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Washington, DC USA

March 18-20, 2002

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Notes of Preparation

This proceedings document was compiled from written and audio-taped notes of the seminar sessions and from printed texts submitted by session presenters and coordinators of discussion sessions. Wherever possible, for accuracy, the available printed texts were given precedence over written or audio-taped notes. In both cases, the presentations appearing in this document have been edited for clarity.

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PREFACE

U.S.-CHINA SEMINAR ON

TECHNICAL INNOVATION

The national headquarters of the Industrial Research Institute (IRI) in Washington was the site of the **"U.S.-China Seminar on Technical Innovation."** Held March 18-20, 2002, the seminar was co-chaired by Lewis Branscomb (Harvard University) and Zhu Zuoyan (National Natural Science Foundation of China). Two days of excellent presentations and intense discussion focused on policies and practice affecting the transition from invention to innovation. Major topics included:

- Creation of Innovations: Research Centers, Institutes and Universities
- Innovations in Large Enterprises and Their Supply Chains
- Globalization: Transnational Dependences in Innovation
- Innovation in Small and New High Tech Enterprises
- Financing Innovations
- Innovation Networks and Social Capital

The U.S.-China Seminar on Technical Innovation was the third event held under the U.S.-China Cooperation Program in Science Policy, Research and Education. This decade long initiative aims to establish a basis for expanded bilateral science policy cooperation between the U.S. and China, and strengthen cooperation in a variety of areas of science and engineering.

J. Thomas Ratchford
Arlington, Virginia
January 30, 2004

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II. INTRODUCTION

Welcome Message

Welcome to Washington DC for the 2nd USA-China Seminar on Technical Innovation! We are honored to have more than forty prestigious academic, business and government leaders from China and the United States. We sincerely hope that you will benefit from this seminar.

This seminar series, scheduled to be held in US and China alternatively, is initiated and sponsored by US National Science Foundation (NSF) and National Natural Science Foundation of China (NSFC) to provide a high-end platform for information exchange and experience sharing on state-of-art research and experience in fostering technology innovation. As we all know, innovation has long been regarded as the touchstone of the quality of an economy system. China is now undergoing radical reform in science and technology system and has made great progress in basic research and high-tech innovation. Meanwhile, the United States continues to examine public policies to build its economy even more strongly on technology innovation. Technology innovation is the best way to gain economic advantage from its strong position in the fields of science, mathematics, and engineering. To enhance competitiveness and maintain sustainable development in the years of globalization, US and China can both benefit from an exchange of scholarly research and practical experience on technology innovation and related areas to foster technical infrastructure development, technology policy-making and innovation efficiency. The sponsors and organizers put together the seminar series to serve as an important platform for prestigious scholars, high-profile policy-makers and well-known business executives to discuss these challenging issues and share their insights from various perspectives.

We'd like to thank US National Science Foundation (NSF) and National Natural Science Foundation of China (NSFC) for their support, members of the organizing committee from both the USA and China for their endeavor to make this seminar a reality. Finally we would like to thank you all for coming and hope you gain both personally and professionally from this event.

Lewis M. Branscomb Zuoyan Zhu

Co-chairs
2nd US-China Seminar on Technical Innovation

II. INTRODUCTION

Sponsors and Organizers

National Natural Science Foundation of China

The National Natural Science Foundation of China (NSFC) was founded in 1986 with the approval of the State Council. It is an institution for the management of the National Natural Science Fund, aimed at promoting and financing fundamental basic research and some applied research in China.

As one of the country's main channels to support basic research and an important part of the national innovation system, NSFC, through improving its operational mechanism and management, works to create a favorable environment conducive to the original innovation of science and technology and to the upgrading of China's capability in original innovation and the overall standard in basic research, so as to make its due contributions to the promotion of source innovation in science and technology, the acquisition of major breakthrough in basic research and the realization of national goal for science and technology development. The Department of Management Sciences, which supports the researches in management sciences, is one of the seven scientific departments of NSFC.

For further information on NSFC, please visit the website: http://www.nsfc.gov.cn

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II. INTRODUCTION

China-US Cooperation Program in Science Policy, Research and Education

The US-China Cooperation Program in Science Policy, Research and Education is a decade long initiative built on the long-standing relationship between the National Science Foundation of the United States of America (NSF) and the National Natural Science Foundation of China (NSFC). The various events that comprise the program serve both as a basis for expanded bilateral science policy cooperation and an integrative factor in strengthening partnerships in specific areas of science and engineering.

The first bilateral event in this program, a "Seminar on R&D and the Knowledge-Based Society: *Linking the Production, Dissemination, and Application of Research*," was held in Beijing, October 24-26, 1999. The second major event was the "U.S.-China Policy Forum on Biotechnology and Biomedicine" held at the Lawton Chiles International House of the National Institutes of Health, December 4-5, 2000.

These and related activities are documented through print and electronic publication. Other events scheduled for later in 2002 will address "S&T Policy Challenges for the Decade" and "Engineering Education."

Information on the initiative and links to various publications can be found at: http://techcenter.gmu.edu/programs/science_trade_policy/us_china.html.

III. KEYNOTE ADDRESSES

China's Policy for Technical Innovation in the New Century

Li Xueyong
Vice Minister, Ministry of Science and Technology

(Abstract)

It is now universally recognized by governments and academic communities that technical innovation is playing an important role in promoting economic and social development. The Chinese government has undertaken a series of explorations in the field of technical innovation policies and implemented a series of national science and technology programs while increasing its R&D input on a large scale, conducting a reform on its scientific and technological system in accordance with the demand of a market economy, formulating taxation policies that encourage technical innovation in enterprises, establishing a number of national high and new technology industry development zones and making some important institutional arrangement in order to encourage scientists and researchers to engage in the cause of technical innovation.

With the acceleration of economic globalization, China is facing formidable tasks of keeping rapid economic growth rate and creating more employment opportunities. While deepening the market reform, China must rely more closely than ever on technical innovation in developing its economy and sharpening its economic competitive edge. The Chinese government will experiment on employing the analysis framework of the national innovation system as the guide to develop China's technical innovation policies. China will improve and strengthen the R&D function of governmental public research institutes and universities, speeding up the development of small and medium-sized innovative enterprises, improving the system for intellectual property rights protection, continuing to research on and formulate policies that encourage innovation in enterprises, expanding international cooperation in the field of scientific research and encouraging theoretical exploration and policy research of technical innovation.

China will participate in the economic, scientific and technological globalization process in more various fields while further expanding the means and channels for international scientific and technological cooperation. The Chinese government attaches great importance to the cooperation between China and the United States in the field of science and technology. There is much more space to be explored in the future for China-US scientific and technological cooperation.

NSFC Supports to the Tech Innovation Researches in China

CHEN Xiaotian
Department of Management Sciences
National Natural Science Foundation of China

Abstract
The researches on technical innovation in China started in 1980's after the opening of this country to the world and the implementation of socialist market economy. The National Natural Science Foundation of China (NSFC) has supported the research projects in this field, timely and effectively. This paper consists of four parts: (1) Brief introduction to the characteristics in financing the researches related to technical innovation; (2) Outline of the granted research projects; (3) Overview of main research outputs achieved; (4) Problems and solutions as well as future plans.

1. Introduction

Since J. Schumpeter proposed the theory about innovation in 1912, the definition and understanding to innovation have been increasingly extended and deepened. The academic circle has being put great interests on innovation since then. In addition, the relevant practical activities have also been carried out and reached positive outputs.

In China, the corresponding researches about innovation started in 1980's. The National Natural Science Foundation of China (NSFC) have supported a lot of research projects in this field, timely and effectively.

2. Characteristics in Financing the Tech Innovation Researches

(1) Being the earliest to funding the researches in China

NSFC was found in 1986. As a new organization for funding scientific researches, NSFC began to allocate grants to the research projects dealing with technical innovation in 1989. This is the earliest time in China to formally support researches in this field. Besides paying attention in research projects, NSFC also actively conducts the concept of technical innovation in China. In 1993, NSFC sponsored a summer school in Beijing, inviting Dr. Lan XUE who worked in George Washington University at that time and other oversea scholars to give lectures. These experts introduced the frontiers of theories and practical achievements in the field of technical innovation, aiming at promoting the development of this discipline in China.

(2) The number of projects supported

NSFC has support about 50 projects in technical innovation researches since 1989. Amongst these projects, 49 are general projects and one major project. The total funding is more than RMB 4 million Yuan. Figure 1 shows the annual number of general projects supported and the funding. The major project supported in 1993 with RMB 1.25 million Yuan is not included in the statistics.

The figure demonstrates that there are strongly financial supports from NSFC to technical innovation research in China. NSFC is the main funding institution in China to support the technical innovation research.

(3) Continuously support some institutes and distinguished scholars

In order to encourage original researches in the field of technical innovation, NSFC selects some institutes and distinguished scholars to support. For instance, the research group of Zhejiang University, including Professors Qingrui XU, Xiaobo WU and Jin CHEN, have been financially supported nine times with 9 projects. This group first

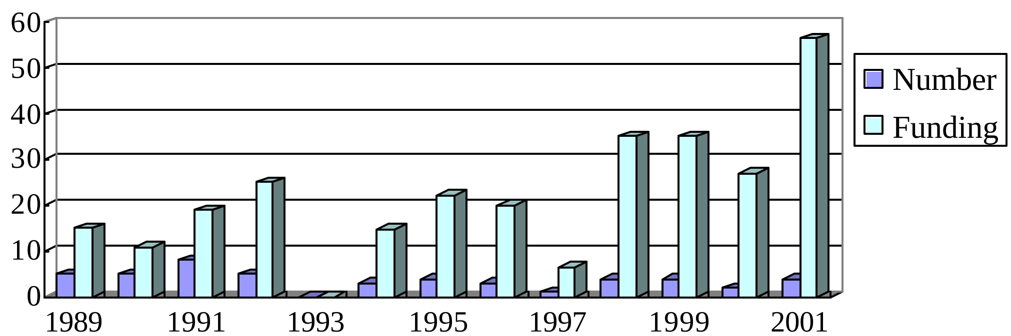

Fig. 1 The annual number of general projects supported and the funding (10000 Yuan)

proposed the way of carrying out technical innovation for China, and developed the portfolio of technical innovation and the corresponding modes for implementation. The group of Tsinghua University also won 6 research projects in this field.

(4) The outputs and influences

The support has generated positive impacts on the development of this field, e.g., greatly improving the theory studies and the implementation of relevant policy measures. Some research results have played important and active roles in decision making for governments and industries. Meanwhile, the research results have obtained recognition and affirmation from Chinese community.

Technical innovation is now well recognized as a major stimulus to keep sustainable and steadily economic growth in China. Correspondingly, there are numerous Chinese scholars who always keep their research interests to technical innovation due to their social obligation. NSFC is response of this research demand in selecting projects to be supported.

3. Outlines to the Supported Research Projects

NSFC mainly supports the theoretical researches in generalized technical innovation. This means that the range can cover all activities of generalized innovation process, starting from an idea to the final application, e.g., the commercialization and industrialization of a technology are also covered.

The research areas to be supported are as follows: to develop new products, new processes and new service systems; to establish new organization and new management systems for realizing innovation; to explore new resources and set up new markets. In recent years, scientists constantly address other types of innovation besides the technical innovation, like as systematic innovation, organizational innovation and mechanism innovation. The research projects in technical innovation supported by NSFC could be classified into three types at three levels.

(1) Three levels

The captioned three levels are referred to macro-level, meso-level and micro-level, according to the research contents in these supported projects.

