China's Emerging Technological Edge

In less than thirty years, China has become a major force in the global economy. One feature of its rapid ascent has been an enormous expansion of the country's science and technology (S&T) capabilities, thanks to the emergence of a large and increasingly well-educated talent pool. Yet China finds itself faced with a number of major challenges as to whether its full S&T potential may be realized. At the heart of these challenges lie a number of uncertainties surrounding the quality, quantity, and effective utilization of China's S&T workforce. Written by two leading experts in the field, this book is the first in forty years to address these critical issues. Building on exciting new research and a plethora of comprehensive statistical materials, its findings will have significant policy implications both for China and the international community, especially in terms of issues relating to national competitiveness and innovation potential.

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China's Emerging Technological Edge

Assessing the Role of High-End Talent

DENIS FRED SIMON AND CONG CAO

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Acknowledgements

Tackling a problem as complex and challenging as assessing the scientific, engineering, and managerial talent-base of a country as complicated and dynamic as the People's Republic of China requires a great deal of patience and persistence as well as a strong collaborative effort. Gaining a real operational understanding of the workings of the overall Chinese statistical system as well as the science and technology (S&T) data system, including the collection, processing, and classification approaches, is not a small task by any measure. This undertaking is made even more daunting by the fact that the Chinese system, generally speaking, lacks the same degree of openness and transparency concerning access to very detailed information about the workings of the Chinese economy and research and development (R&D) system. Nonetheless, we decided to persevere and embarked upon what often proved to be a very taxing and demanding research project. We are happy to report that the strength of our commitment and fortitude has yielded very positive results, including the production and publication of what we hope will be viewed as an important contribution to understanding contemporary China.

Both authors have been studying China's human resources in science and technology (HRST) for many years. Simon wrote his master's thesis at the University of California, Berkeley on "manpower planning in China" in 1975, while Cao studied the elite members of the Chinese Academy of Sciences (CAS) for his doctoral dissertation, the situation among young Chinese scientists with Richard P. Suttmeier, and China's "brain drain" phenomenon later on. Having some grounding in this often complicated field of study helped us to gain traction and find our direction during the early stages of the project.

In writing this book, we benefited from various types and sources of support. The effort actually began in 2005, as a research project focussed on studying the supply, demand, and quality of China's scientific and engineering talent; the specific results from this component of our research are presented and discussed in Chapter 7. That aspect of our research was supported by a grant graciously provided by the International Business Machines Corporation (IBM). In particular, Nicholas M. Donofrio, recently retired from his position as IBM's executive vice president of innovation and technology, served as the champion of the initial project, which has now evolved into a larger study entitled, "The Global Talent Index™." This more comprehensive project has witnessed the continuation of the collaboration between the Neil D. Levin Graduate Institute of International Relations and Commerce under the State University of New York, and IBM. Michael Bazigos has been coordinator on the IBM side, and along with his colleagues – Phil Swan, Martin Fleming, Doug Handler, Seth Hollander, and David Yaun – who not only have lent their help when needed, but also challenged as well as stimulated us. Our interactions with our IBM colleagues were always intellectually intense and frequently yielded new and valuable insights that we believe have found their way into this book.

Many scholars in the China studies field have encouraged our endeavors as they too have recognized the need for a serious stocktaking of China's S&T human capital. These include Richard P. Suttmeier, Jon Sigurdson, William Fischer, Adam Segal, Erik Baark, Yifei Sun, Linda Jakobson, Ding Jingping, and Zhou Yuan, among others. Cao's field research in China was, in part, supported by a grant from the US National Science Foundation to Dr. Suttmeier (OISE-0440422).

