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INVENTIONS AND INNOVATIONS – KEY ELEMENTS IN THE STRIVE
FOR COMPETITIVE ADVANTAGE

THE ROLE OF UNIVERSITIES IN THE STATE INNOVATION SYSTEM

*Document prepared by Mr. Li Wei, Vice-President, Xi'an Jiaotong University of China,
Shangxi Province*

I. INTRODUCTION

1. The “Innovation Theory” was first put forward by the American economist Joseph Schumpeter in 1912. The significance of innovation in economic activity was widely recognized in the following 70 years. Since the 1970s Silicon Valley, Tsukuba and Hsin Chu have been showcases for innovations that have powerfully driven national, regional and world economic development. Innovation capability is generally taken as an important indicator of development sustainability and economic vitality at both the national and the regional level.

2. In recent decades we have gained a more in-depth and extensive understanding of innovations. It is now generally accepted that the term covers not only technological innovations but also innovations in laws, regulations, rules and systems.

3. At the national level, the establishment of a State innovation system, for which no clear definitions have yet emerged, is an integral part of the efforts to improve national competitiveness. We believe that a State innovation system is a network of people and institutions engaging in innovative activity with the interaction between them helping us to apply knowledge in economic activity and translate science and technology into productivity in such a way as to improve comprehensive national strengths and international competitiveness.

4. A State innovation system consists of three parts: a knowledge innovation system, a technology innovation system and an institutional innovation system. The main functions of the knowledge innovation system are generating, disseminating and transferring knowledge, those of the technology innovation system creating, upgrading, learning and disseminating new technology, and those of the institutional innovation system carrying out institutional reforms and formulating new policies so that the first two systems can run smoothly and innovation resources can be allocated so as to promote sustained economic development. In other words, institutional innovation refers to the establishment of a guiding mechanism for encouraging innovation activity. In a State innovation system, knowledge innovation is the basis and technological innovation the purpose, while institutional innovation links and guides knowledge and technological innovation.

II. THE IMPACT OF INNOVATION ON THE WORLD ECONOMY

5. Innovation is a great driver of world economic development, since:

(a) Scientific and technological innovations constitute powerful internal engines powering world economic successes

6. *First, scientific and technological innovation can drive the technological upgrading of traditional industries, which will greatly improve labor productivity.* Seeing the rapid development of electronic technology, traditional industries are planning, one after another, to reform their backward manufacturing techniques by using it. For example, computer-aided design and manufacturing is widely applied in the automobile industry to improve automatic control and information feedback by means of electronic components.

7. *Second, hi-tech revolutions and technological innovations are causing high-tech and new-technology industries such as information, biology and new materials to grow continuously and become the new driving force of world economic development.* Based on

the statistics of the US Department of Commerce and the American Electronics Association, the information industry created 15 million employment opportunities for the United States between 1993 and 1998. Hi-tech and new technology are generating the largest numbers of jobs for America, and the sales and exports in that sector also rank first in the country. A quarter to a third of US economic growth in US is attributed to information technology and only four per cent to the automobile industry. The information industry has become the new engine of the US economy, replacing in that role traditional industries such as the automobile and petrochemical industries and architecture.

8. *Third, innovations create new jobs and ensure sustained economic development.* The new technology reform has triggered an employment reform, leading to changes in the traditional labor market and rapid growth in the tertiary industry. Since the 1990s, the labor force drawn into the information industry has grown at an average annual rate of 9.5 per cent and 12.2 per cent in the last three years. Newly-emerging industries and the IT-backed service sector have provided us with a great number of employment opportunities.

(b) Institutional innovations effectively guarantee the sustained development of the world economy

9. The development and application of information technology enables businesses to increase their operational efficiency and lower their costs by a large margin, and moreover promotes institutional innovation. Businesses are gaining momentum in institutional innovation and reforming their organizational structure and management as follows:

First, innovations in corporate structure and systems, with redesign of business processes. Turning away from traditional business organization theories, many companies are redesigning the most fundamental part of themselves, namely their management structure and operational processes. As a result, they have greatly improved their performance in terms of cost, quality, service and efficiency, and also their flexibility and core competitiveness.

Second, wide application of corporate ecology theories in institutional innovation. The idea that customers, suppliers, leading manufacturers, labor unions, government institutions and semi-governmental organizations constitute a corporate ecology has led to the emergence of an ecological organizational setup which is gradually replacing the traditional organization models and fundamentally changing management models. A corporate ecology integrates all the functions in business development and pays equal attention to the interests of all business ecologies at different stages of growth for an “everybody-wins” result.

