# CHINA'S EMERGING SCIENCE AND TECHNOLOGY TALENT POOL: A QUANTITATIVE AND QUALITATIVE ASSESSMENT[*]

*Denis Fred Simon*
*Cong Cao*
*The Neil D. Levin Graduate Institute of International Relations and Commerce*
*State University of New York*
*U. S. A.*

China's increased prominence in international and regional science and technology (S&T) affairs has generated a growing need for a deeper, more sophisticated understanding of its present and future S&T talent pool. This paper represents an overarching effort to analyze the evolving characteristics – quantitative and qualitative dimensions – of the Chinese scientific and engineering talent pool.

The paper starts with a discussion of the importance of talent to China's science and technology advance, education programs, economic growth, and social development. Then it takes stock of China's S&T talent situation, providing a description and analysis of its structure and main features, including in the tertiary education pipeline. The basic thrust of the paper is focused on providing a forecast of the growing demand for Chinese scientists and engineers (S&Es) in general and those S&Es involved specifically in research and development (R&D) in the early 21st century. The forecast is based on an examination of the key drivers underlying the growth dynamics of S&E talent in China. The paper also forecasts the projected supply of S&Es in China during the same time frame. Finally, utilizing fieldwork and interviews in several Chinese cities, the paper provides a preliminary assessment of the quality of China's S&T talent.

**Strategic Development and Utilization of High-Level Talent in China**

There have been conflicting stories about the prevailing talent situation in China. On the one hand, spending for S&T activities, R&D, and education has been accelerating over the last several years. The overall number of scientists and engineers and other trained professionals has been steadily increasing, and the education pipeline at the tertiary level is filled with literally millions of students entering colleges and universities in recent years. On the other hand, everyone – from the Chinese government and local employers to Western and Asian multinational corporations (MNCs) – is complaining that qualified talent is difficult to find and retain, and thus also is getting more expensive.

In fact, there is growing evidence that China faces a serious talent challenge as it seeks to sustain its economic growth over the next decade or more. The active members of the professional community are relatively young, even among those holding senior positions; many persons available in the talent pool are fresh out of school and basically are inexperienced. According to McKinsey, among Chinese professionals, only 10% of those with at least seven-years of experience are capable of working for MNCs (Farrell and Grant 2005). China's lack of talent is most serious among the 45-55 age group, especially at the high end as a consequences of the lingering effects of the Cultural Revolution between 1966 and 1976. This situation has been further exacerbated by the emergence of a so-called "brain drain" that has kicked in after China opened its door to the outside world in the early 1980s. Many Chinese sent abroad for advanced education have decided not to return to China, even though increasing numbers have started to straddle the Pacific Ocean and keep a foot planted in China's S&T community while they pursue their careers in the West or Japan. In areas where there is a surplus of talent, there tends to be a significant mismatch between the knowledge around which students have been trained and the types of jobs they are asked to perform. Moreover, the situation is worsened by the improper distribution of talent at senior and middle levels from a geographic perspective: while the central government seeks to drive development in Western China as well as the Northeast, talent continues to move east to cities such as Beijing, Shanghai and Shenzhen.

Given the steadily increasing urgency of the situation, the ruling Chinese Communist Party (CCP) and the government have become much more steadfast in their determination to address the country's talent problems. Simply stated, they have stepped up their efforts through the Organization Department of the Party as well as through local governments to train, attract, retain, and better utilize talent. Most important, they seek to create an environment conducive to achieving the goal of "strengthening the nation with talent" (*rencai qiangguo*). Given the checkered history of China regarding the treatment of intellectuals since 1949, this is a major advancement, one that could erase some of the hesitancy some Chinese scientists and engineers have had about returning home to China after starting their careers abroad. To its credit, China's current leadership views talent, along with science and education, as the key to building a harmonious and comprehensive well-off society, to solving the nation's emerging problems in environment, energy, urban-rural and regional development gap, social inequality, aging population, and national security. For the Chinese leadership, the effective training, development and utilization of talent is the key to transforming China into an innovative society by 2020.

It is from these perspectives that in May 2002, the General Office of the CCP Central Committee and the General Office of the State Council formulated an outline for the building-up of China's talent pool between 2002 and 2005. In December 2003, the CCP held its first ever conference on talent, calling for the creation of a more skilled professional labor force. While these measures followed the tradition that the Party administers cadres (professionals being part of the cadre strata), most significantly, Hu Jintao, the CPP general secretary and Chinese president, indicated in the conference that the talent issue is on a strategic level inside the Party and is intimately tied to China's overall, long-term national development.[1] This meeting reinforced a variety of changes with regard to the role and status of intellectuals that had begun with the launch of the reform program and open policy by Deng Xiaoping in the early 1980s. The main difference, however, was the new emphasis placed on the centrality of China's high end talent pool to the core goals of the government and the Party itself.