The projects being at the macro-level deal with technical innovation problems from national points of view. The establishment of national innovation system, the strategies, policies and the corresponding financial investment will be investigated in these projects. List some examples here: Data Base for National Technical Innovation (by Chi MA, 1996), The Mechanism and Policy for High Quality Economic Growth Through Technical Innovation(Jiaji FU, 1996), The Comparison Research for Technical Innovation Systems and Modes in Asia (Yingluo WANG, 1994), New Modes for Technology Import and Diffusion in China (XingmingWANG, 1995).

The central government had adopted some suggestions generated from these projects, which comes to a common understanding in China's top leaders about the importance of technical innovation.

The projects at meso-level are about the regional and industrial innovation problems. These include: The Technical Innovation in Backward Regions (Guang CHEN, 1997), Dynamic Relevancy Patterns of Industrial Technology Evolution and Innovation in China (Gang WU, 1996), The Technology Development and Innovation Process for Contemporary Typical Industries (Xixian CAI, 1995), The Comparison Research of Technical Innovation Mechanism and Efficiency of China's Agriculture in Different

Provinces (Simei WEN, 1991), The Interactive Mechanism between Industrial Organization and Technical Innovation (Guoxin LIU, 1998).

The projects at micro-level investigate the problems raised from enterprises. These projects account for 60% of the total in this field. Enterprises are the principle body for realizing technical innovation activities. Some examples at this level are as follows: Technical Innovation in China's Large and Medium Sized Enterprises (Jiaji FU, 1989), The Internal and External Environments and Strategy for Technical Innovation in China's Enterprises (Baohua XIANG, 1991), Technical Innovation Behaviors in China's Small and Medium Sized Enterprises (Zhengjiang WANG, 1991), The Quantitative Assessment of Enterprises' Technical Innovation (Gang XIANG, 1994), The Evolution Mechanism and Management Modes—Case Study for Enterprises' Innovation Network (Dazhou Wang, 1999).

The above projects focus on the regularity exploration of technical innovation activities in enterprises. The researches benefit a lot of enterprises in enhancing their technology innovation capabilities, improving production efficiencies and increasing core competency.

(2) Three Types

Three types of researches, namely theoretical studies, case and positive studies, and policy studies, can be summarized.

The theoretical studies aim at constructing the theory systems for developing the discipline of technical innovation in China. The researches have explored the basic issues related to the technology import, technology absorbing and assimilation, technology diffusion and innovation efficiency measurement. Examples are as: The Mechanism and Policy of Technical Innovation (Weiwen JIA, 1989), Redesigning the Management Process for Technical Innovation Using IT (Chunlin SI, 2000), The Theories of Technical Innovation in China (Jiaji FU, 1993), Technical Innovation Patterns—Portfolio Theory and Methods (Qingrui XU, 1993), Measurement for Regional Innovation System (Jiancheng GUAN, 1999), Measurement for Technical Innovation in China's SMEs (Kexin BI, 2001).

The case and positive studies mainly aim at investigating the technical innovation activities in various enterprises and regions. Projects are as: Empirical and Comparison Study on Interactive Mechanism of Technical Innovation in Enterprises (Shixu GUAN, 1996), Case Analysis and Theory Study of Technical Innovation (Xinyi GU, 1990), Empiric Study on Technological Innovation (Weiwen JIA, 1993). A lot of experiences or failure lessons for technical innovation activities in Chinese enterprises were obtained from these researches. It also provided examples for applying various theories into real technical innovation. For instance, the experiences from Haier Group and the lessons from Shanghai and Nantong city, have been documented by some scholars.

The purposes of policy studies are to offer scientific evidences and suggestions for governments, industrial sectors and enterprises when they formulate their technical innovation policies. Some examples of these projects are: The Policy Study of Technological Innovation (Shoupeng DENG, 1993), The Policy Study of Tax and Credit for Promoting Technical Innovation (Naijun ZHU, 1991), The Strategy and Policy Study of Energy Technology Innovation with Environment and Efficiency Considerations in Market Economy (Xiaolin XI, 1998).

3. Research Outputs Produced from Projects

Innovation, as a concept and an ideology, has been widely recognized by our state, nations, enterprises as well as individuals. The main research outputs produced from projects supported in this field can be summarized as below, although impossible in a detail manner.

(1) Promoting the formulation of relevant policies for technical innovation

The scholars have provided the theoretical evidences and practical suggestions for establishing the national innovation system and strategy making through their researches on technical innovation. The governmental officers are interested in adopting some viewpoints and suggestions from the research reports by our scholars. This kind of interactions and exchanges between scholars and officers can generate big and good influence in community.

Prof. Shoupeng DENG of the Development Research Center of the State Council, along together with Prof. Jiaji FU, Weiwen JIA and Qingrui XU, finished a major project supported by NSFC. The research results have created huge impacts on the relevant policy formulation by government and institutions. The policy suggestions proposed by Prof. FU and Prof. JIA had been accepted by the State Economy and Trade Committee and the Ministry of Sci & Tech. These suggestions had been taken as the theoretical guidelines for later carrying out the National Technological Innovation Project.

The document "Technology Innovation Strategy of IC Industry" by Prof. Weiwen JIA, had become the base of formulating the IC industry strategy of the Ninth five-year plan by the former Ministry of Electronic Industry.

Due to the positive and active impacts by these projects, most provinces and major cities began to highly address the technical innovation problems in their regions. The scholars who had been supported by NSFC, directly or indirectly apply the proposed theories and methodologies about technical innovation, into the policy formulation and implementation for their home regions.

Professors Xielin LIU, Lan XUE and others had contributed a lot in organizing and implementing the National Technical Innovation Project. In 1999, the central government issued "The Decisions for Enhancing Technical Innovation, Developing Hi-Tech and Industrialization" and sponsored the national conference on technical innovation. Many scholars who had been involved in NSFC research projects, played special roles in these important events.

(2) Enriching the theory research about technical innovation in China

From the research projects, numerous papers, reports and books have been published, so that the theories and methods about technical innovation are being enriched. Through importing and developing the western theories, our scholars have proposed some new concepts and new modes for promoting technical innovation with respect to the Chinese conditions. Prof. Jiaji FU and his colleagues in Tsinghua University, for example, proposed a mode so-called "pitfall in catching up economy" for China's technical innovation, the theory of relatively advantage for imitative innovation, the stage-based measurement framework of technology innovation, the space for choosing innovative products.

Prof. Jiancheng GUAN of Beijing University of Aero. & Astro., revealed and further classified the stochastic factors that affects the diffusion process of technical innovation. He found a kind of stochastic diffusion model equivalent to the well-known Bass' model. Then, he proposed a new stochastic models with supply restriction, considering the governmental and institutional factors. The research results are published in such western journals as *R&D Management*, *Research Technology Management*, *Zeitschrift fuer Innovation* and *Technovation*.

Prof. Xiaobo WU of Zhejiang University, studied the issues about secondary innovation. His researches focused on the different characteristics between developing and developed countries in pushing the technical innovation, concluding that it's much more important for developing countries to absorb and assimilate the introduced technologies than only to import them. The secondary innovation can form relative advantage for backward countries, especially for developing ones, finally catching up the developed countries. In secondary innovation, the two actions, assimilation and absorption, are simultaneously conducted.

Prof. Gang XIANG of Kunming Technology University established a model with multi-variables for quantitatively evaluating the technical innovation in enterprises. The principal components analysis method was employed. He investigated the way to rationally allocate the benefits generated from technical innovation and applied it in Hongta Group.

(3) Promoting the practical activities in enterprises

NSFC encourages the researches in the field of technical innovation, by funding research projects, organizing academic conferences and workshops, connecting governments and scholars, which has greatly promoted enterprises' recognition to the importance of technical innovation. In addition, sometimes the research results serve the enterprises directly, through advices and instructions from these scholars. Now, the Ministry of Sci & and Tech is sponsoring and running a program named "Funds for technical innovation in middle- and small-size enterprises."

(4) Cultivating talents for technical innovation

Through the research projects supported by NSFC, a lot of senior scientists are growing up. These experts are playing increasingly important roles in universities and research institutions as well as practical activities of technical innovation in firms. Some bases for technical innovation research are formed, like Tsinghua University and Zhejiang University.

4. Problems and Ideas for Solving

(1) Problems encountered

(a) Few research results are published abroad. It is a fact that more and more people from different countries pay their attention to China's technical innovation problem, particularly during the transformation period. Most Chinese scholars, however, start their researches in this field simply from introducing western theories and methods, gradually then conduct researches aiming at solving China's technical innovation problem. The methods adopted are still simple; most researches are to describe the phenomena rather than find the laws and reasons behind. Thus, their backgrounds for research are relatively not strong, very original research works are not as many as expected. Few research results are published in international academia, which leads less understanding to the technical innovation research in China. NSFC will encourage joint research projects in which abroad colleagues are combined into the groups, and require Chinese scholars to do their researches according to widely accepted standardization and methodology.

(b) Lack of distinct features. It is believed that a lot of innovations in China, in all aspects, really exist a long with the rapid economic growth of this country. However, some research projects supported by NSFC, do not underline the China's problems, but only follow the works from western countries. Systematic framework for launching technical innovation in China, which combines the latest theories with specific conditions in China, has not yet been established. Our researches lag behind the practice of

technical innovation. For resolving this, NSFC is revising the guidelines for submitting proposals and the measures for checking and accepting completed projects.

(c) Lower founding for projects. Ten years ago, each supported project was only granted RMB 20 to 30 thousand Yuan. This number starts to rapidly increase in recent years, but RMB 120-130 thousand Yuan for each project on average is still lower subject to the work volume required in conducting such project. For technical innovation research, substantial data collection, case studies and reality investigations are needed. The Department of Management Sciences is applying to the upper-level for further increase the funding.

(2) Ideas for future financing and managing works

NSFC has made distinct contribution to the technical innovation researches in China, through its funding, directing and managing. It should be noted that there are still many academic or reality-life problems being open to study, in the special period for transformation. The following are hot topics for research in current China.

(a) The technical innovation suitable in transformation period. China is now getting into an industrialized and information society. Its economic system is undergoing a transformation from a centrally planned to a market driven. China has entered the WTO, hence production, trade and management have to be ruled by a internationally accepted criteria. Then, a lot of new problems for technical innovation have been encountered in our social practice.

It is known that, there exist four basic modes for technical innovation, namely, technology import, technology import and further assimilation, independent and incremental innovation, and independent innovation. Each enterprise will experience one or more of the four modes in its innovation process. All of these four modes exist in China, although in principle, the first two are mainly developing countries and the others mainly for developed countries. For instance, the information industry selects the later two modes for conducting its technical innovation, while most traditional industries choose the first two modes. Therefore, it is extremely important for us to study how to formulate the national innovation strategy, policy and measurement when multiple innovation modes have to be adopted simultaneously.

(b) Specific technical innovation mode for specific industry and region. We have to differ the modes for developing industries from ones for traditional industries. Also, different regions should adopt different modes. The researches originated from industries and enterprises are more useful and meaningful for finding the insights and generating the scientific policies.

(c) Generalized Innovation. Besides technical innovation, other forms of innovations, like as system innovation, management innovation and organization innovation are also very interesting from points of both academic and practical views. These innovations constitute a system consisting of some sub-systems which correspond to these innovations. Although NSFC has already supported some research projects about system innovation and management innovation, these supports are still not enough.

(d) Innovation research in information Era. The network makes some issues both simple and complex. The new requirements for innovation researches are from the technology of virtual organizations. The internal structure and external environment of governmental departments and enterprises are dramatically changing with the development of information technology. Therefore, we should study how the innovation activities can be well conducted and the fruits in technical innovation can be transferred and applied timely.

