized, continuously generated and updated. Knowledge creation process refers to the transformation from tacit knowledge to explicit knowledge. Burns thinks that science communication aims to use proper methods, media, activities and dialogues to trigger one or multiple individual reactions to science, including consciousness, joy, interest and forming ideas and comprehension [6]. From the perspective of science communication, it is a process where innovative individuals gain innovation awareness through previous knowledge accumulation. Tacit knowledge cannot be predicted. If awareness formation cannot be aroused, knowledge creation results cannot be made open willingly. On this basis, science communication contributes to technological innovation.

② Knowledge diffusion process

Knowledge and the ability to create and apply knowledge are the most important source for an enterprise or a region to hold its advantage of technological innovation on a long-term basis. Individual knowledge is the foundation on which to form organizational knowledge. Individual tacit knowledge flow and sharing are the starting point of knowledge creation. Knowledge is continuously created through continuous transformation of explicit knowledge and tacit knowledge. Knowledge diffusion process needs the help of communication and interpersonal communication. Knowledge diffusion is a communication process which faces the public. From the perspective of science communication, science communication contributes to accelerating knowledge diffusion speed and efficiency so as to make new knowledge be communicated into the society. In other words, science communication accelerates technology spillover speed in developed regions and promotes technological innovation and diffusion. However, technology spillover has external nature. It is generally believed that technology spillover damages technological benefits brought about by innovation. On this basis, science communication damages technological innovation.

③ Knowledge transformation process

The formation process of technological innovation superiority is a knowledge-based activity. Knowledge has non-material nature. Knowledge exchange can be based on the precondition that original owners may not lose it and the knowledge can be exchanged and shared many times. Knowledge can be diffused and copied at multiple dimensions such as time and space, and accumulated on the original basis. During knowledge accumulation, new knowledge will appear and be delivered. Knowledge application process refers to the transformation from explicit knowledge to explicit knowledge. From the perspective of science communication, it is social content after new knowledge is applied. In other words, after new knowledge is applied, innovation awareness of the public can be improved. With regard to this point, science communication is beneficial to technological innovation.

Science communication as a tool influences innovation activities of all innovative subjects in technological innovation and cycle. Science communication can arouse the innovation awareness of innovative individuals so as to carry out innovation work. Meanwhile, science communication can promote technological diffusion and the speed of innovation being accepted by the public. This paper will study the effects of science communication on technological innovation through an analysis of panel data.

III. EMPIRICAL STUDY ON EFFECTS OF SCIENCE COMMUNICATION ON TECHNOLOGICAL INNOVATION UNDER KNOWLEDGE PERSPECTIVE

A. Variable selection and quantity analysis

He Jingtong [7] took invention patent application quantity as the explained variable when studying technological innovation factor. In this paper, the author takes invention patent authorization quantity as the explained variable. During selection of the explained variable, three subjects in innovation cycle are mainly taken into account: innovation individual, enterprise and the public. We use the number of college students in every 100000 people to represent the education degree of innovative individuals, use the proportion of the output of high and new technology industry to GDP to represent the ability of innovative enterprises to transform innovation results and use per-capita fund for science popularization to represent the ability of the public to understand and accept science. Besides, the factors influencing technological innovation also include economic development level, development level of overseas-funded enterprises, and research and development input. Thus, per-capita GDP is used to represent regional economic development level; actual foreign direct investment amount in a region is used to represent development level of overseas-funded enterprises; the research and development fund of industrial enterprises above designated size is used to represent input ability of each region in technological innovation.

TAB.1 VARIABLE ABBREVIATION, EXPRESSION AND EXPECTED INNOVATION INFLUENCE

Variable	Expression	Expected influence
Innov	Dependent variable: innovation ability of regional enterprises	
GDP	Regional economic level	+/-
RD	Research and development input	+
POP	Regional education degree	+
IOV	Enterprises' ability to transform innovation results	+
SC	Science communication ability	+/-

TAB.2 LIST OF DESCRIPTIVE STATISTICS OF RELEVANT VARIABLES OF PANEL REGRESSION EQUATION

	INNOV?	GDP?	RD?	POP?	IOV?	SC?
Mean	1706.790	26286.55	167.4038	1534.541	0.403568	8.427016
Median	660.0000	21416.34	85.95000	1485.164	0.422201	3.968216
Maximum	18242.00	83446.49	1065.500	3534.041	0.557529	148.3929
Minimum	3.000000	4297.643	0.400000	460.8094	0.073069	0.397032
Std. Dev.	2854.919	16745.91	214.7013	636.9176	0.098244	17.28972
Skewness	3.169175	1.348124	2.111681	1.014077	-1.559179	5.225031
Kurtosis	14.29235	4.495251	7.366570	4.157445	5.551626	34.06603