The Levin Graduate Institute in New York City provided us with a wonderful environment to carry out our research and study the problems of innovation in China as a whole. President Garrick Utley's support for the idea of creating an actual "Global Talent Index" dovetailed very nicely with the authors' common interest in China's scientific and engineering contingency. Garrick's reference point for turning out an authoritative, useful, and convenient tool for understanding the talent pool in technologically developed and emerging economies was derived from the *Military Balance*, an annual publication produced by the International Institute for Strategic Studies. Other Levin staff members have also been extremely encouraging and supportive, including Michael DiGiacomo, Thomas Moebus, Lin Wei, Christine Li, Leydi Zapata, and Jason Zheng Ye. With Levin's strong institutional support, we have been able to build a first-rate Chinese materials library focussed on S&T policy and innovation in China, including large numbers of important statistical yearbooks, monographs, and other research materials. We are proud of having created perhaps the most comprehensive collection of such Chinese materials outside, if not inside, of mainland China. Having these materials readily available has helped to facilitate the completion of this book and, we hope, helped to enhance its value.

Bilguun Ginjbaata and Howard Harrington helped us analyze the supply and demand data. A huge amount of credit and gratitude goes to Bojan Angelou, who worked tirelessly with the entire team to help build the underlying statistical model and produce the accompanying regression analyses. We are extremely grateful for his valuable contributions.

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At Cambridge University Press, Paula M. Parish, commissioning editor of business and management, recognized the significance of the topic and graciously agreed to work with us when the book was still only a proposal.

In various forms and at various stages, Chapter 7 has been presented at various conferences, including the Qinghua–Stanford Conference Workshop on Greater China's Innovative Capacities: Progress and Challenges, Beijing, 2006; the Conference on Operation, Performance, and Prospects for China's Industrial Innovation System: Impact of Reform and Globalization, New York, 2006; the

INFORMS annual meeting, Pittsburgh, 2006; the Conference on Education for Innovation in India, China, and America, Atlanta, 2007, and so on. Comments from participants at these conferences helped us to improve the chapter as well as the book as a whole.

Finally, but most important, the two of us made many prolonged trips to China to collect data and conduct field research for this book. We truly appreciate the love, understanding, and support we receive every day from our respective families; Denis would like to acknowledge and express his deep gratitude to his wife Fredda, his daughter Melissa, and his son Mitchell, while Cong is greatly indebted to his wife Xiaozuo and his son Yiyang.

Abbreviations

AAAS	American Association for the Advancement of Science
AACSB	Association to Advance Collegiate Schools of Business
BRIC	Brazil, Russia, India, and China
CAE	Chinese Academy of Engineers
CAS	Chinese Academy of Sciences
CASS	Chinese Academy of Social Sciences
CAST	China Association for Science and Technology
CCP	Chinese Communist Party
CEO	chief executive officer
COSTIND	Commission of Science, Technology, and Industry for National Defense
CSIA	China Software Industry Association
FDI	foreign direct investment
FIE	foreign-invested enterprises
FTE	full-time equivalent
GDP	gross domestic product
GERD	gross expenditure on research and development
GPCR	Great Proletariat Cultural Revolution
HHMI	Howard Hughes Medical Institute
HRST	human resources in science and technology
ICT	information and communications technology
IPR	intellectual property right
ISCED	International Standard Classification of Education
MBA	Master of Business Administration
MII	Ministry of Information Industry
MIT	Massachusetts Institute of Technology
MLP	China's Medium- to Long-Term Plan for the Development of Science and Technology (2006–2020)
MNC	multinational corporation
MOEd	Ministry of Education

MOF	Ministry of Finance
MOFCOM	Ministry of Commerce
MOLSS	Ministry of Labor and Social Security
MOP	Ministry of Personnel
MOPS	Ministry of Public Security
MOST	Ministry of Science and Technology
NBS	National Bureau of Statistics
NDRC	National Development and Reform Commission
NIBS	National Institute of Biological Science
NPC	National People's Congress
NRCSTD	National Research Center for Science and Technology for Development
NSF	National Science Foundation, USA
NSFC	National Natural Science Foundation of China
OECD	Organization for Economic Co-operation and Development
PPP	purchasing power parity
R&D	research and development
SCI	Science Citation Index
SEC	State Education Commission, the predecessor of the Ministry of Education
S&T	science and technology
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USTC	University of Science and Technology of China
WTO	World Trade Organization