In conclusion, technical innovation runs through the whole R&D process from basic research, to applied research, to demonstration and industrialization. A lot of things in this process should be integrated. NSFC will constantly support the researches in this field.

Appendix: List of the supported projects in technical innovation research

The sub-projects of the major project granted in 1993

Grant No.	Project Title	PI	Affiliation
79391300	The Research of Technological Innovation,	Shoupeng Deng	The Development Research Center of State Cuncil
79391301	The Theory Research on Technological Innovation in China	Jiaji Fu	Tsinghua University
79391302	The Research on Technological Innovation Patterns: Portfolio Theory and Methods	Qingrui Xu	Zhejiang University
79391303	The Empiric Study on Technological Innovation	Weiwen Jia	Chinese Center of Promoting Science and Technology
79391304	The Policy Study of Technological Innovation	Shoupeng Deng	The Development Research Center of State Council

The general projects supported

Grant No.	Project Title	PI	Affiliation
78970004	The Research on Technological Innovation Impetus and Capability for Chinese Industrial Firms	Changshu Chen	Northeast University
78970024	The Research on Education Patterns of Chinese Technological Innovation	Zhuhua Zhao	Beijing Polytechnology University
78970036	The Research on Technological Innovation of Large- and Medium-sized Enterprises in China	Jiaji Fu	Tsinghua University
78970062	The Research on Technology and Economy Integration about Mechanism and Theory for Technological Innovation	Rongfang Shen	Tongji University
78970064	The Mechanism and Policy of Technological Innovation	Weiwen Jia	Chinese Center of Promoting Science and Technology
79000009	The Secondary Support System of Technological Innovation	Jianguo Qi	Chinese Social Science Academy
79070051	The Research on Manner and Mechanism of Technological Innovation for Hi-tech Development Zone	Guisheng Wu	Tsinghua University
79070063	The Mechanism Research and Empiric Analysis on Technological Innovation and Diffusion for Joint Venture Company	Jinxian Chen	Xi' an Jiaotong University
79070070	The Case Analysis and Theory Study of Technological Innovation	Xinyi Gu	Zhejiang University
79070071	The Study of Technological Innovation and Entrepreneurship	Qingming Huang	Zhejiang University

III. KEYNOTE ADDRESSES

79100012	The Technology Trajectory Research on Electronic Technological Innovation	Yueping Du	Xi' an Electronic S&T University
79100016	The Research on Internal, External Environments and Strategy of Technological Innovation of Enterprises in China	Baohua Xiang	Zhejiang University
79170029	The Comparison Research of Technological Innovation Mechanism and Efficiency of Agriculture for Different Provinces in China	Simei Wen	Agriculture University of Southern China
79170031	The Track Research on Technological Innovation of SMEs for Central Cities of China	Xixian Cai	S&T University of Central China
79170038	The Risk Analysis and Decision of Technological Innovation	Guomin Yang	Jilin Technology University
79170045	The Policy Study of Tax and Credit for Promoting Technological Innovation	Naijun Zhu	Tsinghua University
79170047	The Research on Technological Innovation Diffusion Process, Mechanism and Policy in China	Erzhou Dong	Tsinghua University
79170049	The Research on Technological Innovation Behaviors of SMEs in China	Zhengjiang Wang	Shanghai University
79200012	The Theory and Patterns of Secondary Innovation	Xiaoba Wu	Zhejiang University
79200015	The Research on Product and Market Innovation of China	Hengxue Huang	Wuhan University
79200020	The Rational Research of Firms' Technological Innovation during System Transformation of China	Heng Li	Xi' an Jiaotong University
79270016	The Theory and Empiric Research on Stochastic Innovation Diffusion	Jiancheng Guan	Beijing University of Aero. & Astro.
79270022	The Mechanism and Policy Research to Realizing Economic Growth in High Quality by Implementing Technological Innovation	Jiaji Fu	Tsinghua University
79270046	The Mechanism Process and Policy Analysis on Technology Transfer in Chinese University	Zhixiao Tang	Fudan University
79400010	The Harmonized Development Research on Hi-tech and General Technology for State Owned LMEs	Zhiejin Xu	Jilin University
79460004	The Research on Quantitative Assessment and Distribution of Technological Innovation of Enterprises	Gang Xiang	Kunming Polytechnology University
79470068	The Comparison Research of Technological Innovation Systems and Innovation Modes amongst China and Asia Four Little Dragons	Yingluo Wang	Xi' an Jiaotong University
79570001	The Research on Environment and Personnel Quality of Technological Innovation for Civilian-run S&T Firms	Mingju Ma	Beijing University
79570026	The Research of Technology Development and Innovation Process for Contemporary Typical Industries	Xixian Cai	S&T University of Central China

79570066	The Process, Patterns and Impetus of Sound Technology Innovation in China	Qingrui Xu	Zhejiang University
79570084	The Research on New Patterns of Technology Import and Diffusion in China	Xingming Wang	Chinese People' s University
79600007	The Research of Dynamic Relevancy Patterns of Industrial Technology Evolution and Innovation Policy in China	Gang Wu	Fudan University
79670022	The Mechanism and Policy Research to Realizing Economic Growth in High Quality by Implementing Technological Innovation	Jiaji Fu	Tsinghua University
79670024	The Empiric and Comparison Study on Interactive Mechanism of Technological Innovation and System Innovation of Enterprises	Shixu Guan	Haerbin Technology University
79670086	National (Industrial Domain) Data Base of Technological Innovation	Chi Ma	The S&T Promotion Center of China
79770076	The Research of Technological Innovation in Backward Regions	Guang Chen	Southwest Jiaotong University
79860006	The Research on Operational Regularity and Managerial Mechanism of Sustainable Innovation for State Owned Enterprises	Gang Xiang	Kunming Polytechnology University
79870036	The Research of Interaction Mechanism between Industrial Organization and Technological Innovation	Guoxin Liu	Wuhan Polytechnology University
79870065	The Research on Technological Innovation Audit and Benchmarking of Enterprises	Jin Chen	Zhejiang University
79870099	The Strategy and Policy Study of Energy Technology Innovation in Sound-environment and High Efficiency under Market Economy	Xiaolin Xi	
79970056	The Study on Measurement of Regional Innovation System	Jiancheng Guan	Beijing University of Aero. & Astro.
79970059	Technological Innovation Globalization of Transnational Companies and the Impacts on China	Yun Liu	Hefei Technology University
79900010	The Theory and Practice Study of Sound Technological Innovation Audit in China	Faming Yang	Zhejiang University
79900015	The Research on Evolution Mechanism Managerial Modes and Case Study of Enterprises Innovation Network	Dazhou Wang	Haerbin Technology Institute
70072005	The Redesign Research on Managerial Flow Process of Technological Innovation, Based on IT	Chunlin Si	Fudan University
70073007	The Science Metrics Research in Structure and Performance of S&T Innovative Activities	Liming Liang	Henan Normal University
70171039	The Study on Measurement of Technological Innovation for Chinese SMEs	Kexin Bi	Haerbin Polytechnology University
70172026	The Study on Knowledge Measurement of	Jiancheng	Beijing University of Aero.

	Innovative Organization	Guan	& Astro.
70173004	The Theory and Empiric Research on Innovation Mechanism and Policy of Industrial Cluster	Ming Nie	S&T University of Central China
70173017	The Research on Innovation Process and Assessment System for Chinese Complex Products System	Jin Chen	Zhejiang University

IV. SEMINAR PRESENTATIONS

A. Invention, Imitation and Innovation

From Invention to Innovation

Lewis M. Branscomb
Harvard University

The introductory papers for this seminar reflect the priorities set by the governments of both China and the US as they seek to increase the vitality of their national systems of innovation and growth. Prof. Qinrui **Xu** will be discussing "The Transition from Imitation to Innovation." My discussion focuses on the "Transition from Invention to Innovation." China seeks to build its economy increasingly on indigenous sources of growth; the US wants to accelerate to accelerate its indigenous sources of innovation. Both nations invest massively in scientific and engineering research in the expectation that research is the root of innovations that have the potential to replace old (and in China's case imported) technology and to create new markets where a Schumpeterian franchise offers higher returns that allow growth to be self financed.

National R&D funding, by source: 1953 1998

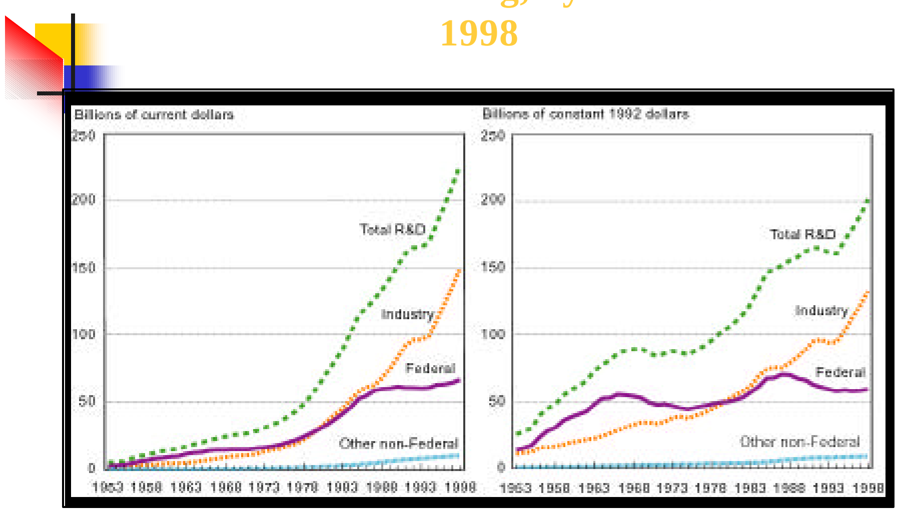

Fig. 1: National R&D funding, by sources: 1953 -- 1998

IV. SEMINAR PRESENTATIONS

A. Invention, Imitation and Innovation

This paper asks, do we understand how research is converted into successful commercial innovations? Are there financial, institutional or entrepreneurial "gaps" that increase the risks and costs of radical, technology-based innovations? What is the role of governments, federal and state or provincial, in promoting the commercial transition from an invention to an innovation? Does the Advanced Technology Program of the US Department of Commerce, which is intended to meet this need, work as intended? How might it be improved?

It is important to remember that virtually all economic growth in the US economy, and indeed all industrial economies, comes from incremental improvements in productivity, products, and markets, not from the exciting new enterprises and businesses based on radical new technologies. These incremental improvements are driven by market forces, made possible by incremental R&D. In the US they are financed almost entirely by private investment. In the last decade total national R&D has risen to over $250 Billion annually, but almost all of this increase has come from private investment growth; government R&D has been, in total, approximately flat in inflation-adjusted dollars.[i] This investment supported a Gross National Product of $10,253 Billions in year 2000.

But the sources of new industries, of new commercial opportunities come from radical, market and technology-based innovations. Figure 2 defines such innovations; they create new markets from new technology. These stem from a tiny fraction of total R&D and create an economic activity of very modest proportions. The total investment of venture capital in year 2000 hit an all time peak of $100 Billion, (still only 1 percent of GNP) up from 20 B in 1998 and back to about $37 B in 2001. Only a fraction of this investment is in high tech, science-based innovations.[1] Nevertheless federal investments in non-military research are motivated to a significant degree by the expectation that new products and new ventures will result.

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[1] In the US where the service sector is substantially larger than the manufacturing sector of the economy, market innovations (such as many of the 'dot.com' businesses) may be much more numerous and overall contribute more to GNP.

