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THEORY OF SCIENCE AND TECHNOLOGY TRANSFER AND APPLICATIONS

SIFENG LIU • ZHIGENG FANG
HONGXING SHI • BENHAI GUO

CRC Press
Taylor & Francis Group
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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business
AN AUERBACH BOOK

Auerbach Publications
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number: 978-1-4200-8741-3 (Hardback)

Library of Congress Cataloging-in-Publication Data

Theory of science and technology transfer and applications / Sifeng Liu ... [et al.].
p. cm. -- (Systems evaluation, prediction, and decision-making series)
Includes bibliographical references and index.
ISBN 978-1-4200-8741-3 (hardcover : alk. paper)
1. Technology transfer--China. 2. Science and state--China. 3. Technology and state--China. I. Liu, Sifeng.

T174.3.T483 2009
338.95106--dc22 2009030789

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Preface

Technology, whose importance to domestic economic development has been widely recognized, has become the main strategy for competition across nations. With the rise in knowledge-based economies and the fast pace of technology development worldwide, there is a growing trend to develop high-end technologies, notably in information technology. Accompanied by economic globalization, the rising trend of globalization in technology enables the rational allocation and flow of the elements of technology without restrictions, allows the sharing of technological activities, and the space flow of technology more frequently. Technology has made a huge impact on economies and societies through technology transfer, which is regarded as an essential step for technology to have a social and a economic value.

Technology transfer has been given considerable importance in China as it is the key for improving core competence and is fundamental for the implementation and transfer of technological innovations to production. However, technology transfer has long been the weak link in establishing a national innovation system and is a great handicap for improving the self-innovation abilities of businesses because of the lack of proper mechanisms, regulations, and policies. To promote knowledge flow and technology transfer, it is important to fully utilize governments, colleges, scientific institutions, and businesses to explore and improve the effective mechanism of technology transfer.

Starting with the concept of technology transfer and its mechanism as the main theme, several issues, such as the measurement, the cost and benefit of technology transfer, the dynamics of the technical diffusion field, optimal allocation of technology transfer, and its game theory, are discussed in this book. Meanwhile, with some empirical studies based on the reality of China's technology transfer, some adventurous attempts and innovations have been made in both theoretical and practical aspects, which reveal the mechanisms, features, effects, and modes of technology transfer. All the studies involved provide constructive suggestions on implementing China's technology transfer in a reasonable way.

The nine chapters of this book are written by the following authors: Chapters 1 and 3 are written by Sifeng Liu, Chapters 4 and 8 by Zhigeng Fang, Chapters 2 and 7 by Hongxing Shi, Chapters 5 and 9 by Benhai Guo, and Chapter 6 by Lizhong Duan.

Jeffrey Forrest, Bingjun Li, Yaoguo Dang, Hecheng Wu, Lirong Jian, Ruilan Wang, Ying Wang, Chuanmin Mi, Jie Wu, Aiqing Ruan, Yanhui Chen, Yingying Ren, Xin Wu, Sandang Guo, Sha Li, Hui Zhou, Hongjiang Yue, Xiaogang Guo, Kun Hu, Chaoqing Yuan, Xiaohua Qin, Hanbin Kuang, Shawei He, Hongyu Hu, Yedong Wang, Qian Chen, Yong Liu, Xiaoyan Qiao, Yaping Li, and Yifan Zhang have taken part in related studies. Professor Sifeng Liu took charge of the draft summarization and final approval.

The research referred to in this book was supported by the National Natural Science Foundation of China; the Social Science Foundation of China, Jiangsu Province; the Soft Science Foundation of China, Jiangsu Province; Postdoctoral Programs Foundation of China, Jiangsu Province; Doctoral Programs Foundation of the Chinese National Educational Ministry; the Social Science Foundation of the Chinese National Educational Ministry; the Research Foundation for Excellent and Creative Teamwork in Science and Technology in Higher Institutions and distinguished professors of Jiangsu Province; and the Foundation for the Master's and Doctoral Programs in the Eleventh Five-Year Plan of Nanjing University of Aeronautics and Astronautics.

Any errors or omissions that may be pointed out by readers and experts in this field will be appreciated.