Towards this end, the CCP Central Committee and the State Council soon issued a formal circular on further strengthening talent, while the Party Central Committee's Department of Organization and the government's Ministry of Personnel started to survey China's talent situation so as to have a better understanding of the nation's talent situation. In the meantime, as China's medium- and long-term plan for the S&T development (2006-2020) was being formulated, the talent issue moved to front and center. In proposing to leapfrog stages in their own S&T development and become a so-called "innovative nation," the final plan suggested that China should focus on the structural adjustment of its talent pool, raising talent's innovative capabilities, and achieving better utilization of the existing talent ranks, while at the same time maintaining a suitable quantitative growth rate.

## S&T Talent in China

### Definition

The precise meaning of the term "talent" is as difficult to define in China as it is elsewhere (Pollak 1999). Operationally, four categories have been identified as the core components of China's S&T talent stock (Du and Song 2004). The first is S&T human resources, that is, the total number of those with at least two- to three-years of college education in an S&T discipline plus those in the S&T workforce who, despite not possessing relevant educational qualification, have equivalent professional experience. This category is the same as the S&T human resources definition used in the OECD's *Canberra Manual* (OECD 1995).

The second category is basically defined as "professionals." This broad category covers those working in 17 professions including engineering, agriculture, scientific research, public health, education, and others. This "professional" category was formulated by the Party Central Committee's Department of Organization and the government's Ministry of Personnel for the purpose of the management of professionals, noted above, and includes only those employed in state-owned institutions and enterprises.

Those personnel who spend at least 10% of their time in S&T activities fall into the third category, S&T personnel. This category counts scientists employed at independent R&D institutes and universities, engineers working inside enterprise R&D labs, and those working inside institutions of dealing with S&T information, graduate students at their thesis or final project stages, S&T administrators, and those who provide services to S&T organizations. This definition differs from that in *Canberra Manual*.

The fourth category is R&D personnel engaged in conducting, administering, and supporting actual R&D activities. R&D personnel in the Chinese S&T statistics are counted by their full time equivalent (FTE), that is, person-years. This definition also is similar to that used in the *Canberra Manual*.

Within the third and fourth categories are scientists and engineers (S&Es), who either hold professional job titles at the middle level or above or are graduates of four-year colleges and above even if they do not have professional standing yet. Thus, there are S&Es engaged in S&T

activities and S&Es engaged in R&D activities respectively, which are both subsets of total S&T personnel and R&D personnel, respectively. This paper is only interested in two subsets: 1) S&Es involved in S&T activities; and 2) S&Es involved in R&D activities.

S&Es in enterprises whose activities are primarily in the areas of production, technical sales and customer services, testing and quality control, and so on are excluded, although they may have the "engineer" title. There are statistical reasons for bounding our target groups in this fashion, namely, the fact that Chinese data is not organized in a manner that would easily lend itself to factoring in these other groups into our analysis without significant consistency issues.

## A Stock-Taking of the Chinese S&T Talent Base

Since 1990, China has witnessed a steady increase of its S&T human resources (Table 1). In 2004, the latest year when such statistics are available, China had 3.48 million persons engaged in S&T activities with 2.25 million being S&Es. In the same year, China devoted 1.15-million person-years to R&D, with S&Es accounting for 926,000 person-years, only second to the U.S. in terms of global comparisons.

[Table 1 about here]

## Characteristics

Chinese S&Es, as their counterparts in other countries, work at universities (15.9% in 2004), research institutes (11.7%), and enterprises (72.4%). The distribution of R&D personnel in the same year was 22.3% at universities, 17.1% at research institutes, and 60.6% at enterprises. The large number of S&Es working inside enterprises in general and engaged in R&D specifically would suggest that the principal source of innovation in China is occurring inside companies. However, the situation in terms of personnel distribution also reflects the impact of the S&T reforms, especially the transition of many former government R&D institutes into the commercial enterprise category.

Geographically, S&Es are heavily concentrated in eastern China, including Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan, which accounted for 59.3% of S&Es and 60.8% of S&Es engaged in R&D in 2004. Further, S&Es apparently are concentrated in seven provinces or municipalities – Beijing, Jiangsu, Guangdong, Shandong, Zhejiang, Shanghai, and Liaoning. Sichuan and Shaanxi in the West, Hubei in central China, and Zhejiang in the East are among the top ten regions with the most S&T human resources.