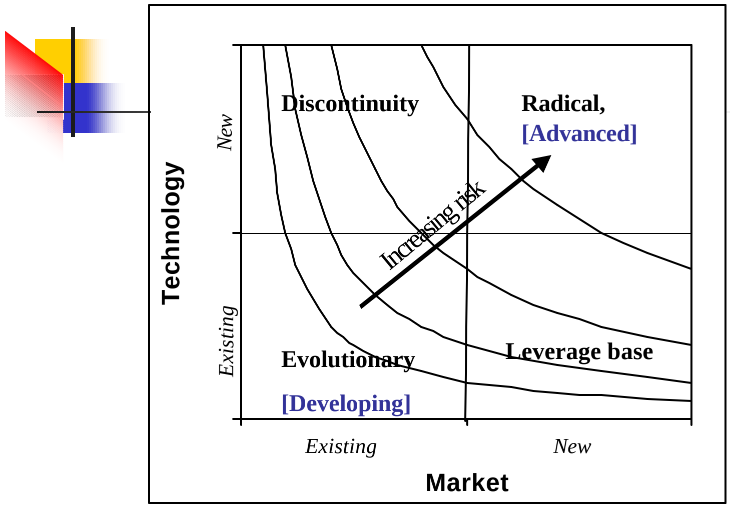

Figure 3

Fig 2: Technology, Market and Innovation

Many of the political arguments about government appropriations to the research funding agencies of government attempt to base policy on inferences about economic outcomes from the aggregate investment of $ 60 billion in non-defense, publicly funded R&D.[ii] The Congress is aware that analyses at this high level of aggregation do not allow quantitative evaluation of the relationship between the policies under which these investments are made by federal agencies and the economic and social outcomes they produce. It was for this reason that the Government Performance and Reports Act was passed in 1993.[iii] It requires every research funding agency to document in their budget submissions not only the outputs in publications and patents and training, but the outcomes in economic and social terms. The agencies have also found this requirement very difficult to satisfy.

The result is that federal S&T policy, as it relates to the expectation of economic outcomes, still depends on the following principles and policies:

- A residue of confidence in the "social contract for science" that takes as a matter of faith that, while the outcomes from science are difficult if not impossible to predict, experience shows that viewed in hindsight they dramatically exceed their public costs.[2]

[2] This idea was articulated in Vannevar Bush's *Science the Endless Frontier* published in 1945 as a report to President Truman. In return for generous public investments in research, scientists committed to a highly creative, competitive, and honest performance.

- Statutes intended to increase the incentives for commercializing government funded science (technology "pull" policies) of which the most significant was the 1980 Bayh-Dole Act, allowing universities and other contractors and grantees to own patents issued from government-funded research.
- A larger number of statutes which can be characterized as technology "push" polices, intended to encourage the transfer of government research to commercial enterprises. These include the Stevenson-Wydler Act and its amendments, for example encouraging Cooperative Research and Development Agreements (CRADAs) which Prof. Mowery will discuss later in this volume.
- Two statutes intended to create government investments in research to create technologies of high commercial promise. These include the Small Business Innovation Research program and the Advanced Technology Program (ATP) managed by the National Institute of Standards and Technology (NIST) in the U.S. Department of Commerce. The ATP statute was highly controversial from the time of its passage in 1988.

With the exception of ATP, none of these statutes was justified by a detailed model of just how advanced research, funded by government, results in high tech innovations. ATP attempts to invest in that process directly, and it has proved highly controversial politically. What, then, do we know about how radical, technology-based innovations come about? What can governments do to foster such innovations? Is ATP an effective policy tool for this purpose, or it is merely "corporate welfare" as its critics claim?

To explore this question we need a model of the processes that relate publicly funded research to successful market entry of new products or processes, in short to innovations.[3] Figure 3 presents such a model.

[3] An innovation is a product or process, new to the enterprise, that is successfully introduced into commerce. The adjective 'innovative' simply means clever, novel, and perhaps commercially promising. An innovative idea is not an innovation, at least not until it is successfully produced and sold.

A. Invention, Imitation and Innovation

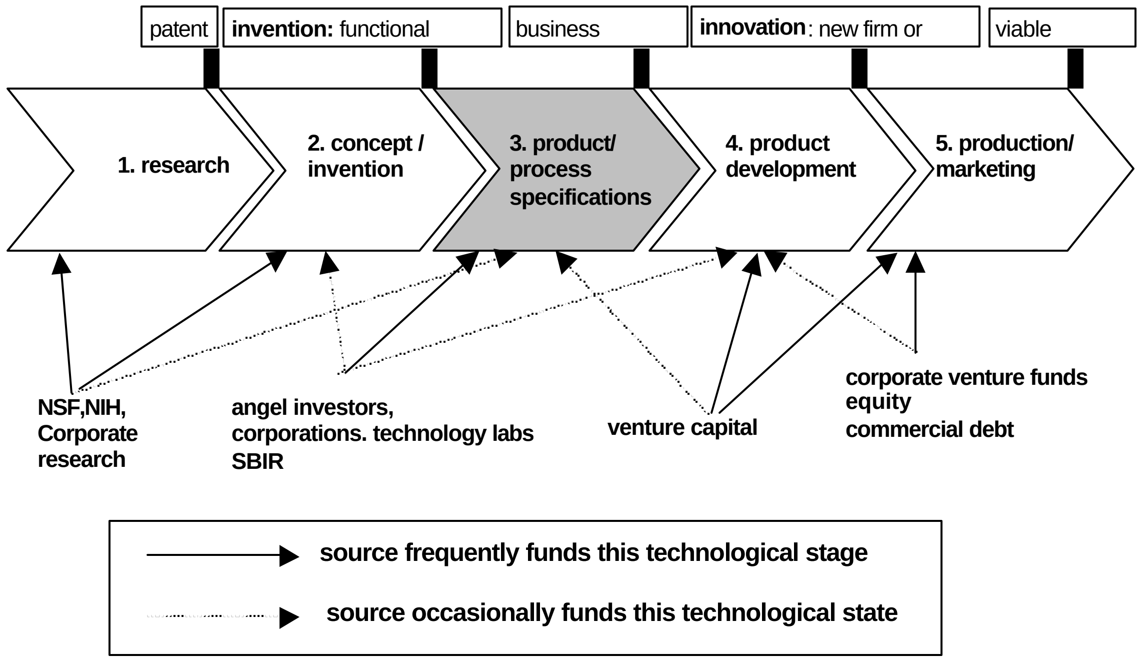

Figure 3. Sequential model of development and funding

This diagram identifies the stages of activity, starting with research (phase 1) leading to a technical concept of commercial value, protected, perhaps by a patent (phase 2). Phase 3 is the most critical phase in the transition from invention to innovation; this is the point at which the technology is reduced to industrial practice, a production process is defined from which costs can be estimated, and a market appropriate to the demonstrated performance specifications is identified and quantified. When this work is completed product development (phase 4) begins, a pilot line is produced and the enterprise is ready to enter the market. At this point an innovation is achieved, and in phase 5 that market is explored with product, feedback from customers is fed back to product development and a business ready to be financed or perhaps acquired is created.

The first two phases lie in the domain of the research enterprise; it may be publicly funded. The technical entrepreneurs who create the concept in phase 2 may have little business experience, but they may have high commitment to their technical vision. The venture capital industry, always looking for opportunities to invest where the returns may by high enough to justify the business risks are unlikely to take the opportunity seriously until phase 5 is reached. In some cases they will invest, in an exploratory fashion in phase 4.

Who funds phase 3, where the work is too market specific for government R&D support[4] and too speculative for venture capital? This will be discussed in some detail by Dr. Auerswald in his paper. Here I want to address the nature of the risks and uncertainties that cause phase 3 to be such a critical step in the linkage of research to the high innovations so important to the economy, and briefly explore the implications for government research policy.

Three elements of disjuncture in stage 3 (figure 3)

The specific region of the innovation space in which we are most interested is bounded at the earliest stage with the verification of a commercial concept through laboratory work, through the identification of what looks like an appropriate market, and perhaps the creation of protectable intellectual property. Congressman Vern Ehlers, among others, uses the term "Valley of Death" to dramatize the particular challenges facing entrepreneurs engaged in the transition from invention to innovation. This term reinforces the "capital gap" perspective on early stage innovation: champions of early stage projects must overcome a shortfall of resources.

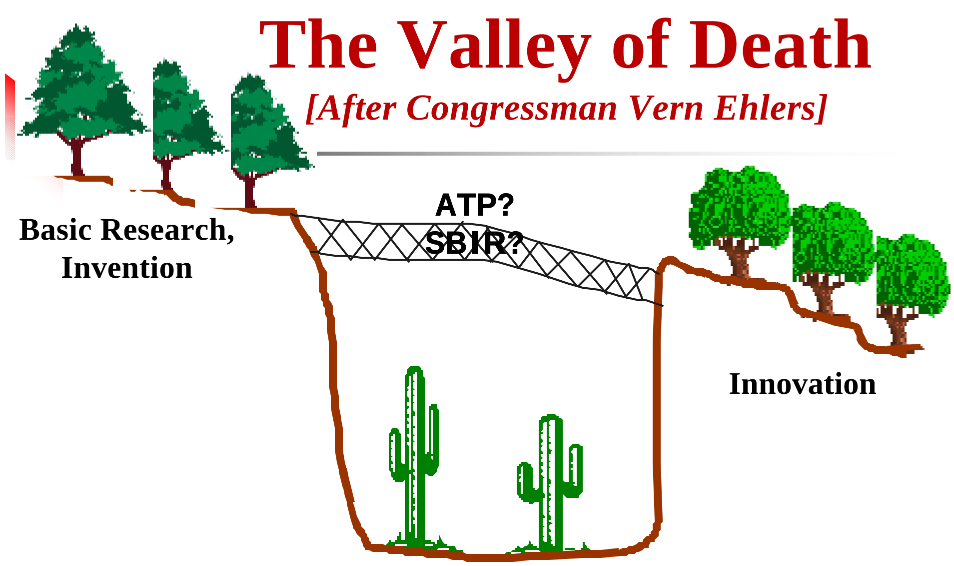

Fig. 4: the Valley of Death Between Basic Research, Invention and Innovation

[4] Where government makes the market, that is, where government funds the research and then buys the product (typical of military procurement) government will fund all the steps leading from invention to innovation.

A. Invention, Imitation and Innovation

The imagery of the Valley of Death (which connotes Death Valley in Nevada, USA) leads to the cartoon drawn by Congressman Ehlers in Figure 4.[5] Death Valley suggests a barren territory when, in reality, between the stable shores of the S&T enterprise and the business and finance enterprise is a sea of life and death of business and technical ideas, of ' big fish" and little fish contending, with survival going to the creative, the agile, the persistent. Thus we propose an alternative image: the Darwinian Sea (Fig. 5).

Fig. 5: The Darwinian Sea between Invention and Innovation

In *Taking Technical Risks*[iv] we identified the three disjunctures that constitute the "Darwinian Sea" in the following terms:

- *Disjuncture in motivation for research*. Initially an innovator demonstrates to his or her own satisfaction that a given scientific or technical breakthrough forms the basis for a commercial product (proof of principle). Subsequently, however, a substantial amount of difficult and potentially costly research (sometimes many years' worth) is needed before the envisioned product is transformed into a commercial reality with sufficient function, low enough cost, and high enough quality, and sufficient market appeal to survive competition in the marketplace. Few scientists engaged in academic research (or the agencies funding their work) are motivated to undertake this phase of the reduction to practice research.

