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A Comprehensive Model of Technological Learning: Empirical Research on Chinese Manufacturing Sector

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Abstract

As the globalization accelerates its pace, made-in-China products have been travelling around the world for the last few decades. But in Chinese firms, their core technologies are still to a large part enslaved to foreign companies. Chinese government suggested Indigenous Innovation Capability as the essential aspect in the process of economic structure adjustment and economic growth mode's fundamental shifts. Technological learning is hereby a key pathway for these firms to develop indigenous innovation capability under the circumstance of the manufacturing industrial structure upgrade. This paper examines the relationship between technological learning, technology capability and innovation performance. Data collected from the sample of 92 Chinese firms are analyzed, and a new model indicating these relationships is testified. The results highlight the importance of technological learning sources, contents and levels, while corresponding policy implications for companies are made in the end.

Keywords: technological learning, technological capability, innovation performance, influencing factor

1 Introduction

> "We are currently going through a dynamic era for the economies of the world where a country can transition fast either upwards or downwards and this trend has become increasingly more pronounced and in an accelerating fashion during the last decade." (Carayannis et al., 2006)

Following the pace of industrial reconstruction within developing countries, enterprises are experiencing a growing need for innovation. Unfortunately, the absence of strong technology capability which contributes to continuous competency often impeded developing countries from improvement of their innovation performance. Technology capability has always been a key component of economic growth and welfare (Archibugi and Coco, 2004). In acquisition of technology capability, the role of technological learning is inevitably fundamental. There is a cycle which links technological learning, technology capability, technical change and production capability (Albu, 1997).

To the case of China, its old-styled policy of "sacrificing domestic market for technology transfer" is now severely challenged. To thrive in fierce global business competition, Chinese firms nowadays are impelled to upgrade their technology capabilities. Enhancing the indigenous innovation capability is now the government's solution to make the shift in economic restructuring and in the mode of economic growth.

To increase the indigenous innovation capability, admittedly, firms can rely partly on the mature mass production platform, which is exactly the advantage of "made in China" episode. However, we must realize that the countries and enterprises with technology advantages tend to be more cautious with the transfer or license of high-technologies, in consideration of their own strategic interest and overall competency. Hence, international enterprises often keep their core technologies unrevealed to their partners in developing countries when transferring product lines, which puts those manufacturing corporations in developing countries into a very disadvantageous situation in global competition. As a result, corporations in less developed countries are urged to put more emphasis on technological learning and technology upgrade, which is the way out from the currently low value-added dilemmas of their industries (Teece, 1990; Carayannis, 1994, 1998).

But there are still many questions uncovered by the existing theories. What are the factors that are influencing firms' willingness to learn? What should they pay attention to during learning process? How does technological learning actually improve the firms' innovation performance? How can a firm develop its own core technology by conducting technological learning? These are not only academic issues, but also significant issues that are fatal to the development of Chinese firms, they are fundamental to the theory of technology innovation management.

This paper is going to study a sample of Chinese manufacturing corporations, providing empirical evidence about how can technological learning improves the innovation performance by upgrading corporations' technology capability. We are anticipating drawing from the results the key factors influencing the technological learning process. In section 2 of the paper, relative literatures are reviewed briefly. In section 3, we'll develop several hypotheses to be tested in the following part of the research. The methodology and results are exhibited in section 4 and section 5. In the end, we provided the implications from this study to manufacturing firms in developing countries.

2 Literature review

2.1 Technological learning

Technological learning is defined as a process through which replication and processes can be made better and quicker, with the possibility of identifying new products (Teece, 1990). It is a process of organizational transform, merging technology and management through individual, team or the whole organization, so as to improve decision mechanism as well as enhance the control of uncertainty and complexity (Carayannis, 1994). Effective technological learning can bring a company competitive advantage by extending the scale of strategic behavior, improving the managerial ability and choosing a suitable strategy for according to the companies' environment (Carayannis, 1994).

Albu (1997) constructed the theory of learning cycle based on the ideas above. He claimed that, the technology ability gained through technological learning can generate and manage technology transformation, feedback the experience to technological learning, hence upgrade the technology ability.

Carayannis (1994) developed the triple-layered technology learning structure. In this architecture, learning takes place in three interacted levels (Carayannis, 1994; Carayannis and Kassicieh, 1996) as the operational learning level, the tactical learning level and the strategic learning level. People learn accumulate experience and learning by doing to learn new things on the operational level. On the tactical level, we have learning of new tactics about applying the accumulating experience and the learning process. And the strategic level is where people learn new strategies and new views of the operating universe.