(c) Marketing innovation is the external motivator of the successes of the innovation economy

10. Economic globalization has accelerated marketing innovation activities. Since the 1980s countries all over the world have benefited greatly from having their national competitive strengths leveraged by regional economic development under the global trading system. The economic growth in South-East Asia and the US economic recovery are two good examples. In the early 1990s economic recession and increasing trade deficits gave rise to trade protectionism in the US. By promoting the export of hi-tech and new-technology products with high added value, the US Government successfully expanded surplus production into the overseas market and created jobs for tens of thousands of Americans, bringing its unemployment rate down to its lowest level in 24 years. At the same time the huge imports of cheap commodities and raw materials from developing countries held the

price index down and kept inflation under control. In fact, global trade became an important driving force in US economic growth.

11. The success of an innovation economy like that of the United States of America represents the triumph of a knowledge economy over a traditional industrial economy. To maintain its great growth momentum and improve its comprehensive national strengths, China must emphasize the fundamental role of science and technology and focus on innovations as it seizes the opportunities and faces the challenges of this era of knowledge economy. With hi-tech development leading the way, we need to apply hi-tech and new technology to the reform of traditional industries, increase the technological content of traditional industries, upgrade industrial structures and product mixes and improve the efficiency and profitability of traditional industries for the sake of the all-round development of the national economy. In the meantime, we should step up institutional innovation and management innovation so as to provide economic development with institutional guarantees and support. We can improve the competitiveness of businesses and our country fundamentally by shifting from “single innovation” to “sustained innovation” from “innovation in individual products” to “innovation in product families” and from “innovation by individual experts” to “innovation by all.”

III. THE ROLE OF UNIVERSITIES IN THE STATE INNOVATION SYSTEM

12. The leading role played by universities in the State innovation system can be attributed to their resources and their strategic position.

13. Universities have rich resources. The 738 universities in China have 5,059 research institutes and 101 State key labs (two-thirds of all the State key labs in China). There are 53 State engineering research centers subordinated to the universities directly under the Ministry of Education, and these research facilities cost about 15.47 billion yuan. The universities have rich intellectual resources, a huge wealth of knowledge, great research capacity and excellent human resources. With 600,000 researchers and a large number of recruits with a master’s or doctor’s degree each year, the universities have an adequate supply of innovative and bold researchers unconstrained by conventional theories, who constitute the main force in both basic and applied research. The universities have the whole spectrum of academic disciplines, and lively interaction between them can generate new ideas and facilitate research and innovation. In addition, they have rich information resources from extensive communications with academic circles outside China, which enable their researchers to keep close watch on the latest developments in leading-edge innovation. The universities are thus in a very good position to participate in State innovation initiatives.

14. Universities are the major players in the knowledge innovation system. The major functions of a knowledge innovation system are producing, disseminating and transferring knowledge. It plays the role of disseminating and transferring the new findings, new laws and new theories from our basic and applied research on nature to the technological innovation system, where they are needed for the generation of new products, new techniques and new industries. The knowledge innovation system of the universities consists of experts and professors engaging in basic and applied research in the relevant academic research institutes. The knowledge innovation system focuses on key discipline, based on work in key labs and key research bases. Its major tasks are as follows: various research-fund projects, including the State Natural Sciences Fund and basic research projects in which the researchers can

choose whatever topics they are interested in. The knowledge innovation system follows the directions determined by State objectives.

15. Universities are among the major players in the technological innovation system. The major functions of the technological innovation system are creating, upgrading, learning and disseminating new technology. It plays the role of initiating hi-tech research and development on the basis of the universities' knowledge innovation strengths, so that research achievements may be translated into productivity and so that China's comprehensive national strengths and international competitiveness may be enhanced. The technological innovation system of the universities consists of experts and professors engaging in technological research and product development as well as R&D centers, sci-tech businesses and consulting institutions. The system is based on the work done by R&D institutions, engineering research centers, technology development and transfer centers, labs, hi-tech businesses and various institutions that combine the functions of production and research. The major tasks of the system include various key research projects, new product development plans, industry development projects and achievement replication plans. Based on the operational model of the market economy, it aims at economic rejuvenation.