[5] Ehlers (2000).

- *Disjuncture between technologist and business manager*. On each side of the Darwinian Sea stands a quite different archetypal character: the technologist on one

> **The Challenge of Value Capture**
> *Gerald Adolph:* There's a certain uneasiness that comes with being in this "valley [of death]" for a business person. The uneasiness goes beyond doubts whether you can be successful technically, and it even goes beyond the question of whether or not you can *create* value... [it relates to] whether or not you are going to *capture* any value... Faster technology development cycles are making it even tougher to do value capture, but it actually is, in our view, an old problem. The sources of leakage of value capture [are] competitive offerings, or consumers or other users who are just unwilling or unable to pay. Any of you who have come up with brilliant innovations and then had to market it to the automotive companies certainly ran into that to the fore. Or there are just structural reasons why it's hard to capture value. If I come up with an innovation in carpets and it prevents the carpet from staining and I call it Stain Master, I can collect value because there's only one step between me, the fiber maker, and the retail chain. It's a carpet company, and they tend not to have particularly strong brands. On the other hand, when I try to try to put that in apparel, when I look at the nature of the chain, there are three and four and five people in between me and the person who ultimately cares about that claim. So, simply by observation, I know that I'm going to have a more difficult value capture problem. (Palo Alto workshop, PA3 p. 10)

side, and the investor/manager on the other. Each has different training, expectations, information sources, and modes of expression. The technologist knows what is scientifically interesting, what is technically feasible, and what is fundamentally novel in the approach proposed. In the event of failure, the technologist risks a loss of reputation, as well as foregone pecuniary returns. The investor/manager knows about the process of bringing new products to market, but will likely have to trust the technologist when it comes to technical particulars of the project in question. The investor/manager is generally risking other people's money. To the extent that technologist and investor/manager do not fully trust one another or cannot communicate effectively, the Darwinian Sea between invention and innovation becomes deeper still.[6]
- *Disjuncture in sources of financing*. This refers to the disjuncture between the research funds available (typically from corporate research, government agencies or, more rarely, personal assets) to support both the creation of the idea and the initial demonstration that it works, and the investment funds required to turn the idea into a

[6] At the DC workshop Arden Bement cautioned that the hypothesized disjuncture between technologists and management may underestimate the extent to which management is involved very early in the technology development process: "[T]he simple model that was posed where one end of the Valley of Death is more or less dominated by technologists and the other end is sort of dominated by management, is probably not coming out in these models. There's a much more disciplined process where management gets involved right up front and is part of the process all the way through, which maybe it dissipates part of the Valley of Death." (DC workshop, DC2 p. 17)

market-ready prototype—the validation of the business case for the project. Typically, few sources of funding are available to aspiring innovators seeking to bridge this "break" in funding sources. They include "angel" investors (wealthy individuals, often personally experienced in creating new companies and/or developing new products); venture capital firms specialized in early stage, or "seed" investments; military or other public procurement; state or federal government programs specifically designed for the purpose; and university funding from public or private sources. The scarce resource in the "Darwinian Sea" is not cash, but time, information, and people—in particular, information concerning the technological *and* market prospects of target projects and the people capable of evaluating and validating that information. What investors lack is *quality* deal flow. They can find plenty of laundromats and dry cleaners, but they can't find quality deal flow in high tech ventures. The "funding gap" is really an information gap.

These three sources of "disjuncture" between inventor and business investor/manager are studied from two perspectives: trusted networks for innovation (or social capital) and challenges to entrepreneurship. The first is a description of the collective behavior of all the institutional participants in a successful innovation in a community like Silicon Valley, Route 128 Boston or the Research Triangle in North Carolina. The ability of the inventor to communicate his evaluation of the technical risks in a project or to gain the confidence of a business investor willing to take the risk and accept failure if necessary is only one element in the network. Perhaps even more important is the experience that many supporting institutions, venture capital firms, banks, law firms, human resource markets, education and research institutions, all manner of business and technical service firms have in dealing with one another. In communities with the highest level of this kind of social capital a handshake is accepted as a commitment, to be followed up by legal documentation later.

The entrepreneurship challenge involves the capabilities of the individual innovators who seek to carry their idea across the Darwinian Sea and participate in the fruits of a successful innovation. The rare individual – a talented business leader with a strong technical background – is able to bridge the Sea personally. A community with strong social capital may offer mentors – usually in the form of angel investors -- who have been successful at commercial innovation and serve both as mentors to new entrepreneurs and as seed investors in their ideas.

A key feature of these networks of innovation is that they are geographically confined to specific locations. Angels rarely invest in a firm more than an hour's drive away; a similar effect is found in seed stage venture firms. Spin-off firms from universities are almost always located within the same urban community. Eighty percent of them are located in the same state as the university from which they sprang.

Given these difficulties, which are deeply rooted in a clash of cultures between researchers and investors, it is perhaps surprising that US universities are so active in seeking commercial return from their faculty-generated intellectual property. But the latest figures are impressive.

More than $1.26 billion in royalties were collected by U.S. colleges and universities in FY 2000. In addition, the *FY 2000 Annual AUTM Licensing Survey* reported 347 new products were introduced to market and at least 454 spin-off companies were created by the institutions, where inventors filed for more than 8,500 U.S. patents.[7] Attesting to the localized economic development impact of strong university research, more than 80 percent of the start-up companies were located in the academic institution's home state or province.[v]

A reasonable explanation for the strong role of US universities in creating new science-based enterprises lies in the depth of technical talent, the entrepreneurial character of competitive, project-funded research, the financial motivations of faculty and university officials, and – most important – the development of the networks of relationships that constitute the social capital required for successful high-tech commercialization. Universities are not only the source of many of the commercially attractive technical discoveries; they constitute a web of capabilities – technical, legal, business management, and application skills that form the core of the social capital in areas like Silicon Valley California and Route 128 Boston.

Thus the emphasis in research and innovation policy in the US Department of Commerce is on focusing the ATP program on the research shore of the Darwinian Sea, with special emphasis on the role of universities. The ATP program is described in some detail in a report by the National Research Council in 2001.[vi]

A recent report from the Secretary of Commerce defends the ATP program as a useful policy tool for encouraging innovation and recommends a series of six reforms in the program.[vii] Two of these would give universities patent rights in projects carried out in partnership with firms and would allow universities to initiate and lead joint projects with firms. Another emphasizes that ATP should be viewed – and managed – as an R&D program, avoiding "down stream" investments in product development. Large firms would be allowed to participate only in consortia, and ATP would improve its access to

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[7] Tenth annual licensing survey released by the Association of University Technology Managers (AUTM). See <www.autm.net>

expert advice. The most controversial "reform" would be a change in the law allowing ATP to recapture a 5% royalty on commercially successful projects. This is unlikely to be accepted by the Congress, and in any case seems to be philosophically incompatible with the notion that ATP does not fund product development, making the association of earnings wtihi ATP projects difficult to establish. It also would appear to provide an incentive for ATP managers that is perverse with respect to the desire to keep the program focused on high-risk, early stage research.

Thus the direction of policy is likely to continue to be rooted in research funding policy, but to allow government agencies to invest further downstream than is traditional for government basic research funding. The application of peer review processes to this kind of work would appear to offer a serious challenge, perhaps explaining why the Defense Research Projects Agency (DARPA), which does not use peer review, is more comfortable with funding advanced technologies of industrial value than is the National Science Foundation.

In summary, the chaotic character of the "Darwinian Sea" is probably necessary to provide a wide range of alternative ways to address issues of technical risk, to identify markets that do not yet exist, to match up people and money from disparate sources. But on one bank of the Sea – the S&T enterprise, technology "push" policies may encourage agencies to fund research closer to the reduction to practice required for a solid business case. And on the other back – the world of business and finance – technology "pull" policies will continue to enhance the incentives for risk taking (for example through moderated capital gains tax rates). Programs like ATP, which has elements of both push and pull, may continue to be viewed as experimental, but will become more securely anchored on the research shore of the Sea and with the aid of a more prominent role for universities in their projects may enjoy increasing support in the Congress.

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[i] http://www.bea.gov/briefrm/tables/ebr1.htm
[ii] http://www.aaas.org/spp/dspp/rd/trtot03p.pdf
[iii] http://www.whitehouse.gov/omb/mgmt-gpra/
[iv] L. M. Branscomb and P. Auerswald, Taking Technical Risks: *How Innovators, Executives, and Investors Manage High-Tech Risks* (Cambridge MA: MIT Press, 2002).
[v] Two-thirds of the 4,346 new licenses/options in FY 2000 were granted to companies with fewer than 500 employees. Start-up businesses were launched to commercialize 626 of the licenses. New licenses rose 11 percent over 1999 survey results. Invention disclosures rose 6 percent from 1999 to a FY 2000 total of 13,032. Patent applications grew by 15 percent from the 1999 total of 5,545 to 6,375 in FY 2000. Patents issued rose 3 percent in FY 2000 to 3,764. FY 2002 saw academic institutions taking an equity interest in 372 deals, 53 percent more than the previous year. The institutions held equity interest in 56 percent of the 454 spin-offs created in FY 2000. Over the ten years AUTM has conducted the survey, nearly 3,400 new businesses have been launched from academic research results. One hundred eighty-four institutions

reported 2,309 start-ups were still independent, operating businesses at the end of 2000. The number of license/options reporting income in FY 2000 rose 8 percent from 1999. Total adjusted gross license income was $1.26 billion in FY 2000, up 46 percent over FY 1999.

[vi] Charles W. Wessner, ed., *The Advanced Technology Program: Assessing Outcomes*. Board on Science, Technology and Economic Policy, National Research Council, (Washington DC: National Academy Press 2001.)

[vii] The ATP study by the Secretary of Commerce can be found at <http://www.atp.nist.gov/atp/secy_rept/contents.htm>

Development of Technology Innovation Management in China

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Abstract: This paper introduces the evolutionary process of technological innovation and technology management in Chinese firms since 1949. Basing on the view of dynamic capability and knowledge management, this paper is to analyze the structure of technological innovative capability and the paths for enhancing it. This paper advances a new paradigm for innovation management, i.e., competence-based innovation portfolio. For enterprise's long-term success, it should cultivate and improve its core competence. This presents the relation between innovation and the competence is very important , especially the integration of technological vs. organizational and institutional innovation, independent vs. collaborate innovation. The basic models of technological capability evolution are analyzed, the path of technological capability evolution in developing countries is brought forward: from imitating capability to creative imitating capability, and to indigenous innovative capability. The path of technological capability evolution of some Telecommunication Co. (as EASTCOM) is studied and some deep learning of the technological capability of Chinese firm are gained. Finally, the relationship between financing tech. Innovation and competence accumulation was discussed.

Key Words: Chinese enterprises; innovative capability; knowledge management, portfolio Innovation, core competence, organizational innovation

During past decades, Chinese industry has made great progress in technological innovation. It is complex result of the changing political and technological environments. The critical factors of successful innovation are that Chinese industry has paid more attention to the acquisition and absorption of foreign advanced technology until 1980s. Since late 1980s, many Chinese firms began to innovate with portfolio view. This new pattern of innovation greatly enforced the competitiveness of their products. Up to late 1990s, a lot of Chinese firms had building strong technological competence and innovative capabilities. They began to deepen their innovation management by managing internal and external technological and organizational knowledge, and by building up their innovative network.

A. Invention, Imitation and Innovation

1. Development of Technology Innovation Management in China

Since late 1940s, technological innovation in China experienced as a 3-stage path.