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Introduction

In the span of less than three decades, China has evolved from a peripheral player to become the most potent engine in the global economy. Along with its rapid economic progress, and the many improvements in the quality of life for large numbers of the Chinese population, a variety of indicators suggest that China's science and technology (S&T) capabilities also are on a sharply rising trajectory. Since the early 1990s, spending on S&T by the Chinese government has been increasing at a rate approximately twice that of overall economic growth. In 2007, China spent RMB (*reminbi*) 366 billion (US $50 billion) on research and development (R&D), or 1.49 percent of its increasing gross domestic product (GDP), highest among countries with similar economic development level, though the percentage is still lower than that of most of the major developed economies (NBS, 2008).[1] Chinese institutions of higher education have been turning out an increasing number of well-prepared graduates. In 2006, China graduated some 159 000 students with masters and doctoral degrees in science and technology, on top of 1.34 million engineering undergraduates as well as 197 000 science undergraduates (NBS, 2007: 794). Unequivocally, this represents the world's highest output in terms of overall numbers.

In recent years, there also has been a steady increase in the number of international papers published by Chinese scientists. Measured by the number of papers included into the *Science Citation Index* (SCI), a

[1] According to the Organization for Economic Co-operation and Development (OECD), using the purchasing power parity (PPP) measure, however, in 2006 China became the world's second-largest spender on R&D (US $136 billion), ranking only behind the USA (US $330 billion) (OECD, 2006). Of course, it should be noted that attempts to measure China's economic output in PPP terms are subject to discussion, as its gross domestic product (GDP) based on that was reduced by 40 percent in a recent recalibration (Porter, 2007). It should also be recognized that the gap in spending between China and the USA remains substantial, with the USA spending being more than twice that of Chinese spending.

bibliometric database published by the Thompson Scientific, part of Thompson Reuters, in 2006 China ranked fifth in the world. Notable achievements have been recorded in a number of emerging scientific fields such as genomics and nanotechnology.[2] Foreign investment, as well as imported technology and equipment, continues to pour into China, making it one of the largest recipients of foreign capital and know-how in the world. While most attention has been focussed on the rapidly expanding export side of China's foreign trade, it must also be remembered that China has become one of the world's largest importers. And, most recently, many of the world's technologically most innovative companies have decided to move beyond setting up manufacturing facilities in China to establishing advanced R&D centers to develop new products and services for global markets as well as the Chinese domestic market. By the end of 2007, there were well over 1000 foreign R&D centers operating in the People's Republic of China.

In early 2006, with a great deal of fanfare, China's leadership issued a new "Medium- to Long-Term Plan for the Development of Science and Technology (2006–2020)" (MLP). In addition to setting ambitious national priorities and formalizing the leadership's commitment to allocate substantial financial and people resources to meet the announced goals, the MLP specifically defines enhancing indigenous innovation capability (*zizhu chuangxin*), leapfrogging in key scientific disciplines, and utilizing S&T to support and lead future economic growth as the major objectives (Cao *et al.*, 2006). In a word, once considered one of the more backward developing countries, China today stands as one of the world's most robust and dynamic economic forces. These trends have led many observers to ask, in a similar vein, whether China also is poised to become a superpower in science and technology (see, for example, Keely & Wilsdon, 2007; Sigurdson, 2006).[3]

Underlying the massive transitions taking place in the Chinese economy and S&T system is the emergence of a very large, increasingly

[2] China is one of the six countries, the others being developed ones, participating in the decoding of the human genome at the turn of the century. On China's achievement in nanotechnology, see Zhou and Leydesdorff (2006).