Acknowledgments

The research described in the book was supported by the National Natural Science Foundation of China (No. 70473037 and No. 70701017); the Key Project of Philosophic and Social Sciences of China (No. 08AJY024); the Key Project of Soft Science Foundation of China (2008GXS5D115); the Foundation for Doctoral Programs (200802870020); the Foundation for Humanities and Social Sciences of the Chinese National Ministry of Education (No. JA630039); the Key Project of the Soft Science Foundation of Jiangsu Province (No. BR2008081); and the Foundation for Humanities and Social Sciences of Jiangsu Province (No. 07EYA017). The authors would also like to acknowledge the partial support of the Science Fund for the Distinguished Professor of Nanjing University of Aeronautics and Astronautics (NUAA) and Jiangsu Province (No. 1009-316011), and the Science Fund for the Excellent and Creative Group in Science and Technology of NUAA and Jiangsu Province (No. Y0553-091). In the writing of this book, the authors consulted widely, referred to the research by many scholars, and were helped greatly by professor Jeffrey Forrest. We wish to thank them all.

Abstract

Starting with the concept of technology transfer and its mechanism as the main theme, several topics, such as the measurement, the cost and benefit of technology transfer, the dynamics of the technical diffusion field, the optimal allocation of technology transfer, and its game theory, are discussed in this book. Although there are some empirical studies based technology transfer in China, some innovations have been made in both theoretical and practical aspects, which reveal the mechanisms, features, effects, and modes of technology transfer. All of these studies provide constructive suggestions on implementing China's technology transfer in a reasonable way.

This book can be used as a textbook for postgraduates or senior undergraduate students specializing in economics and management and as a reference book for those who are involved in management, scientific research, and engineering technology.

Authors

Sifeng Liu received his bachelor's degree in mathematics from Henan University, Kaifeng, Henan, China, in 1981, his MS in economics, and his PhD in systems engineering from the Huazhong University of Science and Technology, Wuhan, Hubei, China, in 1986 and 1998, respectively. He has been to Slippery Rock University in Slippery Rock, Pennsylvania and Sydney University in Sydney, New South Wales, Australia as a visiting professor. At present, Professor Liu is the director of the Institute for Grey Systems Studies and the dean of the College of Economics and Management of Nanjing University of Aeronautics and Astronautics (NUAA); he is also a distinguished professor and guide for doctoral students in management science and systems engineering disciplines.

Dr. Liu's main research activities are in grey systems theory and regional technical innovation management. He has directed more than 50 projects at the national, provincial, and ministerial levels, has participated in international colloboration projects, and has published over 200 research papers and 16 books. Over the years, he has been awarded 18 provincial and national prizes for his outstanding achievements in scientific research and applications, has been appointed as a distinguished professor, and is a scholar and an expert who has made outstanding contributions. In 2002, Dr. Liu was recognized by the World Organization of Systems and Cybernetics.

Dr. Liu is a member of the committee of teachers of management science and engineering of the Ministry of Education, China. He also serves as an expert on soft science at the Ministry of Science and Technology, China, and at the Department of Management Science, National Natural Science Foundation of China (NSFC). Professor Liu currently serves as the chair of the Technical Committee (TC) of the IEEE SMC on Grey Systems; the president of the Grey Systems Society of China (GSSC); a vice president of the Chinese Society for Optimization, Overall Planning and Economic Mathematics (CSOOPEM); a vice president of the Beijing Chapter of the IEEE SMC; a vice president of the Econometrics and Management Science Society of Jiangsu Province (EMSSJS); and a vice president of the Systems Engineering Society of Jiangsu Province (SESJS). He serves

as a member of the editorial board of over 10 professional journals, including *The Journal of Grey System* (Buckinghamshire, United Kingdom); *Scientific Inquiry* (Slippery Rock, Pennyslvania); *Journal of Grey System* (Taiwan, China); *Chinese Journal of Management Science*; *Systems Theory and Applications*; *Systems Science and Comprehensive Studies in Agriculture*; and the *Journal of Nanjing University of Aeronautics and Astronautics*.

Dr. Liu has won several accolades such as the "National Excellent Teacher" in 1995, "Excellent Expert of Henan Province" in 1998, "Excellent Science and Technology Staff in Jiangsu Province" in 2002, "Expert Enjoying Government's Special Allowance" in 2000, "National Expert with Prominent Contribution" in 1998, "National Advanced Individual for Returnee" and "Achievement Award for Returnee" in 2003, and "Outstanding Managerial Personnel of China" in 2005.