No statistics are available regarding the age structure of China's S&T talent contingent. However, a general review of the situation reveals that the S&T cohort in China is relatively young. This can be deduced simply by examining the number of S&E-type graduates over the last several years. Of the current 2.25 million S&Es, half are new graduates possessing at least a bachelor's degree in science, engineering, agriculture, and medicine. For those working at civilian R&D institutions, in 2004, 71.6% were under 45 years old, and 55% of the S&Es with senior titles were under 45 years old. Those between 35 and 49 years old constituted 51.4% of the overall total in 2004, compared with 44.5% in 1999.[2] This indicates that the ranks of China's S&T workforce, while clearly having become more experienced, also has an increasing number of persons holding senior positions with relatively less experience than their counterparts in the West.

**S&T Talent in the Pipeline**

Since 1999, China has witnessed an exponential explosion of enrollment in higher education (Table 2).[3] The total student enrollment in higher education reached 23 million in 2004, including some 14 million in the regular institutions of higher education and 9 million in programs of adult education, TV and broadcast education, and so on. Half of the enrolled students were at the baccalaureate level.

[Table 2 about here]

In particular, undergraduate science majors increased by about three times between 1999 and 2004, as did engineering students, keeping pace with the overall strong growth in total enrollments. The absolute number of graduates in science, engineering, agriculture, and medicine has been increasing steadily. There also are considerably more engineering than science graduates at all levels of study, from undergraduate to doctorate. In 2004, China enrolled 820,000 students into master's and doctoral programs with over 60% in science, engineering, medicine, and agriculture.[4]

In 2004, China turned out 2.4 million undergraduate students and 151,000 graduate students (masters and PhDs). The graduates are the chief source of talent supply to support China's economic and social development as well as scientific and educational enterprises. China awarded 23,500 doctorates in 2004, of which some 70% went to students in science, engineering, agriculture, and medicine. These students are largely deployed in universities as well as think tanks such as the Chinese Academy of Sciences.

## Demand and Supply of S&T Manpower

### Demand and Its Drivers

According to the regression analysis underlying this research, the growth of the Chinese economy has been and will continue to be driven by four main factors: 1) China's increasing integration into the world economy; 2) China's technological development based on the growth of indigenous S&T and R&D activities; 3) the increasing technological sophistication of the PRC economy and society; and 4) the rising level of Chinese participation in the global value chain as reflected in the expansion of high technology exports by Chinese firms and MNCs. As the Chinese economy grows on each of these four dimensions, the demand for scientists and engineers will steadily increase, even allowing for performance improvements, productivity and efficiency improvements, etc. The role of scientists and engineers in the economy and society is also expected to appreciate.

During the past two decades, the Chinese economy has been growing at an astounding 9.5% annually. As a result of its sustained rapid economic growth, China today is the world's fourth largest economy in terms of nominal gross domestic product (GDP) or the world's second largest economy after the USA in purchasing power parity (PPP) terms. China has also been integrated into the world economy, as evidenced by its joining the World Trade Organization in 2001 and the growing participation of foreign companies in the Chinese economy.

More specifically, China's economic growth has been fueled in many key sectors by the large increases in foreign direct investment (FDI) that have occurred since the announcement of the open policy in the early 1980s. FDI continues to be an important component of economic development, although it is probably not going to see the level of significant increases in absolute value as seen in the past – from around US$40 billion in the late 1990s to US$60 billion in 2005. The focus of FDI has been shifting from labor-intensive manufacturing in such product areas as toys, textiles, shoes, and furniture, to higher-value added types of investments in computers and office equipment, pharmaceuticals, and electronics. Essentially, FDI has been the principal growth driver of China's information and telecommunication technology (ICT) industry and related high-tech exports. FDI also has expanded from manufacturing into R&D, evidenced by some 750 R&D centers established by MNCs as of September 2004, with companies such as Motorola, IBM, GE, P&G, GM, Microsoft, Intel, Nokia, Siemens, and Samsung having made significant R&D investment (Wang 2005:8).[5] The forms of FDI also have changed, with two-thirds of the projects now being wholly foreign owned enterprises (WFOEs) in 2004. Within the WFOE structure, foreign firms are more comfortable putting high-technology content into their ventures, likely leading to a quality improvement and structural change in the content and composition of FDI in the years to come.

China is on an explosive trajectory to becoming a knowledge-intensive information society. The country already has the world's largest base of mobile subscribers – 426 million as of mid-2006 and is expected in 2007 to replace the U.S. as the country with the largest number of Internet users (the number was 123 million as of mid-2006). Increasing household PC ownership and telecommunications infrastructure will give the ICT industry further room to grow. The coming launch of the third-generation (3G) mobile service will be another stimulant for FDI and China's ICT industry. Informatization is embedded in the changing composition of FDI and the growth of China's high-tech industries.