According to data availability and effectiveness, the data of 31 provinces, cities and autonomous regions in China are selected from 2004 to 2011. All data come from China Statistical Yearbook, China Population Yearbook, Statistical Yearbook of High-tech Industry and China Science Popularization Statistics etc. Descriptive statistics of each variable are given in the following table, including the number of the observed values, man value, standard deviation, the minimum and the maximum. Since China Science Popularization Statistics were made biennial before 2008, therefore we lack panel data sets about science popularization fund in 2005 and 2007. Such data sets are called Unbalanced Panel Data.

It can be seen from descriptive statistical analysis of relevant variables that the mean value of invention patent authorization quantity is 1706.79; the maximum is 18242; the minimum is 660. This indicates invention patent authorization quantity in different years and different regions has large differences. Similarly, per-capita GDP in different years and different regions, research and development expenses, the number of college students in every 100000 people, the proportion of industrial added value to GDP and per-capita science popularization have certain differences. Thus, it is necessary to further analyze whether each factor has influences on independent innovation ability.

Comparison of Fixed Effect Model and Random Effect Model

The largest difference between Fixed Effect Model (FE) and Random Effect Model (RE) is the basic hypothesis, i.e. whether the variables that individuals do not change with time is related to the predicted variable or the independent variable [8]. Fixed Effect Model views that the variables including individual influence effects are endogenous. On the contrary, Random Effect Model assumes that all regression variables including individual random influences are exogenous [9]. In terms of introduction of the variables in the model, Fixed Effect Model tacitly approves that the independent variables which do not change with time will not impose influences on dependent variables, so such variables are not allowed to appear in the model; Random Effect Model considers that the independent variables which show features of some individuals, but do not change with time can generate influences on the dependent variables, so such variables are allowed to be introduced in the model.

After it is assumed that the explanatory variable is exogenous, the estimator in Fixed Effect Model is unbiased. Similar to the first difference, Fixed Effect eliminates non-observation effect through conversion. It is because of a fact that it is randomly related to the explanatory variable in any period that any explanatory variable which does not change with time will be eliminated. Generally speaking, panel data model will not refuse Fixed Effect Model. Thus, Random Effect Model should be made first. Whether Random Effect Model or Fixed Effect Model is adopted should be subject to the results of Random Effect Model. Before regression analysis, it is necessary to firstly select model form. Generally, Hausman test method is adapted to judge whether Random Effect Model or Fixed Effect Model should be adopted.

The null hypothesis and alternative hypothesis of Hausman test method are set as follows:

H_0: individual effect is unrelated to regression variables (Random Effect Regression Model)

H_1: individual effect is related to regression variables (Fixed Effect Regression Model)

If P value of Hausman test is greater than 0.05, the hypothesis H_0 is accepted, i.e. individual effect is unrelated to regression variables. In this case, Random Effect Regression Model should be selected; if P value is less than 0.05, the hypothesis H_0 is rejected and the hypothesis H_1 is accepted, i.e. individual effect is related to regression variables. In such case, Fixed Effect Regression Model should be selected.

Hausman test results are shown in the following table.

TAB. 3 HAUSMAN TEST RESULTS

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Period random	10.103885	5	0.0723

Note: Random Effect test is realized through software Eviews6.0.

It can be seen from the above results that chi-square value of Hausman test is 10.103885; P value is 0.0723, less than 0.1. This indicates that it is below 10% significance level. Thus, the assumption that the null hypothesis is Random Effect Model is rejected. So, Fixed Effect Model should be selected. This conclusion is consistent with that of Wooldridge (2002) (for such type of data set, Fixed Effect Model should be selected firstly) [10].