16. The institutional innovation system of universities is the product of the State institutional innovation system. The major functions of an institutional innovation system are carrying out institutional reforms and formulating new policies so that the knowledge innovation and the technological innovation systems can run efficiently and allocate innovation resources in an appropriate and optimum manner in order to promote sustained economic development. In the institutional innovation system of the universities, the major players are the research institutions, the faculties, the businesses and related administrative bodies. The functions of the system include initiating innovations, through reform, in mechanisms and institutions in terms of human resources development, institutionalization, risk management and machinery and stimulation systems so that it can link and guide the other two innovation systems. So institutional innovation in the universities is an important part of the State innovation system, and one on which the success system relies.

17. The growth of the knowledge economy has ushered us into a brand new stage in our history and brought about one revolution after another in natural sciences, leading to unprecedented levels of commercialized and industrialized hi-techs and new technology. The development of the knowledge economy also initiated economic and technological globalization, which causes greater interdependence and more intensive competition between countries. Our *21st Century Plan for Vitalizing Education* clearly states that universities shall bring their advantages into full play in the State innovation projects, actively promote knowledge innovation and technological innovation, speed up technology development, engage in research projects on key technology required by economic development and make their due contributions to the reform of traditional industries, industrial restructuring, agricultural development and the search for new growth points. Teaching and research will not be the only responsibilities for a university. Instead of merely teaching and researching, universities will integrate the two with the application of knowledge. By training the innovative spirit of students, generating new ideas and new knowledge, initiating technological innovations, reproducing labor and knowledge and increasing the added value of human resources, universities have become an important factor of productivity and production relationships, constituting the main force in the State innovation system and our efforts in rejuvenating China through scientific research and education. Being fundamental to economic and social development, universities play the dominant role in the State innovation system and an irreplaceable role in driving social and economic development.

18. Universities are incubators of innovative human resources. Innovative human resources will be a decisive factor in the competitiveness levels of countries and sectors. The development of innovative human resources is a strategic task of vital importance to our sustained economic development and competitiveness in the knowledge economy era. President Jiang Zemin once pointed out that “in order to catch up with the latest developments in science and technology, we must accelerate knowledge innovation and the industrialization of hi-techs and new technology by all means, and the key factor in innovation is human resources.” Development of a knowledge economy requires higher levels of scientific and technological capability. Today we need a large number of high-level innovative professionals with extensive knowledge, who are expert in one thing and good at many others, in our efforts to promote sustained development of science and technology and the continuous progress of our society, aiming at harmony between mankind and nature. The chief responsibility of universities, the main force in our efforts to rejuvenating China through scientific research and education, is to develop highly-qualified innovative human resources.

19. What is the definition of innovative human resources? We believe that innovative human resources refer to people who can innovate on account of their strong desire to break new ground, their original way of thinking and their great innovative skills. In the knowledge economy era, the ways of working and living are becoming increasingly humanistic. More importantly, the relationship between man and nature will be based on common prosperity and harmonious development, and human beings would be able to improve their minds in all aspects as they wish. Thus, universities in China should emphasize humanism in human resources development, focusing on fundamental qualifications such as extensive knowledge, comprehensive and solid basic skills, innovative thought processes and great innovative capacity. At the same time, good morale, ambitions and interests, a strong will, devotion to work, a sense of duty and the ability to improve oneself and exploit intellectual potential are also essential prerequisites of human resources development. In addition, high-level innovative professionals should be able to think differently, and to do so intuitively and comprehensively. They should possess a strong interest in the unknown, an intense desire to reveal the nature of things and essential laws, great imagination and keen, original thinking in exploring the implications and evolution of things, a willingness to devote themselves to work and face up to challenges, a critical spirit and persistence.

20. Based on the above requirements, we should develop human resources that focus on the following:

(a) Encouraging the desire to innovate. People with the desire to innovate are willing to innovate and they value innovation. Only when there is a strong desire to innovate will people feel a strong urge to innovate, fully tap their innovative potential and their intellect and set up goals for innovation. We need to remove all the restraints in students’ minds and change their mental inertia so as to create an environment favorable to their growth;

(b) Encouraging innovative thought. Innovative thought includes the ability to think differently, keen observation, creative thinking, unique knowledge structure and vigorous inspiration. In developing students’ innovative ability, we need to focus on training a form of lateral thinking and dialectical, critical reflection in order to encourage students to think from different angles in solving problems so that they may be freed from convergent thought patterns and allowed to innovate boldly;

(c) Encouraging the training of innovative skills. Students' ability to engage in comprehensive analysis of information, practical work and scientific research should be improved;

(d) Encouraging innovative spirit. Students' innovative mentality should be enhanced, their curiosity stimulated and their acceptance innovation developed.