With all of these changes taking place, there is likely to be a concomitant rise in the demand for more S&T talent. The demand also is likely to be exacerbated by China's increased emphasis on indigenous efforts regarding technological development. China's leaders hope to guide the country toward becoming a so-called "innovative nation" by the year 2020, as specified in the new medium to long-term plan for the S&T development (2006-2020) announced in January 2006.

Since 1999, China has increased its spending on S&T, R&D, and education. At 1.34% of GDP in 2005, China's gross expenditure on R&D (GERD) is below the level of most developed economies (which is about 2.7-3.0%) and short of the goal set for that year (which is 1.5%). Nonetheless, it still exhibits the highest S&T spending level among those economies at a similar level of development (GERD as a percentage of GDP was 0.78% for India in 2001, 1.04% for Brazil in 2000). At this time, China is well on its way to achieving its goal of spending 2.0% of its GDP on R&D by 2010. Most impressive is the fact that much of the recent growth in GERD has derived from enterprises. As a whole, the contribution from enterprises – more than 60% in 2004 – has reached the average level of OECD countries. As mentioned, there are some unique reasons for the deepening of R&D activities inside Chinese enterprises, but even taking these into account, the fact remains that the locus of innovation in China is indeed shifting to corporate actors rather than formal independent research institutes.

Similarly, Chinese leadership understands the importance of education to China's potential S&T leap-forward as well as economic and social development. China has increased education expenditures over the last decade and will continue to do so in the years to come. In fact, China has much room to grow in this regard. Measured by education spending as a percentage of public expenditure, China's 3.32% is among the lowest in the world (the same indicator in 2002/03 was 4.1% for India and 4.3% for Brazil). Still, the investment in the upgrading of Chinese universities has been substantial by domestic standards, with universities now becoming a more central player in the R&D system instead just being primarily teaching institutions. New facilities have been built throughout the country, many with advanced equipment and research space. The principal shortage has been in the area of qualified faculty to teach the growing number of university students at the graduate and undergraduate levels.

The growing technological sophistication of the Chinese economy and society is reflected not only in the increasing number of Chinese receiving higher education, as described above, but also in the increasing share of high-tech exports in the country's overall trade. In 2004, China's high-tech exports hit US$165.5 billion, representing a more than 58-fold increase over the level of high-tech exports in 1991. China's high-tech sector also has started to move up the value chain as the result of both the changing structure of FDI and China's indigenous efforts.

Finally, on average, scientific research has outperformed other occupations in wage terms, with those working in the ICT sector being among the best paid in China. Because of the increasing mobility of global talent and in response to some of the prevailing as well as projected shortages of needed talent, wages in these advanced sectors have been steadily converging with international levels in the US and Europe. Headhunters in Beijing and Shanghai report that Chinese firms such as Huawei and Datong as well as Lenovo find themselves paying closer and closer to U.S. wages to attract qualified talent to their R&D labs and engineering-design units.

In summary, China's indigenous S&T initiatives as measured by increasing spending on S&T, R&D, and education will drive the growing demand for S&Es, while the structural changes in FDI will "super-charge" the thrust of demand. The growing informatization of the Chinese society and the growth of the domestic high-end market mainly will serve as the key intervening factors – fostered and shaped by the changing face of FDI and indigenous innovation efforts. The domestic market also will become a more important force underlying the growth in demand, especially when the supply-demand gap becomes narrower.

Supply

In addition to the existing S&T talent base in China, the future supply of scientists and engineers will come from graduating students in science, engineering, agriculture, and medicine to offset the growing ranks of retired S&Es (older generation), and to a lesser extent, from those who return from overseas study and work experiences from abroad (to be discussed below).

However, the problems caused by the increasing supply of college graduates have become quite obvious, revealing themselves as early as three-to-four years after the 1999 enrollment hike. The main source of these problems is that the growth in overall enrollment occurred with no reference or guidelines in terms of specialization or niches, no consideration of demand, nor any preparation for dealing with the qualitative aspects of newly trained graduates. While at this point the economy has not created enough jobs requiring higher education graduates, the peak of college graduates coincides with the growth of the urban working population, the reform at the state-owned enterprises – which involves employee layoffs, and the migration of rural youth to the urban areas. Inevitably and as in many other countries, a surplus of college graduates has emerged. Between 2003 and 2005, only 79-89% of the graduates became employed, though there is no clarity as to the actual match between supply and demand in specific fields.[6]