Chinese scholars considered technological learning as an organizational behavior of obtaining new technology. Xie Wei (2001) proposed the process model of technological learning, which is the introduction of technology – production capability – innovation capability model. Chen Jin (2003) combines the situation of developing countries on the imitation-innovation theory of Korea developed by Linsu Kim (1997), and created the technological learning model. This model merges the triple-layered technology learning, and included multiple learning contents, multiple learning sources, multiple learning agents and multiple learning methods into it.

Hence, we can draw the dynamics of technological learning as follows: 1. Technological learning has its goals. 2. Technological learning is risky, and needs investigation. 3. Technological learning needs interaction with external environment. 4. Technological learning is a multi-layered behavior. 5. It is a long period of processing; the upgrade of capability is divided into phases.

2.2 Technology capability

Technology capability is one of the sources of company competitive advantage, which is an extremely important research area of corporate management theories. This topic is already discussed a lot, from macro to micro aspects; there are quite a lot of literatures on it. This paper is focused on its micro aspect.

Technology capability is divided into four abilities, which are the ability of learning by searching and acquiring strategy by learning from employees, the ability of learning from practicing, the ability of learning from performance feedback, the ability of learning from changes, and the ability of learning by training (Bell, 1984). It is the combination of technological searching capability, technological learning capability and technological innovation capability, and claims that the chain process of searching-learning-innovation of technology constructs the path for technology capability to upgrade (Dore, 1984). Desai's (1984) definition of technology capability includes the ability of a firm to acquire technology, to operate, to duplicate and extend, and to innovate, and clearly generalizes it as the four layers from technology purchasing, using, imitation to innovation. Panda and Ramanathan (1996) decompose technology capability according to firm's value chain, and divide the system into three parts, which are strategic technology capability, tactic technology capability and assistant technology capability. They also pointed out that the control capability is a key for technology capability to be effectively utilized and upgraded. Barton (1992) develops the concept of core technology capability in the discussion of core capability of firms; she claims that the technology includes four systems, which are employee skills and knowledge base, technical systems, managerial systems, and the values and norms of firm. Jonker (2006) defines technology capability as the combination of production capability and innovation capability, the former refers to the ability of improving existent equipment's performance, while the latter includes creation and supporting of new technology, as well as the rebuild of existing technology.

Wei Jiang (1995) defines technology capability as the ability of a firm to acquire advanced technology and information from external sources, combine them with internal knowledge, create new technology and information so as to realize the innovation and diffusion of technology while accumulate the technology and knowledge. Zhang Gang etc. (1997) identify technology capability as the ability of operating technology resources. They claim that technology capability are expressed through the operating of technology resources, and developed through the learning process.

To sum up, the technology capability of a firm includes its potential capability and explicit capability; the former is the capability that is not expressed by the consolidation of communication of existing knowledge, and the latter is the capability that is already consolidated or expressed. Technology capability has the following characteristics: (1) it is the engine of technology development; (2) it has the comprehensive ability needed by technology development; (3) it is sensitive to other firms' technology strategies; (4) it can derive or indicate the causal relationship between behavior and performance; (5) it connotes knowledge; (6) it includes cognition skills and behavior skills; (7) the trait of evolution. By observing these characteristics, we can see that technology capability is the determine factor of create, choose and develop of technology, and innovation is a consequence of technology capability.

3 Theory developments

This paper discusses the impact of technology capability on innovation performance from these five aspects: the source, content, agent, layers and environment of technological learning.

3.1 Technological learning

3.1.1 The source of technological learning

The source of technological learning refers to the knowledge, technology and information sources that enable a company to initiate technological learning. It includes both internal and external learning sources. Companies should integrate all technical information so as to continuously enhance technological learning, hence innovate from existing technologies.

As for the internal learning sources, Zhang Gang (1998) and Chen Jin (2000) pointed out that the executives, in-door R&D, marketing, and manufacturing departments are all information sources (learning sources) for a company. Note that, the learning sources in companies are not isolated, as Von Hippel (1986) has claimed; the innovation ideas are derived from the interaction between R&D and marketing departments. Hence the technology learning source comes from interactions between departments, and these interactions promoted the spread of various types of knowledge, especially tacit knowledge.