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Lizhong Duan received his doctorate in management science and engineering from Tianjin University in 2001. He was engaged in postdoctoral research in systems engineering at the Nanjing University of Aeronautics and Astronautics from 2001 to 2003. He is now an associate professor at the School of Management, Beijing University of Chinese Medicine. Dr. Duan is a member of the standing committee of the Grey System Society of China and the Chinese Society of Optimization, Overall Planning and Economical Mathematics. His main research interests include technological diffusion and technological innovation management, and the application of grey system theory in medical diagnosis and management. He has published two books and more than 20 papers.

Chapter 1

Summary of Technology Transfer

1.1 Definition of Technology Transfer

1.1.1 Basic Meaning of Technology

People's understanding of technology is diverse; the definitions of technology are varied too.

The original meaning of technology was proficiency. In the proverb "Practice makes perfect," "perfect" meant technology. Now, it is understood that technology is a process or a process system. Diderot, a distinguished enlightened thinker, materialist philosopher, and education theorist in France in the eighteenth century, gave a concise definition of technology in the *Encyclopedia*: "The technology is varieties of tools and rules system that is collaborated for a common purpose." Some scholars also define technology on the basis of its purposes, components and functions, such as Gaynor (1996) who pointed out that technology can be described in different ways: first, that technology is the realization of resources into products or services; second, that technology includes knowledge and resources, which can help to reach established goals; third, that technology is an entity of science and engineering, which can be used in production processes and product designs, and also in the exploration to gain new knowledge. Li Ping (1999) considers technology as an effective means used by people to engage in various economic activities in spite of scarce resources, and the extension of technology includes products, processes, human resource, and organizations. Huang Jingbo (2005) holds that technology is a combination of knowledge, methods, skills, and special know-how that is used by humans in understanding and utilizing nature.

In essence, technology is a kind of systematic expertise associated with production processes of goods and services, and is a combination of the means, methods and skills created and developed by humans, to realize the needs of society. In terms of social productivity, the overall technical forces include technical skills, work experience, information knowledge, and equipments of solid tools, namely technical personnel, technical equipment, and technical information in the whole society. The other characteristics of technology include purpose, sociality, and pluralism.

Any new technology arises for a purpose, and the purpose of that technology runs through the entire process of technical activities. Hence, modern technology has strong utility and commercial features. The sociality of technology requires collaboration with the community and social support; it is also subject to a variety of social conditions. These social factors directly affect the success of technology and the development process. The pluralism of technology ensures that it can be expressed not only as tools for tangible equipment, machinery, entity material, and other hardware; but also as processes, methods, rules, and other knowledge software, as well as information and design drawings that are not material entities in themselves but material carriers of other manifestations.

1.1.2 Establishment and Evolution in the Definition of Technology

The descriptions of technology transfer can be summarized as follows:

Technology transfer is the flow of technology and is an important means of technology development.

Technology transfer is the transfer, proliferation, promotion, and transplantation of technical achievements in different countries, regions, sectors, industries, or enterprises.

Technology transfer is the flow of technology in different sectors, regions, and enterprises. Through technology transfer, technology combines with production processes to form new combinations and systems of technology. As a result productivity is enhanced, and economic benefit is improved continuously.

Technology transfer refers to organized delivery activities between supply and demand. In the process of technology transfer, the two sides are mutually constrained and interrelated. As a dynamic process, the realization of technology transfer is the result of the joint efforts of both supply and demand.

Technology transfer refers to the transfer of technology from production to application, making full use of the technology and realizing its value. Technology transfer includes the combination, transplantation, transmission, communication, and popularity of technology.

The international community discussed the issue of technology transfer for the first time in the first session of the United Nations Conference on Trade and Development in 1964. The meeting defined the input and output of technologies among countries as technology transfer. It is important to understand that technology

transfer is not the physical transfer from point A to point B. It is also necessary to ascertain the systematization and complexity of transfer activities to make the connotation of technology transfer clear. As understood universally, technology transfer can be expressed as a certain type of technology-based diffusion process, which represents a certain technical level of knowledge. The United Nations' definition, in "International technology transfer in the draft code of conduct," refers to it as the transfer of system knowledge on the manufacture of a product, producing methods or providing service, but does not include the sale of goods or simply rent. Two representative views are more enlightening: the first is the definition made by Rose Bloom of Harvard University. In his view, technology is acquired, developed, and utilized through a path which is entirely different from its origin, and this process of technical change is technology transfer. The definition stresses the point that we must emphasize the adaptability of technology and environment in this shift, and not simply the move from one place to another. The other view was put forward by the American scholar Sipei, S.A. Based on the organized thought of human behavior promoted by anthropologist Harrington, technology transfer is organized work to achieve the goal and to make the necessary technical information move reasonably. He limits it to the planned and rational flow between the government and enterprises, and emphasizes its orderliness and regulations.