21. The approach adopted by Xi'an University of Transportation is to establish a human resources development model featuring a harmonious "knowledge – ability – personality" relationship. Here knowledge means the basic and leading-edge know-how of each discipline as well as knowledge in humanism, nature, society and art. Ability refers to analytical and practicing capabilities, the former meaning the logical and intuitive intellectual ability to analyze, summarize, judge and discriminate and the latter including the ability to engage in practical work, to experiment and to handle interpersonal relationships, organize and coordinate as well as professional skills. Personality building focuses on students' ideas, morality, ideals and sentiments, and emphasizes the fundamental qualifications of independence, innovation, devotion and perseverance. Our specific measures include the reform of teaching content and curriculum through a deepening of teaching reform, a readjustment of curricula and the optimization of training programs. Ten trial teaching centers for basic courses were set up. We are actively engaged in research on human resources training and its reform, using a variety of qualifications and abilities. In 1992 we started minor courses in an organized manner and adopted the "major plus minor" system, encouraging students to enrol in minor courses. We are also cooperating with businesses to set up student research teams for work on specific problems in real production. We have set aside student innovation funds to encourage inventive and innovative ventures. We have in addition set up a variety of student clubs to increase their independence and their interaction, both among themselves and with the outside world. In short, we have done our utmost to offer a favorable, free and competitive campus environment to our students so that they can acquire a variety of abilities and skills and the innovative thinking in the new era.

22. Universities are sources of ideological and knowledge innovation. As our economic and political reforms deepen, the ideas of "university autonomy," "academic freedom" and "combined teaching and research" are gradually accepted and international exchanges in the field of social science increase as universities play an increasingly important role in our society. While developing human resources and engaging in scientific research, universities also play the role of a "brain bank," involved in social reform, offering advice in science and technology and promoting social progress. In addition they assume the important responsibility of providing society with innovative ideas and knowledge. They do after all have the following advantages:

(a) Concentration of high-quality human resources. Universities have gurus, experts and scholars with great academic accomplishments as well as a whole range of human resources among bachelors, masters, doctors to post-doctorates. Every year, a flow of energetic young people committed to the exploration of truth will come to replenish the pool of intellect at universities. They have active minds, quick responses and the courage to challenge authority. In a free environment of academic autonomy these young men, unrestrained by conventional thinking, could easily generate new theories, new methodologies and new technology. They constitute a vital new force in ideological innovation and knowledge innovation;

(b) The leading edge of research and knowledge integration. In universities, there are a number of academic leaders with broad vision and profound theoretical knowledge. They work hard in their specialties, continuously acquire new knowledge and propose new ideas in an attempt to take or maintain the lead in academic research. There is a whole range of disciplines in universities, which can easily interact and integrate. So universities are very well-placed to develop borderline disciplines and newly-emerging disciplines and to initiate knowledge innovation;

(c) Rich sources of information. Statistics show that in a research project, researchers often spend one-third or even more of their time searching for information. An advanced information system greatly improves the efficiency and quality of scientific research. University libraries are better than local ones in terms of size, standard and management. A number of talented people devoted to library science and library management can make efficient services available to scientific research. University libraries also have larger and more diversified collections of books and academic journals than the libraries of governmental research institutions, and they have started to put their collections and information on computer networks. Gradually, libraries will be networked on a regional or national, even a global basis. Moreover, universities are involved in extensive international exchanges, keeping themselves well informed of new ideas, methodology, technology and experience;

(d) Free academic environment. A good academic environment is favorable to human resources development and scientific research and allows a hundred schools of thought to interact. In addition, it helps academic communities to communicate, cooperate and network in a more coherent way. Renowned universities like Xi'an University of Transportation have a profound historical and cultural background and combine human resources development with scientific research, while a good academic environment encourages inspirational thinking, active minds and innovation and helps generate innovative thinking, attitudes and achievements. Whitehead made an incisive observation on the special role played by universities in ideological and knowledge innovation when he said that universities are there not to impart knowledge to students or offer research opportunities to teachers, but to bring young people and senior experts and professors together in an effort to probe knowledge imaginatively in such a way as to translate the stimulating atmosphere generated by such active imaginations into knowledge. In such an atmosphere, a fact is no longer just a fact but is endowed with inexpressible potential.

