A Comparative Analysis of the National Innovation Systems of China and Australia

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Abstract

This paper presents the findings of a visiting scholarship research that was carried out at the Faculty of Engineering, University of Technology Sydney, Australia. Based on the extensive literature review, government databases and international statistics, it introduces an analytical framework for comparison of the national innovation systems (NIS) of China and Australia in regards to their strengths and weaknesses. This is done through individual examination and comparison of functions of typical institutions involved in innovation to reveal the structural characteristics and performances of the two systems. The interactions among these institutions are then analysed to illustrate their dynamics and efficiency. The comparison has shown clearly that China's NIS has several weaknesses and gaps due to its developing and transition stage. There are positive signs that Chinese Government has recognised the nature and scope of the problem and seems to work in the right direction. This paper aims to support this process by providing some recommendations that could help bridge the gaps between the NISs of China and Australia. Due to the fact that both, China's and Australia's NISs, have their unique characteristics but share numerous complementary features, there is a large potential for further cooperation between the two national innovation systems.

Key Words: National Innovation System, Technology and Innovation, Research and Evelopment, Science and Technology

1. Introduction

Although no universally accepted definition exits, a national innovation system (NIS) is generally recognised as a system that comprises the complex functions and interactions among various actors and institutions (Smith, 1996; Kumaresan and Miyazaki, 1999; OECD, 1999). The performance of a NIS largely depends on how these actors and institutions including Government agencies, enterprises, universities, public and private research institutes, bridging institutes, and other contributing institutions, etc. function and interact with each other to develop and apply innovative knowledge. Consequently, the functions of these institutions and

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their interactions must become the main focus when studying national innovation systems. According to the OECD (1999), NISs have the following six different functions:

- Technology and innovation policy formulation
- Performing R&D
- Financing R&D
- Promotion of human resource development
- Technology diffusion
- Promotion of technological entrepreneurship

OECD (1997) also defines the following four activities as the main interactions within the NISs:

- Joint industry activities
- Public/private interactions
- Technology diffusion
- Personnel mobility

According to the OECD research results (1999), two main sources are responsible for the NIS diversity. The first source is the country size and the level of development of that country. The second source relates to the respective roles of the main actors in the innovation system, and the forms, quality and intensity of their interactions.

Using these OECD research findings and other relevant information as guidelines, a brief summary the evolution processes of the NISs in China and in Australia are given in section 2 and 3. Then, in section 4, the characteristics of the two NISs are compared in a tabular form. In the following section 5 and 6, the gaps between the two NISs are identified and some recommendations and guidelines provided to overcome these gaps. Finally, the section 7 provides a brief conclusion on the results of this research. A comprehensive reference list and useful glossary are also provided at the end of this paper.

2. The Evolution of NISs in China

Prior to the economic reforms in late 1970s, China implemented a Soviet-style planned and centralised economy. According to Lan (1997), during this period several fundamental structural deficiencies can be identified in China's national innovation system. These included the separation of R&D function from production processes, the prominent role of non-industrial research institutions, and the absence of intellectual property right (IPR) control mechanisms. Technology transfer in China was hampered by factors (i.e., incentives), involving both supply and demand sides of the technology transfer process, and the absence of a market for technological knowledge. In addition, China's restrictive personnel system hindered the exchange of staff between public research institutes (PRI) and industrial enterprises, thus blocking another useful channel for technology transfer. The reformation process of the Chinese science and technology sector in the past three decades can be divided into three phases (Lan 1997, Liu 2001, Lin 2004).

During the first phase (1985 ~ 1992), a systematic reform of the entire national innovation system began after the publication of the Central Committee's landmark resolution on the Structural Reform of the Science and Technology System in March 1985 (CCCPC, 1985) which then became the cornerstone of China's national innovation system. This resolution identified three main areas where structural reform was mostly needed: the operating mechanisms, the institutional structure, and the management of S&T personnel. The reform efforts focused on the appropriation system, technology markets, management of public research institutes (PRIs), S&T personnel system, and institutional structures of PRIs.

During the second phase (1992 ~ 1998), the guiding principles of S&T reforms have gradually changed and took the role of "maintaining the national basic research" and "decentralisation of research and development institutes." This reform directive intended to create a policy environment to encourage spending on research and innovation by enterprises and the development of innovative mechanisms for financing S&T by Local Governments.

The third phase (1998-to date) is characterised by the fact that the Chinese Government began to organise the study of innovation systems, rather than simply describing the role and performance of particular actors, institutions and policies.