The external learning sources include customers, suppliers, universities and other research institutes, competitors and distributors. While in the case of Chinese firms, their external technology information mainly comes from the following three ways: 1. seeking all chances to obtain the newest international technology information; 2. accessing to market technology information through sales personnel and marketing researchers; 3. R&D stuff visiting markets and clients to get the technology information.

Based on these discusses about technological learning sources, this paper have the two hypotheses as follows:

H1: Technological learning source has positive influence on technology capability, which is to say, widen the technological learning source can promote the upgrade of technology capability.

H2: Technological learning source has positive influence on innovation performance, which is to say, widen the technological learning source can improve the innovation performance.

3.1.2 The content of technological learning

Knowledge can be categorized as explicit knowledge and tacit knowledge. The former can be demonstrated and shared – no matter it is written down or stored in someone's mind, while the latter is hard to be demonstrated, it is experience, know-how, or inspiration, or the like. Because of its difficulty to measure and imitate, tacit knowledge is bearing a much stronger importance than explicit knowledge.

Hence, the contents of technological learning should include scientific knowledge, technologic knowledge, experiential knowledge, and know-how. Scientific knowledge refers to systematical-theoretical knowledge, which is the infrastructure. Technologic knowledge refers to knowledge that is relative to technology, focuses on the application of knowledge. Experiential knowledge and know-how are tacit knowledge derived from practice.

Tacit knowledge is the focus of technological learning, as it is where most of a corporation's competitive advantages come from. The absorption of tacit knowledge directly affects the outcome of technological learning (Tang & Zhou, 2004). As the acquire of tacit knowledge needs huge amount of R&D and manufacturing practice, as well as a continuous improving process, it is of high priority for Chinese firms to accumulate this type of knowledge when practicing their established technology.

Hence, this paper makes the two hypotheses based on the previous discussion about the content of technological learning:

H3: Technological learning content has positive influence on technology capability, which means enhancing the absorption of technological learning contents can promote the upgrade of technology capability;

H4: Technological learning content has positive influence on innovation performance, which means enhancing the absorption of technological learning contents can improve the innovation performance.

3.1.3 The agent of technological learning

The agent of technological learning includes individual, team and the organization as a whole. Individual learning is the process in which an individual obtains knowledge and skills; team learning is a whole team obtaining knowledge and know-how through in-team communication and interaction; while organization learning is the "Kaizen" process in which various types of information are effectively processed, interpreted and responded. Organization is an agent that is able to learn, process information, rethink experience, as well as maintain a huge amount of knowledge, skills and specialty, it is usually constrained by subsystems such as the structure, procedure, culture of the organization and its technology. In order to promote the technological learning of a firm, we need to enforce each of those types of agent's learning, meanwhile enhance the communication and interaction of each learning agents, so as to establish the internal environment that is good for organizational learning.

Hence, two hypotheses based on the previous discussion about the agent of technological learning are made as follows:

H_5: Technological learning agent has positive influence on technology capability, which means enforcing the interaction between different agents can promote the upgrade of technology capability;

H_6: Technological learning agent has positive influence on innovation performance, which means enforcing the interaction between different agents can improve the innovation performance.

3.1.4 The levels of technological learning

Carayannis (1998) developed the triple-layered model of technological learning, which includes operational learning level, the tactical learning level and the strategic learning level. The operational level of learning refers to the knowledge, skills and experiences accumulated during practice, which belongs to the short-medium term of learning, focuses on the master of technologies and equipments that are just introduced into the firm. The tactical level of learning is a medium-long term process of learning. It establishes a new decision making system for the firm by changing the technology decision systems or adding new rules to the established systems. And the strategic level of learning falls into the category of long term, which focuses on the reconstruction of some strategic issues of the firm. This process may extent a firm's knowledge of the limitation and potential of its own strategic environment, which usually results in the change of rule of the game, or the establishment of a brand new industry. The different layers of technological learning are interdependent on each other, ignoring any one of them is going to jeopardize the others.

Hence, this paper establishes the following hypotheses:

H7: Technological learning levels have positive influence on technology capability, which means emphasizing on the comprehensive learning on all levels help to promote the upgrade of technology capability;

H8: Technological learning levels have positive influence on innovation performance, which means emphasizing on the comprehensive learning on all levels help to improve the innovation performance.

3.1.5 The environment of technological learning

Carayannis (1998) defined the environment of technological learning as the scale of learning activities and the environmental factors that influence the content and process of learning. It is mainly consisted of the executive's attitude to learning, the funding and the correspondent motivation mechanism.