[3] In fact, according to a recent assessment by the Georgia Institute of Technology, China already tops the USA on the Technological Standing reading, which combines four indicators – National Orientation, Socio-economic Infrastructure, Technological Infrastructure, and Productive Capacity (Porter *et al.*, 2008).

well-educated talent pool. The term "talent" (*rencai*)[4] is a concept that has gained increasing popularity and importance in China over the last few years; specifically, it denotes those Chinese with higher-caliber abilities and skills of strategic significance to the country's modernization and national wealth creation.[5] Leveraging the significant investments that heretofore have been made to modernize and upgrade the country's higher education system and R&D infrastructure, China hopes to capture and harness the country's most strategic resource – its talented people – to embark on a quest to close appreciably the prevailing technological gap between itself and the West in fields ranging from biotechnology to nanotechnology. The launch of the MLP reflects a commitment to rely more on "brains" rather than "brawn" to bring China into a strong, leadership position during the early part of the twenty-first century.

At the heart of the debate about whether China's potential can be realized, however, lie a number of critical issues all touching upon, or dealing directly with, lingering uncertainties surrounding the quantity, quality, and effective utilization of China's current and future scientific and technical workforce. Will China have sufficient talent to compete head-on with the USA and the world's other leading technological nations? Is China's indigenous talent qualified to meet the needs of the country's economic, scientific, and education enterprises? How will demographic trends in China affect the supply of college-age candidates for university enrollment? What has been the impact of Chinese scientists and engineers who have been trained abroad and have returned to the People's Republic of China? Is China still facing a "brain drain" problem, and if so, how serious is it? And last but not least, what factors with regard to the changing complexion of the Chinese economy and foreign investment will affect the supply and demand for high-end talent?

Building on some very exciting original field research as well as a plethora of comprehensive statistical materials and analysis dealing with

[4] Originally, "talent" means "currency." In the Bible, the parable of the talents tells how three servants approach the different amount of talents given by their master in accordance with each servant's ability – invest or keep it – and end up with different outcome, which, according to Stringer and Rueff (2006: xviii–xix), "helped shape out understanding of the concept of talent, and subsequently, how the word itself acquired its modern meaning."

[5] In Chinese terms, *rencai* can also mean "treasures."

the structure, size, and composition of the scientific and engineering talent pool in China, this book tries to answer these critically important questions. The analysis offered in this book has significant policy implications for both China and many other countries, such as the USA, especially in terms of such issues as national competitiveness and innovation potential.

From the perspective of both contemporary China studies and the literature on competitiveness, the book is long overdue in that it is the first comprehensive look at China's human resources in science and technology (HRST) in over four decades – since the publication in the 1960s of *Professional Manpower and Education in Communist China* by Leo Orleans (1961) and *Scientific and Engineering Manpower in Communist China* by Chu-yuan Cheng (1965). Although breaking new ground at the time, both books were constrained by serious data availability and quality issues. Ironically, both books appeared around the time of China's successful testing of its first atomic weapon in 1964; this somewhat unexpected development reinforced the need to monitor S&T developments in the People's Republic of China. Fortunately, Orleans continued his work in this field, taking advantage of the opening up of China's relations with the outside world and the expanded availability of statistical data from China. Orleans contributed several, more detailed monographs in the 1980s on China's scientific workforce (Orleans, 1980, 1983) and Chinese students in the USA (Orleans, 1988, 1992). Between then and now, however, while such organizations as the Organization for Economic Co-operation and Development (OECD) and the US National Science Foundation (NSF) periodically provide quantitative updates and analyses of China's scientific and technical workforce in the context of international comparisons of graduate education around the world and the global mobility of talent, there has been virtually no detailed scholarly book-length work devoted to the topic, even though the topic has become steadily more important as China's expanded prominence in international and regional S&T affairs has generated a growing need for a deeper, more sophisticated understanding of its present and future S&T talent pool. While Chinese academics have published some work on the topic in recent years – most notably: *Stride from a Country of Tremendous Population to a Country of Profound Human Resources* (Research Group on China's Education and Human Resources, 2003); *Report on China's Talent 2005* (Chinese Academy of Personnel Science, 2005); *China Education and Human Resource Development Report 2005–2006* (Min & Wang, 2006); and *Report on the Development of Chinese Talent* series (Pan, various years), most have been more descriptive and qualitative in nature, and have not taken both the supply and demand aspects of S&T talent into consideration.[6]