1) Imitation Stage (early 1950s-1957)

This is a hard time for China's 3-year economy recovery to the first 5-year plan period since the liberation in 1949. During this period, the science and technological policy is "Learning from Soviet Union."

Under the imitation stage, there were also adaptive and incremental innovation for the following two main reasons:

- It is necessary adaptive to our natural resources and national conditions. China is a large country with wide and different regions. The agriculture machine developed to use for North China faced the plane and wide area, while in South China it has to work in the narrow and water region.
- The improvement of the acquired technologies was required to solve the existed defects of copied technologies. For the improvement of the acquired technologies, thousands and millions of workers were involved in the great movement of "Innovative Suggestion Movement of the Workers." As a result, such a initiative learning and suggestion system is still working well in many Chinese firms. As a result, the suggestion have offered great effectiveness to firms on productivity and cost-saving of the products.

2) Creative Imitation (late 50s to '78)

During this stage, the technological innovation policy was "From Imitation to Self-Design," it means that we should not limited to adaptive and incremental innovation. During this stage, there was a learning movement since 1958. It oriented to free the thinking model, i.e. learn to think freely and creatively. The main objective was against dogmatism. As the result of freeing worker's minds, there appeared a great movement of participation.

Following the participation movement, there appeared an integration of 3 to 1, which includes: (1) integration of worker, engineer and manager; (2) integration of user, manufacturer and research lab; (3) integration of research lab, manufacturer and university.

As the result of these two great movements, plenty of self-designed and developed new products such as 10,000 ton oversea ship from Shanghai Jiangnan Ship-building Company and 10,000 ton water press machine in Shanghai Heavy-machine Manufacturer were appeared.

The weak point of this stage was “close door.” Moreover there existed a quite huge gap from the contemporary state-of –the –art in the world. The main problems of this stage were, first, enterprise were not motivated, there was no pressure to force them to innovate; and second, R&D and economical sectors (firms) belong to separate system. As the result, there was low efficiency of research result implementation.

3) Improvement to Secondary Innovation (since 1978)

The extremely important policy during the middle 1970s was the open-door policy and reform of economical system as well as S&T system. The big change was the integration of market mechanism with planing system, instead of high centralized plan system. These changes strongly motivated the firms to develop their ability of research, development, and technological innovation. Competition appeared and forced firms to apply research results to develop new products and technology for achievement of competitive advantage. As a result, R&D integrated with manufacturing in firms, and this greatly shortened the gap between R&D and manufacturing.

It was big leap to shift from improvement to secondary innovation. It took a long time to accumulate knowledge through “learning by doing”, and “learning by R&D.” And the creation during this process played a big role.

During this stage many research institutes were organized in large state-owned enterprises. In the middle 1990s, the technological centers were established in large firms to carry out the long term innovation projects. As a result, many high level products were developed. For example, the 5^{th} generation of oxygen-generation machine product innovated by Hangzhou oxygen-making Generator Manufacturer (HOGM) largely shorten the gap from the state- of-art technology level.

Due to the differences in the political institutions, education systems, and national resources endowments, as well as technological infrastructures, the nature and the pattern of technological innovation in developing countries are very different from those in developed countries. For developing countries, innovation often originates from imitation and improvement of imported technology. Such a innovation pattern in Chinese firms is called the “3-I pattern,”: imitation, improvement , and innovation.

2. Two Fundamental Innovation Pattern-----Secondary Innovation

The key to implementing the “3-I”pattern is to select the proper product innovation and process innovation locus. From the classic theory of innovation distribution pattern, process innovation follows product innovation as described as Abernathy and Utterback (U/A pattern); however, our research of case studies showed a new innovation pattern: process is more important than product innovation at the early stage, and than the product innovation became more essential. We call it the "secondary innovation pattern"[1] (see Figure 1).

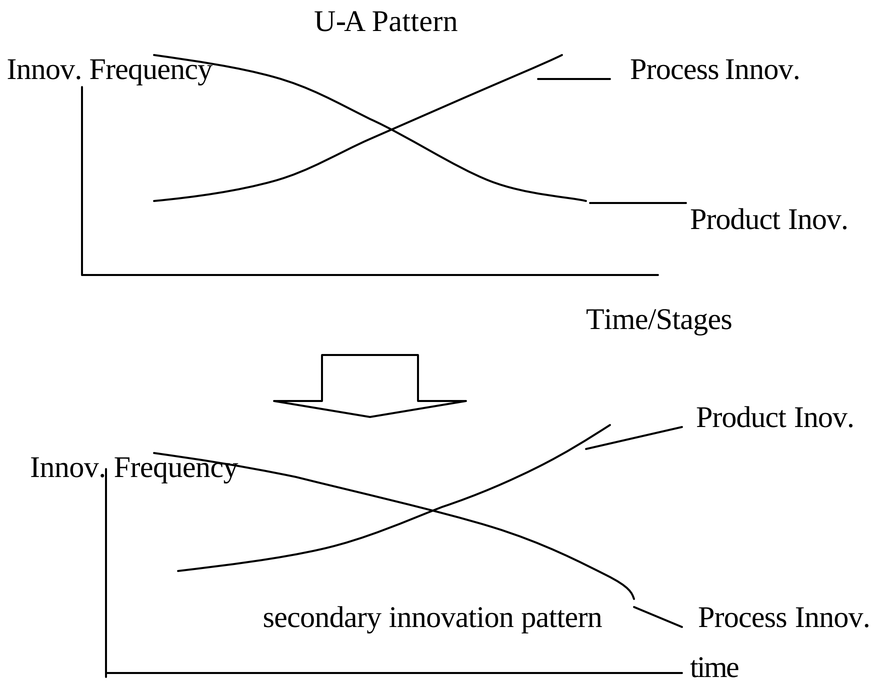

Figure 1 Two Innovation Pattern

Several Chinese firms grasped this concept and developed their technology by following the steps of the above mentioned three stages of innovation, with emphasis on process innovation first. As a result, they spent less time and cost to keep abreast of the state-of –the art of advanced technology. So, we argue that the secondary innovation pattern is more suitable for developing countries.

3. Paradigm Shift in MOTI

Technological innovation has been a powerful force for economic development, productivity growth and firm' s long-term success throughout history, intensive studies of its industrial role and influence have begun to illuminate some of the important aspects of the relationship between innovation and competition (Poter,1985; Nelson, R. and Winter, S.,1982; Abernathy and Clark, 1985).

These studies recognize that innovation is not a unified phenomenon: some innovation disrupt, destroy and make obsolete established competence; others refine and improve (Abernathy and Clark, 1985; Henderson and Clark,1990). Abernathy –Clark model draws attention to market knowledge, and the Henderson-Clark model unbundled component and architectural knowledge, they all focus on the impact of an innovation on a firm's capabilities.

Based on the view of competence accumulation, process innovation is important for firms to achieve competitive advantage. Process innovation does not only follow product innovation, there is a kind of long-range process innovation which is developed for strengthening firms'core competence and capability. This type of process innovation is said to be strategic process innovation, including: key innovation which is developed for the future product innovations; fundamental technological innovation such as FMS, CIMS, and CAD etc.

Since there are several kinds of process innovations, various strategies of developing the complete process innovation systems are existed, the following is the two modes of technological innovations.

a) Traditional mode(Utterback and Abernathy, 1976). This is the linear process mode: process innovation follows product innovation as shown in figure 1.

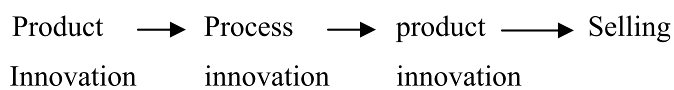

Figure 1 Traditional innovation mode

b) Process dominate mode. This is the process innovation leading mode just shown in figure 2. Under this mode, the fundamental process innovation directed by firms' long term technology strategy were going far in advance of the product innovation.

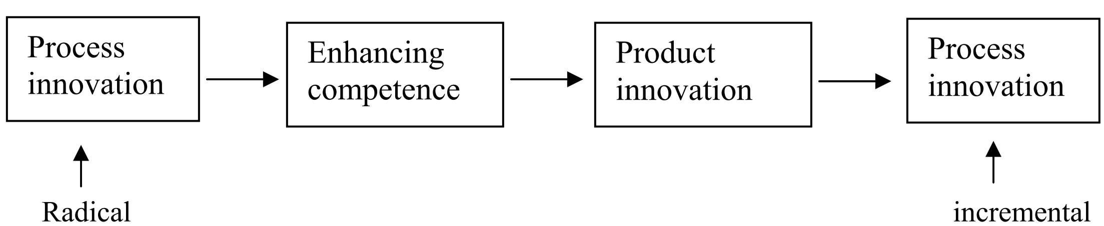

Figure 2 Process dominate innovation

Besides the portfolio between product innovation and process innovation, the matching of technological innovation with the organizational and cultural innovation is also important. The organizational and cultural innovation pertains to organizational structure and administrative processes which can affect technological innovation, especially the architectural innovation (Henderson and Clark, 1990). Architectural knowledge is often tacit and embedded in the routines and procedures of an organization, making changes in it difficult to discern and respond to.

The key of a firm's innovation capabilities is its ability to recognize the potential of an innovation, which rest on the way it collects and processes information and is a function of four factors (Afuah,1998): (1) its strategies, organizational structure, system, people, (2) its local environment, (3) its dominant managerial logic and value, (4) the type of innovation in question.

Organizational and cultural innovation plays important role in technological innovation in Chinese firms. It improved the environments for technological innovations such as offering the autonomy for firms, greatly motivating the enterprises to innovate. It also happened to free the minds of the stuff and workers, set creative climate for innovation.

The rate of technological change, together with increasingly complex nature of many technologies, means that few organizations can now afford to maintain in-house expertise in every potentially relevant technical area. Therefore most R&D and product managers now recognize that no company, however large, can continue to survive as a technological island. In addition, there is a great appreciation of the important role that external technology source can play in providing a window on emerging or rapidly advancing area of science. This is particularly true when developments arise from outside a company's traditional area of business, or from overseas (Tidd,et, 1997). The competence-based approach emphasizes the process of competence accumulation or learning. Competence development requires a firm to have an explicit policy or intent to use collaborate innovation as an opportunity to learn. This suggests that the acquisition of external technology and collaborate innovation should be used to complement internal R&D, rather than being a substitute for it.

According to our research, innovation portfolio should extend to 5 aspects as shown in figure 3. It means innovation portfolio should be well-balanced in between the following pairs, i.e., balance between product and process innovations; balance between radical and incremental innovations; strategic balance between visible innovation benefits vs. hidden innovation benefits; coordination between technological and organizational innovation; and using collaborate innovation to complement indigenous innovation.

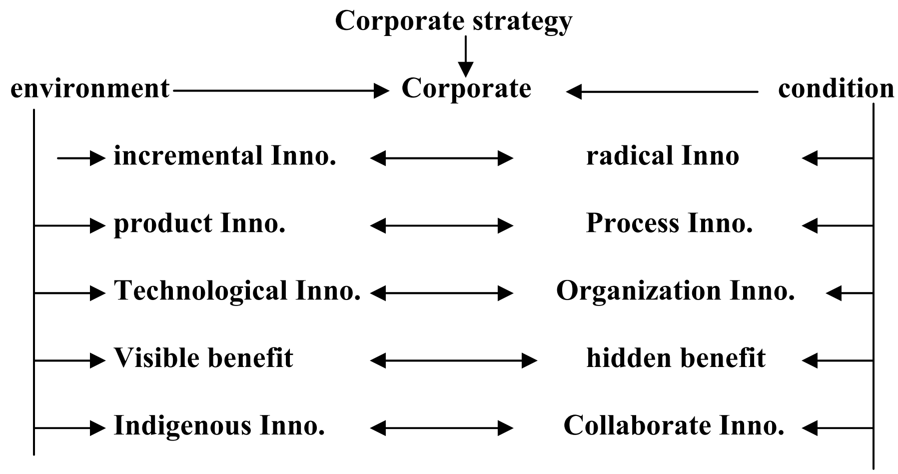

Figure 3 Innovation portfolio

We give a case of Hangzhou Oxygen-making Generator Manufacturer (HOGM) to show the role of the portfolio innovation in Chinese firms.