23. Universities therefore provide a favorable environment for knowledge and ideological innovation in terms of material resources, human resources and also environment. They play the role of intellect bank in State decision-making processes. A most typical example of this is the nationwide discussions in 1978 on the criteria of truth which were triggered by an article entitled *Practice is the Only Criterion of Truth*, written by Hu Fuming of the Department of Philosophy of Nanjing University. The historical research that followed the discussions helped liberate people's minds and promote social progress. Currently, some research institutes attached to universities have become ideological sources for governments at all levels, and also for businesses, in their economic and political decision-making. They are duty-bound to help businesses and society at large to innovate and become the radiant point for new ideas and new knowledge.

24. In research and development, universities are driving the growth of social productivity. Social progress has led to changes in the functions of universities, which have evolved from knowledge teaching alone, via knowledge teaching and generation to today's harmonious

integration of knowledge teaching, generation and application. Technological innovation and application has become an important function for universities. It is our eventual goal to fulfil the knowledge innovation, dissemination and application functions of universities and to combine production, learning and research thereby making our due contribution to knowledge innovation and to the active development of hi-tech for industrialization.

25. It is our belief that in universities, especially comprehensive engineering establishments such as Xi'An University of Transportation, we should focus on both teaching and research in order to invigorate the production sector. To improve teaching and research we must combine production, learning and research. Our guidelines are to offer services in exchange for support and to devote ourselves to common development. We shall try to reform traditional industries through the application of hi-tech and new technology and also develop new industries. Our purpose is to promote the translation of scientific research into productivity in our university and encourage teachers to focus on both theoretical research and practice. We also develop hi-tech businesses in an effort to exploit our work and gain support for teaching and research in return. *(1) Led by academic development, we try to create a favorable environment for innovations and facilitate the application of innovations.* Using State research bases and key laboratories, we encourage model projects that combine production, learning and research. We leverage leading-edge disciplines to develop unique industries and key hi-techs, and a number of dynamic entities have emerged, combining teaching, research and industrialization purposes. While scientific research is translated into productivity, the university also reaches new levels of academic endeavor and development. *(2) We promote technological innovation and its application with the focus on building research bases.* In order to encourage and develop technological innovation and its applications, we are setting up a science park, a State technology transfer center and are preparing for a productivity advancement center to strengthen the interaction and communication between researchers, businesses and society. We will thus be able to carry out targeted, market-oriented research that is consistent with our national circumstances and especially the situation in the West. As a result, the university cannot generate research results and theses for laboratory purposes alone; it must aim at providing businesses and complete packages of mature technology and equipment tailored to industry trends. Our technological research is thus increasingly translatable into productivity, and the university has helped improve technological development and the competitiveness of businesses. We have become an engine of social and economic development. As we help industrialization, we firmly believe that industrialization should support academic development, and leading-edge technology must be translated into competitive strength. The market is an important source of finance for our academic development, and market strength will ultimately become a valuable resource for supporting academic development.

26. At present, our university serves business in three ways: first by reforming traditional businesses through hi-techs and new technologies, second, by directly engaging in hi-tech and new-technology businesses, and third, by establishing engineering technology centers together with businesses, by setting up research funds and co-founding economic entities that link the university more closely to business.

27. Owing to economic and technological globalization partnerships that combine production, learning and research pursuits go beyond school or national boundaries. In order to integrate with international practice in our teaching, research and technological industrialization, we shall involve ourselves in the international division of labor and competitiveness and shall combine production, learning and research on the international level. Aiming at leading-edge technology across the world, we shall broaden our vision in

these efforts, and in doing so try to bridge the gap between our innovations and state-of-the-art innovations by leveraging the advanced technology outside China for the benefit of our own technological innovation. By setting up joint research institutes with large businesses in China to introduce leading-edge technology and equipment from outside China, we can help improve their technological assets and their capacity for innovation. At the same time, we are strengthening our cooperation with joint ventures and research institutes and taking advantage of their advanced technology in our own innovative work. We are in addition actively attracting human resources, especially returning overseas students, who will bring our research capacity and innovative ability up to new levels.

IV. SUMMARY

28. The significant role of innovation in maintaining a country's sustained development and competitiveness in this knowledge-economy era is widely recognized. Countries all over the world are building up their State innovation systems with the focus on innovation. Using the unique influence of universities and our advantages we can establish a strategic position in the State innovation system. By leveraging our strengths in developing innovative human resources and promoting ideological, knowledge and technological innovation, universities will give a great impetus to social and economic development, to our comprehensive national strengths and to our international competitiveness.

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