In addition to much scholarly attention paid to the relations between Chinese intellectuals, including scientists and engineers, and the state (see, for example, Goldman *et al*., 1987; Goldman & Gu, 2004; Hamrin & Cheek, 1986; Miller, 1996), there have been studies written in the West about China's HRST from other perspectives. One of the most interesting was *Thread of the Silkworm*, by Iris Chang (1996), which is the story of the life of one individual Chinese scientist, Qian Xuesen, often seen as the father of the Chinese missile program. Chang's story about Dr. Qian is especially relevant to the present book because she documents the experiences of an individual who, under some pressure, returned to China after building what seemed to be a successful career as a defense scientist at Cal Tech in the USA. Lueck's (1997) study of Chinese intellectuals during and after the Tiananmen Square incident on June 4, 1989 also tries to bring into focus the challenges of working in the R&D profession in a rapidly changing Chinese environment. And recently Cao has systematically examined the characteristics of the leading academicians (*yuanshi*) of the Chinese Academy of Sciences (CAS), and to a less extent, the *yuanshi* of the Chinese Academy of Engineering (CAE), and the process through which Chinese scientists have been elected into the elite (Cao, 2004a; Cao & Suttmeier, 1999), and China's emerging scientific elite (Cao & Suttmeier, 2001).

All of these works provide some degree of understanding about the world of the Chinese scientist and engineer, but few attempts have been made to conduct the type of overall stocktaking of high-end S&T talent resources that was produced in the early 1960s. This book, in its own way, attempts to fill the prevailing gap by bringing together a significant volume of new statistical data and interview information about the scientific and engineering community in China. It represents

[6] While copy-editing this book we learned that the China Academy of Science and Technology (CAST) just released a report on China's HRST (CAST, 2008), but we are unable to incorporate it into the book as we have not had chance to read it.

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the first of its kind in terms of incorporating a statistically based supply and demand approach and model to forecast the growth and availability of China's S&T talent over the next five years and to analyze the massive new availability of original policy documents and statistical materials on Chinese S&T talent. Compared with the raw materials that Orleans and Cheng, respectively, had to work with, we have clearly had some major advantages, stemming in no small way, from the premium that Chinese officials have placed on cooperation with the West and providing increased access to foreign researchers. This availability and increased access for foreign researchers affords observers of the Chinese scene a greater ability to determine where China's scientists and engineers stand when compared with their counterparts elsewhere.

The book also offers a timely assessment of the strength and weakness of China's S&T talent pool. Because of the relative scarcity of accurate information on the subject as well as the misrepresentation of the information, there have been growing political concerns in the USA and other developed countries about the increasing size of the Chinese scientific and engineering talent pool and its implications for the economic and technical future of OECD countries and beyond. Many of these concerns reflect an incomplete, and sometimes exaggerated and distorted, picture of the Chinese talent situation and education system. For example, the source of the figure of 1.6 million Chinese engineers used in a McKinsey study on global outsourcing seems to be derived more from popular perceptions or anecdotes rather than actual statistical analysis (McKinsey Global Institute, 2005) and a most recent study of the Chinese health biotechnology sector introduces an absurdly higher number of Chinese scientific and technological personnel – 55.75 million – from a Chinese source but does not clarify what this number means (Frew *et al*., 2008: 52).[7] As a recent study from Duke University correctly points out – and in fact, as Chinese education statistics also indicate – not every so-called "engineer" graduating from a Chinese university is equal (Wadhwa & Gereffi, 2005). Of the 1.34 million "engineering students" graduated from Chinese colleges in 2006, for example, more than half – 57 percent – were in the short-cycle, two- to three-year abbreviated programs (*zhuanke*); that is, the level of education and formal training that these

[7] We could not find this number in any official S&T statistics.

graduates received is much lower than that obtained from a certified program conferring a more traditional bachelor's degree. Further, if we exclude those who entered domestic and foreign graduate schools after their bachelor's degree as well as those with low quality and mismatched skills, and those who chose a non-technical profession, the number of qualified, available job candidates in engineering would fall to around 200 000 (see Chapter 7). While still large, this number represents only 35 percent of those with an engineering bachelor's degree or much smaller percentage of the total pool of engineering graduates. The surge of Chinese college graduates since the late 1990s has further disturbed the debate about whether China has raised the quality of its graduates at the same time as it has increased enrollments. This book will help demystify the size and composition questions surrounding China's talent pool, leading to a deeper, more thorough understanding of China's current and future human resources in the S&T pipeline.