The core product of HOGM is the Large-scale Oxygen-making Generator (OMG). Since 1956, HOGM has begun to monitor foreign OMG technology development, with a aims to build the technological base. Then at the beginning of 1970s, HOGM imported the foreign technology. By doing these, HOGM efficiently enhanced its manufacturing capability and design capability through portfolio innovation and learning by doing. After near 40 years technology accumulation, HOGM has transferred from technology acquisition to self-reliance design & manufacturing since 1990s.

During the process of technological development, HOGM adjusted organizational structure at both corporate's and divisional level as well as R&D structure (see table 1).

Table 1 Technological innovation and innovation portfolio in HOGM

Product generation	1,2 (1956-1979)	3,4 (1979-1987)	5,6 (1985-)
Technological innovation pattern	Monitoring , imitation & importing	Importing & indigenous design	Indigenous development
organization	functional	SBU	SBU, Joint venture
R&D organization	Project engineer	Cooperation with Univ.	Cooperation with Univ.& institutes
Incentive	Traditional	Payment incentive	Payment, Job & culture

4. Competence-based Innovation Portfolio

Since 1990s, the core competence of the firm has become a hot issues, whatever from theoretical or practical respective. Many articles has argued the importance of core competence in the advantage gaining, but as a whole, there still leave many things to do to uncover the inner logic of core competence conversion into competitive advantage.

A firm's core competence and capability is consist of four elements whose interaction determines how effectively the organization can exploit it. Those elements are knowledge and skills: technical know-how and personal know-how, including ties to important groups such as government regulatory bodies or the scientific community; managerial systems: tailored incentive systems, in-house educational programs, or methodologies that embody procedural knowledge; physical systems: plant, equipment, tooling and engineering work systems, and production lines and information systems that constitute compilations of knowledge; and values: the attitudes, behaviors, and norms that dominate in a corporation (Leonard-Barton,1992).

While the four elements of core competence are intertwined with each other, innovation, either competence destroying or competence enhancing, always relate to the change of these four elements. This is why that portfolio view of innovation is also essential in the core competence issue of firms.

The relationship between core competence and portfolio innovation is the mutual interactions as followings:

1) The choice of innovation portfolio is based on the firm's core competence;
2) Portfolio innovation is the pathway for core competence to be cultivated and enhanced, because the core competence is the complex interacted result of firm's technological, organizational, cultural elements.

In order to gain some inside looks into the firm's core competence building and enhancing process, we will examine the basic patterns and its rules in competence building. From the experiences of Chinese firms, there are three patterns as following:

- Pattern 1: build core competence via Secondary Innovation, that is, through technology importing, absorption and self-reliance innovation. The preconditions of this pattern are that the firm should have strong absorptive capacity, while there exists a large gap in core technologies.
- Pattern 2: build core competence through collaboration with other organizations. This include equity-based associations, such as joint ventures and direct investments, and nonequity associations, such as technology licensing, technology exchange, testing agreements, technology sharing agreements, and research

contracts. The preconditions of this pattern are that the firm should have a good relationship or cooperation experience with partners.

- Pattern 3: build core competence through in-house development. This offers the potential to protect existing competencies and to develop new competencies within a organization (Cohen and Levinthal, 1990). The preconditions are that the firm should have grasped a certain mix of core technology, and also, the technological change should not be too frequently and severely.

Kunming Pharmacy Corporation (KPC) is very successful in the integration among technological innovation, strategic innovation and organizational innovation and has developed rapidly since 1990. The three dimension of innovation in KPC can be showed in figure 4.

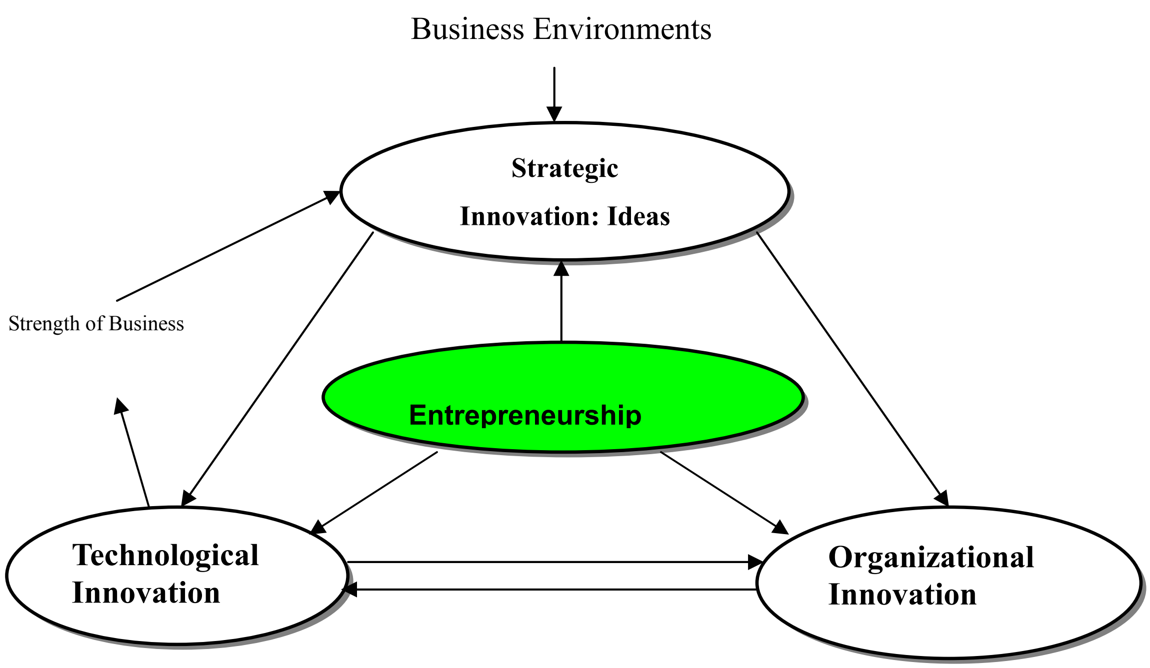

Fig.4 Three Dimension of Innovation in KPC

- Strategic innovation (ideas):
- ✧ Timely transformation on strategy and pitch on preponderant industry: from compositive medicine to botanic medicine
- ✧ Set up domestic and international strategic alliances to reinforce competence and improve the technology and management bases
- Technology innovation:
- ✧ Combination between radical innovation of new medicine and incremental

innovation

- ✧ Combination between production innovation and process innovation
- ✧ Combination between self-innovation and co-innovation
- ✧ Integration between technological innovation and innovation of organization and culture
- ● Organizational and System innovation:
- ✧ Reformation on KPC's ownership: KPC 36.8%, Jinding Corporation 36.8%, ESOP 19.6%, Fuheng Corporation and Bada Industry each 3.4%
- ✧ Reforming the mechanism of decision-making: democratic, scientific decision-making
- ✧ Innovation on marketing system: setting up a distribution system facing customers directly

Innovation in pharmacies is a kind of science-based innovation and so the acceleration of technological competence is much more important. To enhance its competence on technological innovation, KPC has taken many corresponding innovations in organization. The integration between technological innovation and organizational innovation in KPC can be seen from three aspects.

Firstly, KPC set up its Center of Research and Development in 1992 and the center is directly led by her CTO. Now KPC has successfully developed five kinds of first-level new medicine, which account for one fifth of Chinese first-level new medicines. Secondly, KPC always tries to set up domestic and international strategic alliances to reinforce competence and improve the technology and management bases. The domestic and international strategic alliances of KPC and their benefits are showed in table 2.

Table 2 The Strategic Alliances of KPC

Name of Collaboration	Collaborator	Benefits for KPC
Kunming BerkNorton Pharmaceutical Corporation (1992)	BerkNorton an American Pharmaceutical Corporation	➢ Marketing channels ➢ ARTEMETHERI becomes the first Chinese first-class new medicine exported to American markets
Kunming Conperit Pharmaceutical Corporation (1996)	Conperit a Switzerland Pharmaceutical Corporation	➢ Level on manufacturing ➢ KPC successfully gained GMP certification
Kunming Yagechen Pharmaceutical Corporation (1998)	a Hongkong Pharmaceutical Corporation	➢ Ulteriorly improve KPC's level on marketing and management ➢ More funds for innovation

Thirdly, KPC set up a lot of Medicine Distribution Centers in many cities and provinces since 1990 to carry out the achievements of technology innovation. Let's take ARTEMETHERI, a typical medicine of KPC, as the example. The successful marketing innovation of ARTEMETHERI can be seen from figure 5.

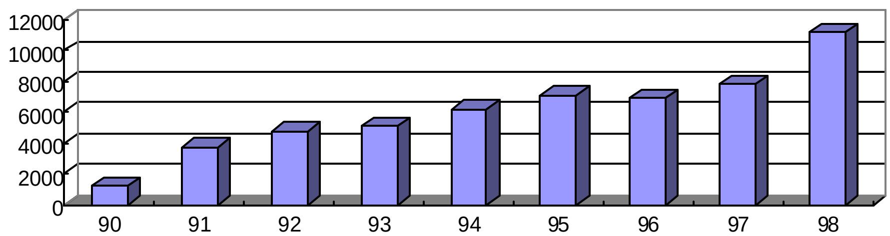

Fig. 5 Sales of ARTEMETHERI in KPC (thousand)

- Integration between technology innovation and culture innovation:
  - ✧ Building the kind of corporation culture focusing on technology innovation: for example, every year there is a technology innovation session in KPC and every one in every section must take part in it.
  - ✧ Training the agglomeration and team-workship among technological personals: for example, there are many communication meetings among different items.

5. Path of Leverage Innovation Capability

Frame of technology innovation capability accumulation

We expect that different types of technological change will tend to have different relationships with firms' existing capabilities and, therefore, influence the choice between internal development and external acquisition of new knowledge. According to our research on some Chinese firms, the methods of acquiring new knowledge not only relate to the types of technological change, they also relate to the firms' technological capability and investment ability.

There are three types of change within a technological system: encompassing, complementary, and incremental changes (A. Nagarajan and Wmitchell, 1998). Encompassing change involve radical alteration of core competence. Complementary change involve radical alteration of complementary assets that do not also involve radical alteration of core activities. Incremental changes involve incremental adjustments to core or complementary activities.

Encompassing, complementary, and incremental changes often have substantially different effects on a firm's existing knowledge and, in turn, on the methods that firms use to acquire new knowledge.

A. Invention, Imitation and Innovation

The accumulation of a firm's technological capability is a long-term, path-dependent process in which knowledge learning and knowledge creating interact. The path selection of firm's technological capability accumulation has some requirements to the firm's current technological capabilities. The accumulation of technological capability is also a process of capital investment. So, we must consider the firm's financial ability in selecting the paths of accumulation. Table 3 shows the methods and paths that firm should use to accumulate technological capability.