The attitude of executive determines a firm's learning circumstance to a large extent. A positive attitude can usually earn the positive response of the employees, hence intensifies the employees' learning initiative and motivation, and establishes an active learning circumstance. Funding support includes two aspects, which are software and hardware; the former refers to the training of employees, while the latter refers to the construction of network information system, etc. Motivation mechanism is the key of encouraging employees to learn, motivate timely and effectively can facilitate the firm's technological learning.

Hence, two hypotheses based on the previous discussion about the environment of technological learning are made as follows:

H9: Technological learning environment has positive influence on technology capability, which means improving the environment of technological learning helps to promote the upgrade of technology capability;

H10: Technological learning environment has positive influence on innovation performance, which means improving the environment of technological learning helps to improve the innovation performance.

3.2 Technology capability

Moreover, this paper extracts the firm's technology capability as an intermediate variable, considers both the direct effect of technological learning on innovation performance and the indirect effect caused by technology capability. Hence, we make the following hypothesis about the relationship between technology capability and innovation performance:

H11: Technology capability has positive influence on innovation performance, which means the upgrade of technology capability can improve a firm's innovation performance.

3.3 Conceptual Model

The conceptual model of this study is shown in figure 1. In this model, the five elements of technological learning are extracted as the causal variables which have indirect influence on innovation performance through the intermediate variable of technology capability, as well as some direct influence on the final outcome.

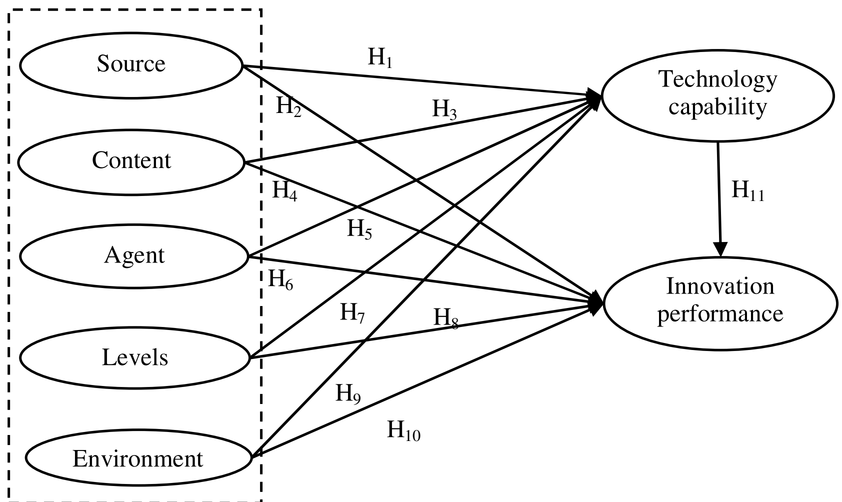

Figure 1 The model: technological learning's influences on innovation performance

4. Methodology

4.1 Sample

This research is based on the corporations' level, sampled 127 firms with 251 questionnaires, within which 192 are collected back. There are 118 valid questionnaires from 92 corporations. The valid reclaim rate is 65.5%. In order to control the data veracity and validity, the writer takes the following methods: (1) Control the sampling objects. The samples are typical large manufacturing corporations in China, involving companies that produce marine containers, tractors, electric meters, axletrees, etc. Those large corporations are ones with strong R&D capability and in need of technological learning. The interviewees are mainly consisted of engineers of R&D departments, managers and executives, with others from the marketing, sales or engineering departments; 80% of the interviewees have got at least a bachelor's degree. (2) Control the delivery process of questionnaires. There are two ways adopted, face-to-face interview and mail delivery. For those target corporations located in Shanghai, Hangzhou, Shenzhen, Qingdao and Luoyang, we conducted face-to-face interviews, with immediate feedback onsite. Others are sent by mail to related interviewees. These initiatives have proved effective in controlling the veracity and validity of data.

4.2 Definition and measurement of variables

4.2.1 Independent variables

The scale of technological learning is divided into five segments according to different dimensions. There are twenty-five factors interpreting these five dimensions. The variable indicators are shown in the following tables (See Tables 1).