Objectives and organization of the book

In making a substantial investment in the data collection efforts that form this book's underpinning, we were driven by three main objectives. First, simply and succinctly stated, our goal has been to enhance overall understanding of the supply, demand, and utilization of scientific and engineering talent in China. In this regard, we strongly believe that it is important to differentiate fact from fiction with respect to the formal statistical and popular media-driven data coming out of China and other parts of the world about the Chinese talent pool. As suggested, there is a considerable amount of hyperbole and exaggeration in the air that simply needs to be corrected or debunked. If government, enterprise, and university decision-makers in China and abroad do not have appropriate data and analysis to support their policy decisions, the chances of critical mistakes and blunders occurring are enhanced.

Second, we wanted to connect the Chinese case with the larger discussions about global talent so that we may all better understand how China's emergence as a more prominent player in the global innovation system will affect and influence the shape and nature of that system in the years ahead. Whether we accept the idea of a global talent *pool* or the existence of *pools* of talent, the fact remains that

China's S&T personnel are playing a more active and productive role in world science and technology affairs. Thus, we are interested not only in what role Chinese scientists have played and will play in their own S&T community at home, but also in the role they have played and will play on the larger international stage.

And, third, we wanted to encourage others, including our counterparts in China, to build on this work. As part of the preparatory work for its new MLP, which was launched in January 2006, the government assigned to one of 20 strategic research teams responsibility for addressing China's high-end talent needs for the coming 15 years. Unfortunately, this study was not made available to us, but from what we understand, it was heavily driven by a supply model without ample consideration of the changing nature of the demand side – the only demand variable is R&D expenditure.[8] This has led some observers to suggest that while the Japanese may have developed the "just in time" philosophy, in the realm of talent development, Chinese thinking is apparently characterized by a "just in case" mentality! We believe that the type of approach used in drafting the MLP requires reconsideration. Our hope is that more study will be done in China on this important topic, and that other foreign scholars will be given a chance to collaborate with their Chinese counterparts. It is our ambition to build one more cooperative bridge between China and the West so that the integration of the People's Republic of China into the world S&T community may continue in a constructive and harmonious manner.

In this regard, this book should also be viewed as a link connecting together existing research, statistical information, and analytic models and methodologies regarding the study of science, engineering, and management talent in other countries with the Chinese case. The analysis offered in the book tests the applicability and validity of the prevailing literature about talent development and utilization at the national level.

With all these in mind, the book, which is composed of nine chapters plus an appendix, is divided into three parts. The first part,

[8] At least we knew that the team working on HRST based its analysis on the data published in China's statistical yearbooks, and the result was disclosed in a paper published in a Chinese journal (Li & Yu, 2004).

which includes the initial two chapters, reviews the literature on the relations between human capital and economic development and discusses the dilemmas and challenges that China faces as it seeks to move beyond its role as a "factory to the world." The next five chapters constitute the second part of the book. Chapter 3 introduces the concept of HRST, an internationally used definition, and discusses its applicability to the study of Chinese S&T talent. The chapter then provides a stock-take of China's overall S&T talent pool, including its structure and characteristics. As part of a broad examination of the development of the higher education system in post-1978 China, Chapter 4 analyzes the pipeline through which China produces undergraduate and graduate students, especially in science, engineering, and management, and identifies the problems and issues faced by China in turning out a larger volume of such students. Chapter 5 examines how Chinese S&T talent has been utilized from the perspective of prevailing policy goals versus and the real-world situation. Chapter 6 discusses the impact of the "brain drain" problem on China's ambition to become an innovation-oriented nation.