3. The Evolution of NISs in Australia

Compared to China, Australia is a small but a high-income market economy. According to Gregory (1993) the characteristics of the Australian national innovation system can be described as follows:

- Low level of science and technology expenditure
- High level of Government involvement in financing and undertaking research
- Low level of private sector research and development
- Exceptionally high dependence on foreign technology

In the 1970s, R&D spending in Australia was relatively low, but starting from the mid-1980s business sector expenditures increased and the Government share of R&D spending began to fall. Irrespective of the source of finance, there is a feeling that R&D should be more applied and nearer the product market. Block funding has been reduced and directed grants increased. Research agencies have been encouraged to raise private sector money.

Since the second half of 1990s, the Australian Government has shown a stronger willingness to invest in people and enhance their capacity to generate new ideas and turn those ideas into new products and services, creating jobs, wealth and other benefits for Australia. In January 2001, after an extensive consultation and review process, Australian Government announced a five-year $3 billion comprehensive and integrated package of funding for science and innovation called Backing Australia's Ability (Australian Government, 2001). The recent major steps to boost innovation activities included:

- Increased support for business innovation, venture capital and technology diffusion
- New policy and funding framework for high education research and research training
- Further injection of funds into health and medical research
- Establishment of Biotechnology Australia and allocation of additional funds for targeted biotechnology initiatives.

The scope of Backing Australia's Ability (BAA) includes programmes that are directed to public sectors and business R&D; adoption of technology; commercialisation of research; venture capital; school and university education; skilled immigration; intellectual property protection; public awareness of science and innovation; and entrepreneurship. It focuses on the Government's commitment to three key elements in the innovation process:

- Strengthening the ability to generate ideas and undertake research
- Accelerating the commercial application of these ideas
- Developing and retaining Australian skills

After analysis of the Australian innovation capability over the past quarter century, Gans, *et al.* (2003) concluded that both the public policy and private sector initiatives have transformed Australia from a class "imitator" to a second-tier innovator economy. These improvements are the consequence of policies ensuring macro-economic stability and the implementation of micro-economic reforms that have opened Australia up to global competitive forces (Gans, *et al.*, 2003).

4. Comparison of NIS of China and Australia

The following table summarises the characteristics of the NISs in China and Australia. A tabular form has been chosen as it allows a direct comparison of the two systems. Most of the information presented in this table was compiled from databases published in the period between 2001 and 2003. For detailed and full information as well as for the acronyms, please refer to the comprehensive list of references and the glossary at the end of this paper.

Table 1. Comparison of the national innovation systems of China and Australia

	China	Australia
Country size	Population: 1.3 billion	Population: 20 million
Level of Economy	US$ 800 per capita, but rising rapidly. Catch-up country	Nearly US$ 20,000 per capita, increasing steadily. Developed country
Model of Economy	Transition economy	Market economy
Government agencies	MOST, MOE, NDRC, etc.	PMSEIC, DEST, CSTACI, etc.
Characteristics of Government	Central authority. Section divisive.	Coordination and advisory.
Innovation policies	Programs and plans focus on fund subsidies of programs.	Integrated package (BAA and BAA2). Balance of fund subsidies and indirect incentives.
Financing R&D (S&T)	Business sectors account for 2/3 of total funding (similar to the OECD). Government is still main funding source of S&T.	Government accounted for almost the same fund as the business sector (46.3% of all).
Performing R&D	In 2002, R&D expenditure was around 1.23% of GDP (0.6% in 1996) BERD/GERD reached 61.2% in 2002 (42.9% in 1997). HERD/GERD stayed around 10%. Basic research/ total R&D remained around 5%.	R&D/GDP was 1.53% (OECD: 2.25%) (BERD/GERD was 47.1% (69.6%). HERD/GERD was 27.1% (17.1%). Basic research /GERD was 25.6% (South Korea: 12.6%).
Education	5% of the population aged 25～64 has completed tertiary education. Everage education period was 8.32 years.	25% of population has completed tertiary education. Average education period was 13.1 years.
Human resources in science and technology (HRST)	HRST was 21.86 million people in 2002, but accounts for less than 3% of the total population employed. Around 1.03 million R&D personnel, including S&E 810,500 employees. In other terms, number of researchers in China is less than 1.1 per thousand employees.	HRST account for 35% of total employment, ranking 3rd in OECD in 2002. Around 10 per thousand employees devoted to R&D activities. Number of researchers in Australia is around 8 per thousand employees.
Technology bridging agencies	Large number of public agencies already exists, such as science park, technology incubator productivity promotion centres, etc. However, there are only a limited number of qualified private professional consultants available.	Large number of private professional consultants available. Also some public agencies, such as TTO and CE of university, incubator, AIC, CRC, Technology parks, etc. are active.
Technology entrepreneurship	Venture capital developed rapidly but slowed down since 2000. High-tech firms attracted 85.8% of total venture capital investment. It has still various shortcomings. There are more than 400 incubators but qualified professional services are relatively weak.	Venture capital investment as a share of GDP is at 0.1%. Only 20% was invested by high-tech firms. BITS provide funds to incubators to assist early stage ICT firms. SBIP aim to support small business incubators.