B. Model construction

The model is constructed as follows:

$$LNINNOV_{i,t} = \alpha + \beta_1 LNGDP_{i,t} + \beta_2 LNRD_{i,t} + \beta_3 POP_{i,t} + \beta_4 IOV_{i,t} + \beta_5 LNSC_{i,t} + \varepsilon$$

Where, LNINNOV represents the quantity of invention patent authorization in each region; LNGDP represents per-capita GDP; LNRD represents research and development expenditure in each region; POP represents the number of college students in every 100000; IOV represents the proportion of the output of high and new technology industry to GDP; LNSC represents per-capita science popularization; is the constant term; $\beta_i (i = 1,2,3,4,5)$ means the influence coefficient of each factor on the ability of independent innovation; ε is the random error term. Since we select and use Fixed Effect Model, no matter what measuring unit is selected for the variables appearing in the logarithm form, it will not influence estimated values of parameters.

The results of regression analysis of the above models with Fixed Effect Model via EVIEWS software are shown in Table 4.

It is therefore known from the aforementioned analysis results that R-squared of model regression is 0.971293; F statistics value is 179.8405; P value is 0, much less than 0.05. This means integral fitting effect of the model is relatively ideal. Seeing from regression coefficient significance of each influencing factor, the influences of per-capita GDP, research and development expenditure and the proportion of industrial added value to GDP on the quantity of invention patent authorization are significant at 5% level (P<0.05). In addition, the influences of per-capita GDP and research & development expenditure are positive; the influences of the proportion of industrial added value to GDP are negative. On the other hand, per-capita science popularization has no significant influences on the quantity of invention patent authorization. This indicates that the influence of science communication on technological innovation ability is not effectively significant. This is consistent with the previous analysis results.

V. DISCUSSION

From the perspective of technological innovation cycle, science communication effects on technical innovation in two aspects. First of all, science communication promotes the creative awareness of innovative individual, and plays a positive role in technological innovation; second, with promoting technology diffusion, science communication has also increased the technical spillover effect which is negative for technological innovation. Because of the positive and negative effect cancel each other out; the conclusion of this paper is not significant. In future research, if the developed areas and underdeveloped areas could be considered separately, we would get different conclusions.

TAB.4 REGRESSION ANALYSIS RESULTS OF MODELS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.485604	1.760840	-1.411602	0.1601
LNGDP	0.748703	0.245650	3.047842	0.0027
LNRD	0.647086	0.150221	4.307569	0.0000
POP	-3.23E-05	0.000185	-0.174063	0.8621
IOV	-3.143580	0.775269	-1.054842	0.0001
LNSC	-0.012387	0.042673	-0.290279	0.7720

R-squared	0.976724	Mean dependent var	6.396012
Adjusted R-squared	0.971293	S.D. dependent var	1.604037
S.E. of regression	0.271774	Akaike info criterion	0.404295
Sum squared resid	11.07619	Schwarz criterion	1.028633
Log likelihood	-1.599463	Hannan-Quinn criter.	0.657301
F-statistic	179.8405	Durbin-Watson stat	10.12545
Prob(F-statistic)	0.000000		

REFERENCES

[1] Ikujiro Nonaka, The Knowledge-Creating Company：How Japanese Companies Create the Dynamics of Innovation [M], Oxford University Press, 1995.
[2] Ikujiro Nonaka. A Dynamic Theory of Organizational Knowledge Creation [J]. Organization Science, vol. 5, pp: 14- 37, 1994.
[3] Michael Polanyi. The tacit dimension [M].London: Boutledge and Kegan Paul, pp: 160-164, 1966.
[4] Gupta AK, Govindarajan V. Knowledge Flows and the Structure of Control within Multinational Corporations [J]. Academy of management review, vol. 16 (4), pp: 768-792, 1991.
[5] Australia Academy of Technological Sciences and Engineering, Australia Innovates [J]. The Innovation Cycle, vol.4, 2007.
[6] T. W. Burns. Science Communicating: A Contemporary Definition [J]. Public Understanding Of Science, vol. 12(2), pp: 183-202, 2003.
[7] He Jingtong, Li Feng, An Analysis of Factors Restricting Self-independent Innovation—Based on BACE Method Used to Make An Analysis of Inter-provincial Data in China [J], Nankai Economic Studies, 2007.
[8] Green. Cochrane Handbook for Systematic Reviews of Interventions Version 5.0 [M], pp: 183, 2008.
[9] Mundlak. On the pooling of time series and cross section Data [J]. Econoetrica, pp: 69-85, 1978.
[10] Wooldridge, J. M. Econometric Analysis of Cross Section and Panel Data [M], MIT Press. 2002.