Table 1 The indicators for technological learning

Dimension	Variables	Sources
Technological learning source	Customer Supplier Distributor Competitor Technological conferences Colleges and universities R&D institutes Internal functions Executive R&D department Marketing department Manufacturing department	J. Chen & W. G. Qu (2000); Cooper (1979, 1980a, 1981, 1988); Cooper & Kleinschmidt (1981, 1995); Montoya-Weiss & Calantone (1994); E. Von Hipple (1988, 2001); Khurana & Resenthal (1997); Tae Joon Lee (2004); G. Zhang (1998); W. Xie (2000).
Technological learning contents	Science knowledge Technique knowledge Experiential knowledge Know-how	J. Chen& W. G. Qu (2000); Elias G. Carayannis (1998, 1999, 2000, 2002)
Technological learning agents	Individual Team Organization	J. Chen & W. G. Qu (2000); Elias G. Carayannis(1998, 1999, 2000, 2002)
Technological learning levels	Operational level Tactical level Strategic level	Elias G. Carayannis(1998, 1999, 2000, 2002)
Technological learning environment	Executive support Funding Motivation	Elias G. Carayannis(1998, 1999, 2000, 2002); Tae Joon Lee(2004)

4.2.2 Dependent variables

The dependent variables of technology capability and innovation performance are measured by the following seven factors (See Table 2).

Table 2 The indicators for technology capability

Dimension	Variables		Sources
Technology capability	R&D capability	R&D ability R&D expenditure	D. Archibugi (2004,2005)
	Production capability	Technology ability Equipments The ability of solving production problems	H. Panda, K. Ramanathan (1993,1996); J. Wei & Q.R. Xu (1995)
	Marketing capability	The ability of identifying customers The ability of providing offers to customers The ability of coordinating marketing and sales	H. Panda, K. Ramanathan (1993,1996)
	Human resource capability	Number of science & technology engineers Training of employee per year Technique employee ability	D. Archibugi (2004,2005); J. Wei & Q.R. Xu (1995)
Innovation performance	New products Patents Technology know-how		Cooper (1987,1988,1990,1993,1995); Cooper & Kleinschmidt (1995)

4.3 Reliability and validity analysis

As usual, reliability is gauged via Cronbach α value which should be over the threshold of 0.70 and the item-to-total correlation over 0.30 to be considered reliable. The results are shown in Table 3.

Table 3 Reliability analysis of variables

Variable class	Variables	α	Threshold
Independent variables	Learning source	0.7604	α≥0.70
	Learning content	0.8011	
	Learning agent	0.7552	
	Learning levels	0.7220	
	Learning environment	0.7847	

Dependent variables	Technology capability	0.7259
	Innovation performance	0.8165

Conduct factor analysis to the 25 independent variables, extract the principal component with characteristic roots greater than 1 as factors, we get five factors which can interpret 60.040% of the total variance. This indicates that the independent variables in this research are of constructive validity. Conduct the previous analysis to the 7 dependent variables, two factors are extracted and interpret 71.995% of the total variance, which indicates that the dependent variables in the research is also of constructive validity.

4.4 Measurement model

The original model of this research is shown in Figure 2. There are 25 independent variables (S1-S11, C1-C4, A1-A3, L1-L3, E1-E4) and 7 dependent variables (R, P, M, H, IP1-IP3). Meanwhile, there are 11 paths corresponding to the 11 hypotheses made in the previous section.