In the late 1970s, the concept of technology transfer came to China. The time that the Chinese were introduced to this theory can be traced back to as early as 1978. Tang Yunbin (1978) quoted the definition made by H. Brooks of Harvard University. Brooks holds technology transfer is knowledge developed in a certain group or agency, but this kind of knowledge is realized in matters of other groups or agencies. There are two types of transfers in his opinion; one is vertical transfer, which refers to knowledge transferred from general and common areas to more specialized fields, often from the basic new scientific knowledge to the field of application technology, namely the broader technology transfer. The other one is horizontal transfer, it refers to technology transfer from one application to another application, in the narrow sense of technology transfer. This horizontal transfer is divided into three categories: the first is achieved through trade, namely buyers introduce advanced technology through the purchase of advanced products.The second is the pure or original meaning of technology transfer, which is the technical trade of licensing trading. The buyers introduce technology to self-production, using the technology itself for trading. This is the so-called turnkey package deal. The contents of transfer include production technology and the corresponding equipment, plant, as well as staff training, and production preparation.

In 1982, the *Outlook* magazine no. 8 published an article "What is technology transfer?" to explain the term. In the interpretation, technology transfer was defined as the transfer of the results of science and technology, information, the transfer of ability, transplantation, import, promotion and popularization, and so on. For example, industrial production will put raw materials, technology, equipment, products, drawings, technical programs, design, as well as some theoretical research

results and ideas for exchange in areas, or departments. Scientific technology transfer can happen in many forms. There are two general types and five channels. Of the so-called two types, one is inner transfer, and the other is transfer to production applications. The five channels are from the laboratory to production (including basic research, applied research, application of research and development to production), from military to civilian application, from the advanced region, sector, or industry to backward regions, sectors, industries, from the urban to rural areas, from domestic to foreign countries.

From the 1980s, many Chinese scholars began to study the issue of technology transfer. The most representative of their work is the gradient theory of technology transfer promoted by Yulong Xia and Zhongxiu He. In March 1982, Yulong Xia of Shanghai Institute of Science published an article named "Gradient theory and regional economics" in the magazine *Research and Suggestion* and promoted "gradient theory." In the same year, Zhongxiu He of the Tianjin Science and Technology Commission submitted a paper "On the gradient transmit of technology" at the World Assembly of Sociology. It was the first time that the "Domestic technology transfer to promote the law of gradient" was promoted. They pointed out that there is a natural gradient distribution in the economic and technical development in China—coastal, central, and remote areas—due to the economic and social imbalance. The mainland and a number of remote areas are rich in resources. But owing to historical reasons, insufficient funds, and slow development, technological development is poor, resulting in quite a few areas still in the traditional and backward economy. The central region is in the middle level whereas the coastal areas are equipped with "advanced technology"; the strength of their economy is obvious. Domestic technology should be adopted by the technical services, the transfer of outcome, compensation trade, joint ventures, and joint companies to achieve the transfer gradient of technology, namely, transferring "advanced technology" to "intermediate" and "traditional" technology. Later, the theory of evolution became the guiding ideology of China's macroregional development. Some academics have suggested a gradient transfer theory with a different view. Yuan Gangming (1997) pointed out that China's western region can introduce and develop advanced technology on their own and do not have to accept the technology delivered by the main coastal areas. In the western region, there have been a large number of successful cases of introducing and developing advanced technology to go beyond gradient sequencing and get faster development. The gradient policy favors the developed regions and delays the development of underdeveloped areas, which will only increase regional disparity. Kai Liang and Lianshui Li (2005) put forward the counter-gradient theory and pointed out that less developed areas should develop in leaps and bounds, taking advantage of the income tax preferential policies extended to technology transfer in the Chinese Corporate sector to assess the effect of analysis using cost–profit analysis, charts and draws analysis, and other methods.

In the late 1990s, the academic community reached a consensus: the time and space spread of technology was defined as technology diffusion, the transfer from

the laboratory to the production unit was referred to as technology transformation, technology owners granted the right of application to other people; all of which is collectively referred to, in the broad sense, as technology transfer. This book is in favor of such a consensus.

The connotation of technology transfer is still in the development stage while the study of technology transfer theory has been developed further. With worldwide competition in science and technology, technology transfer research has a wide range of areas for research and an equally wide scope for increase in the content.