The second part of the book ends with Chapter 7, a forecast of the demand and supply of scientific and engineering talent in China in the years to come.

The last part consists of two chapters. Chapter 8 surveys the talent situation in key technology fields, highlighting China's relative strengths and weaknesses, and Chapter 9 contains a discussion of the changing role of scientists and engineers in Chinese society and political economy, as well as offering an examination of the potential impact that China's S&T talent will have on global technological competition and international scientific advances during the first part of the twenty-first century.

Data sources used in this book

The data used in this book were drawn mainly from open-source primary Chinese language materials along with statistical data published in China by the National Bureau of Statistics (NBS) through the China Statistical Press. We also collected substantial amounts of data and information from other Chinese government agencies, including the Ministries of Science and Technology, Education, Labor and

Social Security, Personnel,[9] and Information Industry. In addition, useful materials were secured from the CAS, the CAE, the Chinese Academy of Social Sciences (CASS), and the China Association for Science and Technology (CAST). Many hours and days over the course of more than a year were spent in Beijing and Shanghai tracking down and rummaging through piles of old, but sometimes relevant, Chinese ministerial yearbooks, statistical data books, magazines, and scholarly books. Overall, we tried to go back as far as the available statistical materials would allow us to highlight more precisely in our statistical model growth trends and changes in the talent stock over time; as we quickly discovered, however, the reliability of the existing data became progressively suspect. These problems were compounded by the impact of the Dengist-led program of reform and structural change, launched in 1978 and especially after 1992: the entire complexion of the Chinese economy has undergone a substantial transformation, especially in terms of the role of markets and the design of S&T organizations.

That said, it also is the case that China has made tremendous improvements over the last 10–15 years in pushing its S&T statistical system to be more accurate, open, and transparent. Unfortunately, as will be discussed later in the book, the available S&T data in China still remain plagued by quality problems, especially when compared with similar types of data from the OECD countries. In reviewing the data used in our analysis, we try to highlight in the text and the Appendix where we believe that existing data is simply off the mark and where possible, why (see also Gao *et al.*, 2006 for a discussion on the progress and problems of China's S&T statistical system). While throughout our research the problems associated with the data situation created multiple challenges, the only saving grace, if there is one, is that Chinese researchers and scholars must depend on the same sets of statistical materials and data that were made available to us, as they did for the MLP. In this sense, we feel confident in both the integrity and the completeness of the data contained in this book, even if it is not ideal from the perspective of our overall research goals and objectives.

[9] The Ministry of Personnel and the Ministry of Labor and Social Security were merged into the Ministry of Human Resources and Social Security in 2008, but the book uses all their original names unless to specify the impacts of the change.

Early on, we made the strategic decision that we could work within the framework of the current data problems and shortcomings; we did not believe there was much utility in trying to wait until such time as Chinese data may "catch up" with international standards to support the study of China's S&T system in general and HRST in particular. Instead, after multiple discussions with Chinese policymakers and researchers working in this issue area, we decided that we could "scrub" the reported data where necessary, filter and correct aberrant data points, and adjust for obvious inconsistencies to improve the quality of the overall dataset. Our conversations with an array of Chinese S&T policy analysts, academics, and government officials from the Ministry of Education, Ministry of Science and Technology, and Ministry of Personnel, as well as with the NBS, the CAS, and the CASS, among others, helped us to better understand not only the statistics themselves but also the actual trends and patterns of supply and demand, quality, location, and utilization of S&T talent in China.

In the final analysis, utilizing various Chinese statistical yearbooks and other open documents, we constructed a comprehensive working dataset on the scientific and engineering talent pool of the People's Republic of China, which yielded a broad range of information about the evolving Chinese S&T system, higher education system, and personnel situation. To further ensure the integrity of the data and analysis, we also carefully cross-checked all information and tried to provide useful interpretations to make the data as internationally comparable as possible. At the risk of exaggeration and claiming too much credit, as presented in this book, we believe that the final dataset used to produce this book and the associated analysis is the most comprehensive, most systematic, and best available inside and outside of China at present.