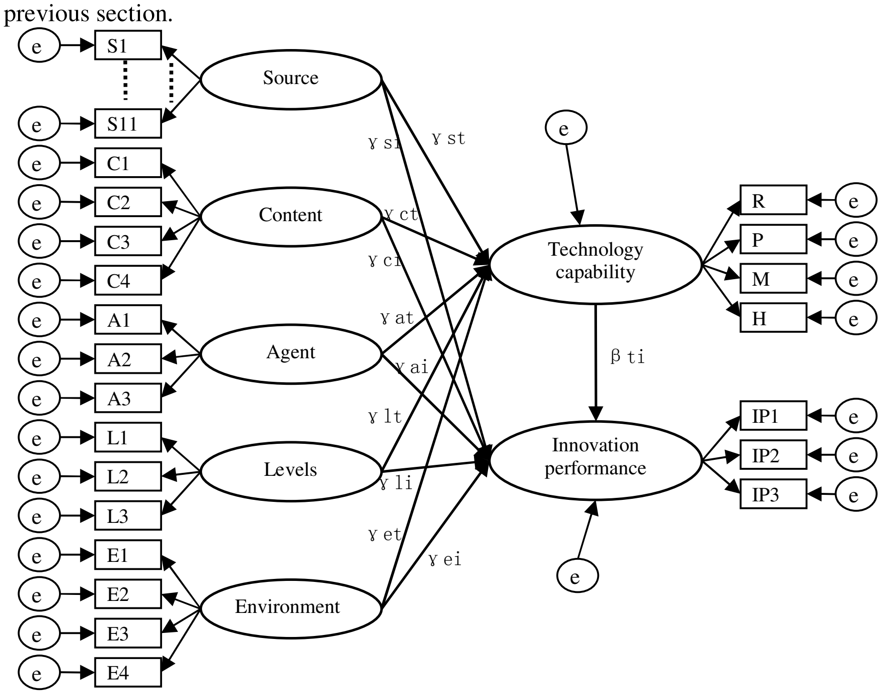

Figure 2 Original model of the research

Running Amos 4.0 to test the overall goodness of fit, we got the following results: $\chi2 = 1228.480$; df = 440; $p = 0.000 < 0.05$; $\chi2/df = 2.792 < 3$. Other indicators are: TLI = 0.903, CFI = 0.915 > 0.90; Standardized RMR = 0.076, falls into the scale of 0.05-0.08. But the NFI = 0.874 < 0.90; RMSEA = 0.124 > 0.08, which indicates that the original model cannot fit very well into the sample data. Hence, amendment of the model is needed. The result is that deleting the path of γei can bring most significant decreasing to$\chi 2$, so the path of environment's direct influence on innovation performance should be deleted from the model. Test again for the overall model fitness, we can get the following results: $\chi 2 = 939.771$; $df = 441$; $p = 0.000 < 0.05$; $\chi 2/df = 2.131 < 3$; TLI = 0.938, CFI = 0.945 > 0.90; Standardized RMR = 0.065; NFI = 0.901 > 0.90; RMSEA = 0.098. Note that all other indicators are fit into the required values except RMSEA, which is still larger than 0.08. But according to Steiger (1990), models with RMSEA < 0.10 have already got an acceptable fitness, so we tend to accept this adjusted model here.

5. Results

After the adjustment of the model, the final results are generated by Amos 4.0. The hypotheses are tested according to the previous model, and all are approved except Hypothesis 1 and 10. Figure 3 shows the adjusted relation model of this research.

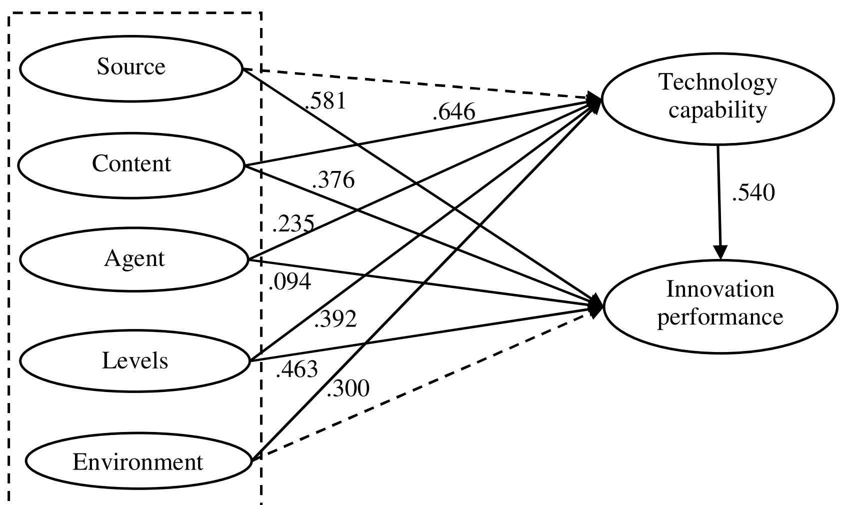

Figure 3 The adjusted model of influence factors

The paths in Figure 3 are all direct effect paths that can be computed from each of the coefficients in the conceptual model. In order to explicit the overall influence on this model, we need to test the indirect effects on those paths, and the total effect among those variables, which is the summary of direct and indirect influences. The effects are decomposed as shown in Table 4.

Table 4 Effect decomposition and key factor identification

Variable relationships	Direct eff.	Indirect eff.	Total eff.