Table3 the path selection of firm's technological capability accumulation

TC / FA / Tech.. change	Strong		weak	
	strong	weak	strong	Weak
encompassing	acquire	Collaboration R&D	acquire	Technology importing
complementary	Internal R&D or acquire	Collaboration R&D	acquire	technology importing
Incremental	Internal R&D	Internal R&D	Collaboration R&D	Technology importing

In table 2, TC = technological capability, FA= financial ability

Case: The Westlake Electronic Company (WEC)

The core product of WEC is TV set. During the process of technological development, WEC accumulate its key competence through technology importing, assimilating, indigenous development and collaborate innovation, see Table 4. This process is typical in Chinese firms .

Table 4 The process of technological competence accumulation in WEC

Core Tech. platform	time	Path of accumulation	technologies
Color TV. set production Tech.	1985-1986	Tech. Importing, internal R&D	21" TV set
Large screen TV. set product Tech.	1987-1990	Internal R&D	25", 29" large screen TV. set
Color monitor production Tech.	1993	Tech. importing	
NICAM digital Tech.	1996	Internal R&D	NICAM TV.
Digital TV. set production Tech.	1995-1997	Internal R&D	Product 3000 digital TV. set
Informational TV. set	1998-	Collaboration R&D	Build digital industrial collaboration

Spiry Process of Technological Capability's building paths

In this paper, we focuses on the interaction and reinforce to each other of internal R&D and external knowledge in the process of technological competence evolution, the model of the two paths' circle action is put forward. In every phase of technological competence, the path of technological competence accumulation transforms from external knowledge assimilation to internal learning, these form three circles from external path to internal path (Figure 5).

The Imitative stage. Through technology acquiring, firms began to come into contact with advanced technologies and methods of management, then walk up mainstream trajectory of technology development. These firms must learn by doing, then they can use importing technologies and methods of management. So after importing technology, firms must assimilate these technologies by internal learning, that is, their route of competence development must switch from exterior to interior.

The creative imitation stage. In previous stage, firms come into being imitative capability, set up foundation for farther innovation. But the assimilation to manufacture technologies and methods can' t lead to directly formation of innovation capability, because these belong to two different levels of technology capability. So, from imitative capability to creative imitation, firms must have a flight of knowledge. It is very difficult for firms to achieve this flight only depending on themselves effort. So in this stage, firms have to start from external route again, it is a crosscut of gaining success. Also, in order to master the R&D knowledge which are gained through interfirms learning (e.g. cooperation R&D and alliance), firms must assimilate these knowledge by learning in the process of internal R&D.

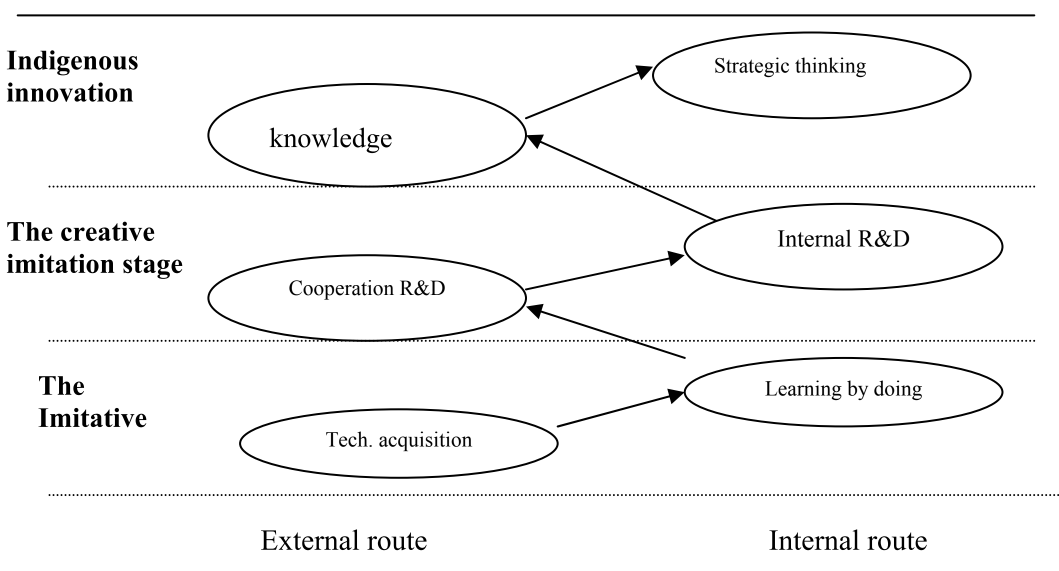

Figure 5 Spiral Process of Technological Capability Accumulation

Indigenous innovation stage. Though indigenous innovation is a form of innovation close to creative imitation, they have substantial difference. At this level capabilities can be described and understood not only in terms of what they do and how they do it, but also in terms of "why," beyond the static efficiency criterion and that dominate the other two learning loops, here we are in the realm of dynamic efficiency. The firms should think from the view of global competitive, the firms must set up broad network of knowledge, assimilate all profound ideas, promote their wisdom further more. Meanwhile, the firms analyze and long for the development trend of industrial and technology, understand market and consumers' demand, and make sure their the positions on technology-market and innovation strategy.

System Dynamic Modeling on Technological Capabilities Accumulation

The accumulation of technological competence is a complex process, there are many factors which affect its evolution and change. Here, we mainly analyze the impact of capital accumulation rate on technological competence process.

The SD model is composed of four subsystems: technological competence subsystem, finance subsystem, market subsystem, and capital distribution subsystem (as shown in figure 1). There are multi-feedback interactions among these subsystems, which determine the interdependence between technological competence and the capital accumulation. In this system, the gap of TC (technological competence) will be figured out first according to its existing technological capabilities and its anticipant technological capabilities, then select the accumulation path of TC according to its financial ability and industrial-technological dynamics.

The devotion to accumulation of TC breeds knowledge learning and knowledge creating, then knowledge learning and knowledge creating enforces technological capabilities, marketing competence and organizational capabilities. Moreover, this improves the effectiveness of accumulation path selection of Tech competence. The accumulation of Tech competence brings two feedback, it affects the accumulation path selection of Tech competence through reducing the gap of Tech competence on the one hand; on the other hand it affects the accumulation path selection of Tech competence through improving the firm's performance and enhancing financial ability.

The policy analysis. Today, capital scarcity is the major problem in most Chinese firms. It's necessary to speed up the capital accumulation. So we mainly analyze the influence of different capital accumulation rate acting on firm development. By this, it is necessary to make estimation on the rate of capital accumulation. We choose the increase rate of sale and technological competence index as analysis quotas. In this SD model, technological competence is defined as the weighted integrated value of four kinds of capabilities, that is: technological assets, technological organization, external technological network, and technological strategy.

From the simulated results of SD model, the Tech competence index is in an obvious increasing trend as the capital accumulation rate varies from 25% to 40%. The higher the rate is, the faster Tech competence leverage. Furthermore, we study the condition that capital accumulation rate varies from 20% to 25%. The simulated results of SD model (as shown in figure 5) indicate that 20~22% is the lowest capital accumulation rate which can ensure Tech. competence increasing. So it's necessary for Chinese firms to keep the capital accumulation rate no lower than 20~22%.

On the other hand, when capital accumulation rate goes up to 35%, firm's Tech competence rise obviously. When capital accumulation rate is 40%, the firm's Tech competence and the increase rate of sale rise obviously (as shown in the figure) before 1997, but after 1997, the increase rate of sale began to decrease and Tech competence almost didn't rise. If we study the change of Tech competence further when the capital accumulation rate falls into the range between 35% and 40%. The simulating result in figure 6 indicates that around the 37% is best capital accumulation rate in this special case.

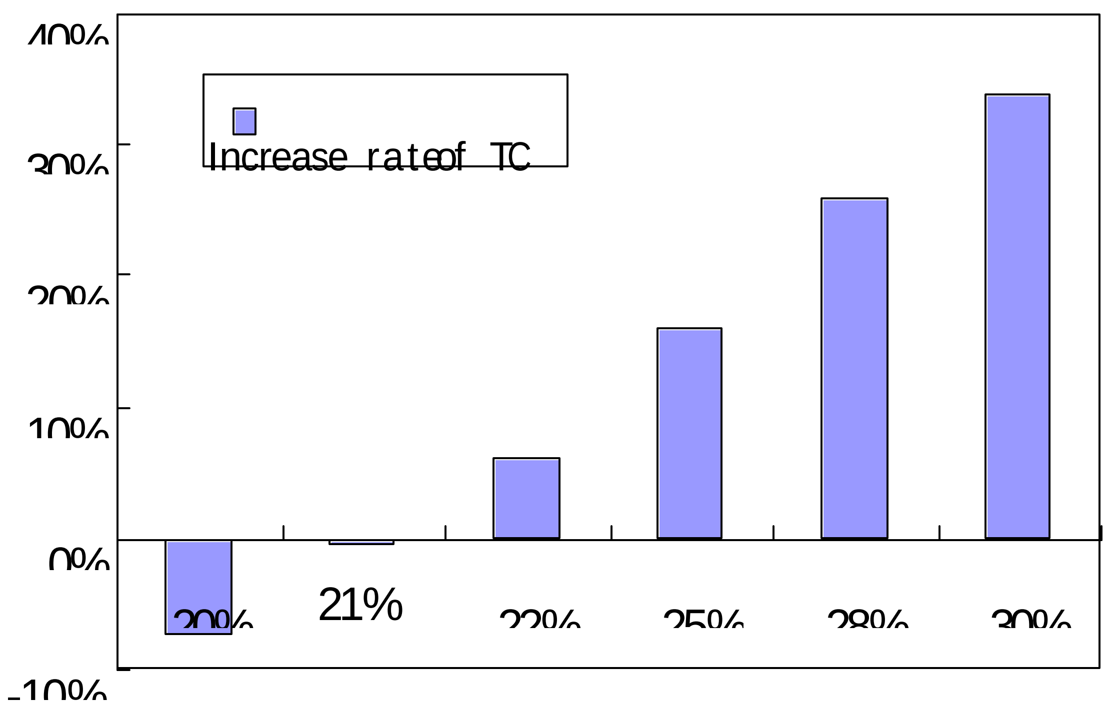

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Figure 5 The breaking point of TC(1)

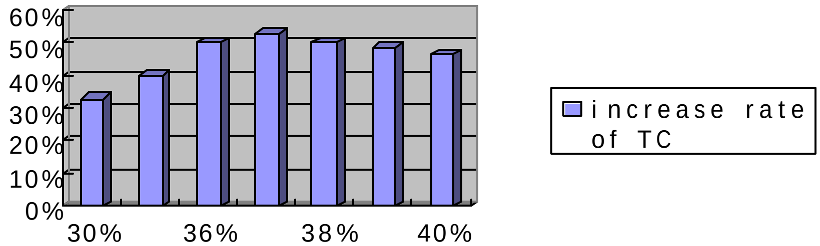

Figure 6 The breaking point of TC(2)

4. Conclusion

For competitiveness and sustainable competitive advantage in the ever fasting market change and technological change, it is essential for top management to change and deepen the ways to manage innovation. This paper advances a new paradigm for innovation management, i.e., competence-based innovation portfolio. There should be a paradigm shift in the technological innovation management from conventional technological management to knowledge. Firms have to distribute R&D capital with right rate of importing and indigenous in order to go to 3I (Imitation- Improvement -innovation model from the vicious circle; They must do themselves capital accumulation, then they have enough capital to support indigenous R&D; The impact of capital accumulation on tech. Competence is the result of interaction of many factors, so it is necessary to use SD simulating and modeling technique in order to find better rate for capital accumulation under variety of contexts.

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