Collaborative R&D	Most organisations are cooperating more in the upstream stages of the R&D than in the downstream stages.	Collaboration among researchers, as well as collaboration between researchers and research users quite common. Have also good records, e.g. CRC.
Technology transfer and commercialisation	Three main mechanisms: Technology transfer contracts; technology markets; R&D institutes transition and spin-offs.	Development is uneven.
Networking and cluster	NETRC, NKL, etc. are funded by Government. Supply-customer chains built by firms. 53 New and High Technology Industry Zones (more interaction on innovation); ICT processing clusters; Tradition manufacturing industry clusters.	ARC Research Networks initiative Strategic Research Networks, CRCs The technology parks; regional primary industry clusters.
Personnel mobility	Mobility of personnel is greater than before. Movement of HRST among different institutes is not active, especially for international mobility, although more overseas students return to China.	Mobility of personnel domestic and international are both active. Emigrating many researchers and skilled technicians from other countries.
Performance of NIS	S&T papers ranked 5th. Share of world scientific publications was 3.56% which ranked 8th.	Contributing 2.88% of the world's output of research publications and ranked 11th.
Patent and IP protection	The framework of IP protection is not full functional. Sum of domestic patents has increased rapidly in recent years. Patents granted by USPTO, EPO and JPO to residents of China is much lower than in developed countries. China has a high level of international co-inventions, benefited from FDI and multinational research affiliates.	IP protection is among the world's best. Share of triadic patent families accounts for 0.67% of total OECD. The US patents of other countries cited Australian patents at a ratio of 0.72, well behind technological leaders such as Singapore (1.55) and the US (1.15).
Technology and knowledge-intensive industries	The value added of new and high-tech accounted for 9.2% of total manufacturing industry. The knowledge-intensive services are weaker.	The high and medium-high technology manufacturing accounted for 4% of total value added, the knowledge-based services accounted for 22% (ranked 4th in OECD).
Technology-intensive exports	The share of high-tech export as percentage of manufacturing exports was 18.6%. Its share of world's high-tech export was 4.1% (2001).	Australia's share of world's high-tech export was only 0.3% (2001).

5. The Gaps between the NISs of China and Australia

Compared to Australia and other OECD countries, China's NIS displays several shortages and weaknesses:

Firstly, China is still in a process of transition resulting in gaps and weaknesses in the administrative systems and incentive mechanisms. The Chinese Government controls much of the power over the NIS; however, coordination appears to be ineffective as the power is shared by different ministries and agencies. This is perhaps one of the main reasons why Government's interventions often distort the competition among the actors and reflect on the inefficiency of NISs.

Secondly, the total input to S&T and innovation appears to be insufficient for the demand. The level of R&D expenditure is lower than in Australia and much lower than the average level of OECD countries in 2002. Especially the national input of basic research seems to be at lower rate (only about 5%) as a percentage of GERD in China. This shortage should hamper the science performance and innovative capability in a long term. China has a great shortage of the quality employees, i.e., HRST, R&D personnel and researchers, which has been still a major obstacle in updating China' NIS.

Thirdly, the collaboration between researchers and research users in China is weaker than in Australia. There are also large gaps in technology transfer and commercialisation compared with Australia and other developed countries. Although the Chinese Government has recognised this problem and has enacted with several policy changes but the progress is slow and ineffective.

Finally, regarding the output of NISs, China has a relatively small impact on the world's scientific publications. The total volume and the share of international patent families (i.e. USPTO, EPO and JPO) are low. Most of Chinese enterprises have little innovative competence. The quality knowledge-intensive service industry is in its infant stage.

6. Recommendations

Based on the analysis above, several recommendations and policy advice could be provided to the Chinese policy makers. These include the following:

Firstly, the Chinese Government must continue to advance the structural reform of S&T mechanism, address the specific factors that restrain innovation venture, and foster entrepreneurship and creation of new technology-based firms. China's tertiary education system should be re-configured to increase the output of graduates with innovation culture, and intensify R&D activities, especially in the basic research field.