Innovation performance ← Learning source	0.581	0.000	0.581
Innovation performance ← Learning content	0.376	0.349	0.725
Innovation performance ← Learning agent	0.094	0.127	0.221
Innovation performance ← Learning levels	0.463	0.212	0.675
Innovation performance ← Learning environment	0.000	0.162	0.162
Innovation performance ← Technology capability	0.540	0.000	0.540

After the decomposition and adding, it is clear that the key factor that influences innovation performance is the contents of technological learning (with a total effect of 0.725), and the second is the learning levels (with a total effect of 0.625); although the learning source has no influence on technology capacity (which means no indirect effect on the output), it has a relatively significant direct influence on the output (with the direct effect of 0.581).

To sum up, we can make the following conclusions: (1) The source of technological learning has a positive influence on innovation performance, but it doesn't influence the technology capability; (2) The content of technological learning has a positive influence on both technology capability and innovation performance, and the latter is the most significant one; (3) The agent of technological learning has a positive influence on both, but neither is significant; (4) The level of technological learning has a relatively distinct positive influence on both; (5) The environment of technological learning has positive influence on technology capability, but it's unclear if it influences the innovation performance; (6) Technology capability has positive influence on innovation performance, it is sound to be placed as the intermediate variable; (7) The factors with most significant influence on innovation performance are the learning content, learning levels and learning sources.

Hence, the adjusted model shown in Figure 5 is a reliable framework for Chinese firms to analyze their own paths towards higher innovation performance through technological learning.

However, this paper has not taken into account the comparative analysis of different industries when considering the influence, hence we cannot figure out the possible effects of the industry factor; moreover, as the sample are mostly established corporations, there are little evidence about the emerging firms' situation, hence we are not able to discover the possible effects of scale of firms. Further studies can focus on comparative research on different industries or different scales of firms, looking for the influence of industry characteristics and scale factors, which can generate more specific results for firms of different industry and different stages.

6. Conclusions and implication

Improving the situation of technological learning is one of the key paths of realizing indigenous innovation. From the theoretical and empirical study in this paper, we can draw the following conclusions as suggestions:

(1) The source of technological learning: internal communications should be emphasized. Firms should make efforts to extend the sources of learning. Compared with the clear and specific external learning sources, the internal learning is tend to be

underestimated or ignored, many resources are hence not fully utilized, which is a common fault made by many corporations in China. Internal communications within or between functions is a solution to this situation, it can make the learning more effective and more natural.

(2) The content of technological learning: focus on the absorption of tacit knowledge. In this era with tremendous explicit knowledge surrounding the world, it is the tacit knowledge which calls for long-term accumulation and perfection that is needed by the corporations in China. The core technology competency is the real chasm between Chinese firms and those established international corporations. However, it is not acquirable from a short period of time. In order to cross this chasm, firms need to focus on their own tacit knowledge, and look for opportunities to leap after long-term accumulation.

(3) The agent of technological learning: enforce the whole-learning of organization. It is implied by the results of this research that the communication and interaction between individuals, teams and the organization as a whole can improve the innovation performance of a firm. Nowadays, Chinese firms are still putting too much emphasize on unitary learning, namely the form of individual learning, but ignoring team learning and organization learning. In this circumstance, a more multi-agent learning process is able to improve the learning efficiency.

Besides the internal learning system, firms should establish a sound external learning system as well. The latter is based on industrial networks that is consist of customers, suppliers, manufacturing factories, research institutes and other related elements in a value chain. This network may even include the sponsors, industry associations, and government agencies.

(4) The levels of technological learning: improve the strategic learning level. It is indicated in the results that multi-layered learning can improve the innovation performance effectively. In the interviews and investigations, we noted that Chinese firms are comparatively short of strategic learning, some firms are even running without an explicit long-term vision, not to mention a reliable environment identification or strategic evolution mechanism. Hence, on the one hand, firms need to promote their strategies to their employees, plant them into everyone's heart; on the other hand, the executives of firms need to absorb experiences from external sources, and learn from inter-corporation collaborations, so as to keep an insight into their own industry sectors, hence make the appropriate decisions.

(5) The environment of technological learning: optimize the motivation mechanism for technological learning. Compared to executive support and funding support, the problem of lacking an appropriate motivation mechanism is the fatal one that most Chinese firms confront with at present. Motivation mechanism is the key to encourage employees to learn, but it is not functioning as anticipated in most of the enterprises we investigated. Firms should commit to optimize their motivation mechanisms, inspiring learning agents' enthusiasm on technological learning with it. Other than physical awards, the opportunity for employees to prove themselves in their teams is more important.

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