1.1.3 Discriminate Correlative Definition of Technology Transfer

1.1.3.1 Technology Innovation

The concept of technology innovation was firstly proposed by economist, Joseph Schumpeter. Schumpeter used the word "innovation" for the first time in his book *Theory of Economic Development* (German), which was published in 1911 followed by an English edition in 1934. The book reads: Innovation is the economic system, which took place in a serious deviation from equilibrium. It cannot make a new equilibrium in the balance on the basis of the old through the gradual adjustment to achieve. In 1928, Schumpeter published a new article "Instability of capitalism" in the *Journal of Economics*, which discussed innovation for the first time. In his view, innovation is a productive resource for innovative applications, with nongradual characteristics; innovation needs a large amount of venture capital before benefits can be reaped, the resistance to success stems from the unprecedented and uncertain nature of the innovative activities. In 1939, Schumpeter systematically described the theory of innovation in his book *Business Cycle*, where innovation is described as the introduction of a new economic system in the production function. It is mainly generated by the role of entrepreneurs. Innovation can be divided into technology innovation and nontechnology innovation. An important characteristic of his innovation theory is that he looks at it as the reason that capitalist society appeared a significantly nonbalanced economic cycle. In 1951, Solomon wrote an article titled "Capitalism in the process of innovation—on the theory of Schumpeter" in the *Economics Quarterly*. Solomon thought the significance of technology innovation is that it is a major source of economic change consisting of two parts—conceptualization and development work. It laid the foundation for the definition of future technology innovation. In 1953, anthropologist H.G. Barnett wrote a book *Innovation—The Basis of Cultural Change*. In his book, he analyzed innovation in sociology and psychology, and proposed that innovation is essentially systematic attention to the process, with special emphasis on the innovation of a process with a nonprogressive nature. In 1954, W.R. Maclaurim published the article "Invention and innovation to the order and its relationship with economic growth" in the *Economics Quarterly*. In his opinion, innovation emerges when invention is introduced into commercial applications in the form of a new or improved product or process. Moreover, he pointed out that invention and innovation are both completed at different stages

by ordinary individuals or institutions, indicating that invention and innovation overlap between these two stages, but they have different characteristics. In 1962, J.L. Enos gave a complete definition of technology innovation for the first time in the "Oil-refining industry of invention and innovation," pointing out that innovation is the successful outcome of a series of activities, which include the search for innovation, the implementation of the funding, the establishment of organizations, employment of workers, the development of the market, etc. In 1963, a corporation named Arthur. D. Little separated the concepts of invention, innovation, and diffusion in an article titled "American industrial technology and innovative form and issue" for the United States National Science Foundation. In their opinion, technology is taking the lead in developing and refining inventions of practical value on the product or process ideas. Technology innovation is the invention for a commercial application. The proliferation of technology innovation is widespread. In 1974, C. Freeman in his book on "Economics of industrial innovation," defined technology innovation as new products, new processes, and new systems or the beginning of a new device from the laboratory to its commercial success in application and the whole of the activity process. In 1977, E. Mansfield published his book *New Industrial Technology in Production and Application*, in which he pointed out that innovation is the whole process of development of a new product from the time of the exploratory work until the new product is available for sale. At this point, the basic concept of technology innovation got a commitment, and formed a relatively consistent. In 1985, R. Moss of the Bell Labs Moss in the United States gave a "definition of technology innovation," published in *Project Management Journal*, pointing out that in their collection of about 350 articles on technology innovation literature, 75 percent showed striking consistency. This is now the definition of technology innovation—the process beginning from the idea of a new concept to the success in a meaningful way of the practical application of the idea for nontechnical phenomenon. Economists generally believe that productivity growth and a corresponding increase in the per capita income depends on the continuous process of technical change. This process, to a large extent, is reflected in the success of the new infrastructure development, production, and distribution. Wang Yingluo and Jia Liqun summed up all the past versions and defined technology innovation as follows: it includes new products, materials, technology, or other systems based on the direct use of natural and technical knowledge, as well as the application, development, design, drafting of the product specification, manufacturing production prototype, and preproduction processes.

1.1.3.2 Technology Diffusion

Technology diffusion is a topic widely explored by economists, and is closely linked with technology transfer, technology spillover, and many other related concepts. Technology diffusion is the simply the description of the movement of technology from one place to another, or from one user to another. In general, a technological innovation is limited in its economic and social impact on productivity improvement,