Secondly, The Chinese Government should not only enforce funding of R&D, but also provide both financial subsidies and tax concession incentives to stimulate the business investment in R&D and foster co-operation among the elements of the national innovation system.

Thirdly, strengthening technology diffusion mechanisms should become a policy priority in China. A market-oriented incentive environment should be fostered and preserved to boost public/private bridging institutions. The Government should encourage transfer of technologies originated in universities. Flexible labour markets should be fostered to facilitate the diffusion of tacit knowledge and skills.

Fourthly, the Chinese Government should reduce the obstacles that prevent the formation of networks, ensure closer collaboration between public research institutes and private businesses, and ease the access of firms to knowledge-intensive services. The Government should nurture the development of innovative clusters in which all actors could co-evolve.

Fifthly, China should encourage openness to the international flow of goods, investments, people and ideas, which in turn will increase its ability to absorb S&T from around the world. The Government should create a more internationalised science community, join international R&D cooperation programmes (e.g. EU structural programme), and initiate bilateral or multilateral programmes (agreements) with relevant countries.

And finally, the innovation policy requires a strong coordination between the various ministries and agencies involved in the innovation process. The effects of the National S&T and Education Coordination Lead Group (NSTECLG) which allow for a more cooperative approach should be enforced. The modern S&T management system should be established in China. The performance of Government S&T activities should be assessed by qualified and socially grounded agencies. At macro level, a reform of traditional centralised governance system is needed to create a qualified and effective S&T governance system.

7. Conclusions

This study employed an analytical framework for comparing the national innovation systems of China and Australia. The functions of typical institutions involved in innovation have been individually examined and compared to reveal the structural characteristics and performances of the two systems. The interactions among these institutions have been analysed to illustrate their dynamics and efficiencies. The comparison of the national innovation systems of China and Australia has revealed that while each NIS has its own unique structural characteristics, there are serious gaps between the NISs of China and Australia. Most of the weaknesses and shortcomings of the NIS of China seems to result from organisational problems such as government policies, administrative systems, control mechanisms, and collaboration among various parties involved. This is not surprising as the country is still in a process of transition. There are positive signs that Chinese Government has recognised the nature and scope of the problem and seems to work in the right direction. This paper aims to support this process by providing some recommendations that could help bridge the gaps between the NIS of China and Australia.

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Glossary

ABS:	Australian Bureau of Statistics
ARC:	Australian Research Council
ATO:	Australian Taxation Office
BAA:	Backing Australia's Ability
BAA2:	Backing Australia's Ability-Building Our Future through Science and Innovation
BERD:	Business Expenditure on Research and Development
BIHECC:	Business/Industry/Higher Education Collaboration Council
BITS:	Building on Information Technology Strengths
COMET:	Commercialising Emerging Technologies
CRC:	Cooperative Research Centre
CSIRO:	Commonwealth Scientific and Industrial Research Organization
CSTACI:	Commonwealth State and Territory Advisory Council on Innovation
DEST:	Department of Education, Science and Training
DIMIA:	Department of Immigration and Multicultural and Indigenous Affairs
DITR:	Department of Industry, Tourism and Resources
EPO:	European Patent Office

FTE:	Full-Time Equivalent
GERD:	Gross Expenditure on Research and Development
HERD:	Higher Education Expenditure on Research and Development
HRST:	Human Resources in Science and Technology
ICT:	Information Communication Technology
IP:	Intellectual Property
JPO:	Japanese Patent Office
MNE:	Multinational Enterprise
MOE:	Ministry of Education (China)
MOST:	Ministry of Science and Technology
NDRC:	National Development and Reform Commission (China)
NHMRC:	National Health and Medical Research Council
NIS:	National Innovation System
NSTELG:	National S&T and Education Lead Group
OECD:	Organization for Economic Cooperation and Development
PDF:	Pooled Development Fund
PMSEIC:	Prime Minister's Science Engineering and Innovation Council
PRI:	Public Research Institution
PSF:	Pre-Seed Fund
R&D:	Research and Development
SBIP:	Small Business Incubator Program
SIPO:	State Intellectual Property Office (China)
SME:	Small to Medium-sized Enterprise
SOE:	State-Owned Enterprise
SSTC:	State Science and Technology Commission (China)
S&T:	Science and Technology
USPTO:	US Patent and Trademark Office
VCLP:	Venture Capital Limited Partnership