Consequently, as the economy reaches an even higher level of labor excess among college graduates over the next few years, the supply of S&Es will be even less responsive to labor market conditions because of the continued expansion of enrollments. Under such conditions, wages may not be the most accurate barometer for understanding the supply and demand for S&T human resources in China as Chinese leaders do not seem prepared to retreat on their "higher education push" and their associated commitment to grow and improve tertiary education.[7]

Demographics

The supply of S&Es also is tied integrally to a nation's demographics. It is clear that China's 18 to 22-year-old group cohort, the college-bound one, will begin to shrink after 2010, apparently due to the one-child policy (Figure 1). The decrease of college graduates obviously will have a negative impact on the overall number of S&Es entering the workforce. That is, even if China wants to maintain a large pool of S&Es in reserve, it might be unable to do so because of the unfavorable demographics.[8] It is under these circumstances that China probably has a narrow "window of opportunity" from now to 2020 and beyond to grow its high-quality S&T workforce from the perspective of ensuring a better match between the demands of the economy and technology system and the types of graduates and professionals being educated within the country's institutions of higher education.

[Figure 1 about here]

## Forecast

The research study which provides the principal source of data for this paper is aimed at analyzing and projecting supply and demand trends re: China's high-end talent pool to 2010 using a linear regression-based methodology. Along with assessing the dynamics of supply and demand for high-end S&E talent, it looks specifically at S&Es involved in R&D activities to gauge the technological potential and innovative capacity of China from a people perspective.

Variables and Data Sources

National data between 1989 and 2004 with the following variables:

Dependent variables

- Scientists and engineers in S&T activities (S&Es in S&T)
- Scientists and engineers involved in R&D activities (S&Es in R&D)

Independent and intervening variables

- Spending: S&T expenditure; Gross expenditure on research and development (GERD); Education expenditure
- Integration of Chinese economy into the world: FDI utilized
- Informatization of society: Gross industrial output value (GIOV)-IT as% of GIOV, embedded in FDI utilized and high tech exports.
- Technological sophistication: graduating undergraduates and graduate students in science, engineering, agriculture, and medicine; high-tech exports
- Relative wage of R&D profession to the national average wage – a proxy that reflects the market force

Data Sources

- *China Statistical Yearbook* (Beijing: China Statistics Press, various years)
- *China Statistical Yearbook on Science and Technology* (Beijing: China Statistics Press, various years)
- *China Statistical Yearbook on Education* (Beijing: China People's Education Press, various years)
- *China Statistics Yearbook on High Technology Industry* (Beijing: China Statistics Press, various years)
- *China Labor Statistical Yearbook* (Beijing: China Statistics Press, various years)
- *China Population Statistical Yearbook* (Beijing: China Statistics Press, various years)

Models (Figure 2)

Linear regressions have resulted in two models with significant coefficients:

- Model 1: S&Es in S&T (or S&Es in R&D) = f (FDI, S&T expenditures)
- Model 2: S&Es in S&T (or S&Es in R&D) = f (High-tech exports, and R&D wages relative to national average wages)

Problems of multicolinearity were identified due to the limited number of observations and also the nature of the independent variables, which prevented us from including more independent variables into the regression models.

Forecast of Demand for S&Es

In addition to the historical trends, forecasting the demand and supply for China's S&Es has taken into account the following available information (see below). Our goal has been to analyze supply and demand conditions using a linear extrapolation based on recent historical growth trends as well as taking into account possible discontinuities in growth reflecting possible changes in the drivers of economic development over the next 5, 10 and 15 years.

- Forecasts of China's economic growth by Goldman Sachs (known as the BRICs report[9])
- Forecasts of China's population growth by the United Nations Population Division
- Chinese government's policy initiatives in the areas of science and technology as well as higher education; talent growth and development; high-tech development, and several other areas, e.g. ICT.

Using our historical and discontinuity models, we have come up with three scenarios – historical, downward, and upward – for each of the demand models between 2005 and 2010.

- **Historical**: values of the independent variables forecasted using their historical trends;

- **Model 1, upward**: FDI 8% increase and S&T expenditure (or GERD) 15% increase annually;
- **Model 1, downward**: FDI 2% decrease and S&T expenditure (or GERD) 5% increase annually;
- **Model 2, upward**: High-tech exports historical trend and R&D relative wage 10% increase annually;
- **Model 2 downward**: High-tech exports only 10% increase and R&D relative wage flat after 2004.

From these different extrapolations, we have assessed a broad range of possibilities, which represent the lowest and highest possible outcomes on the demand side, and a narrower one, which we believe to be most likely to happen (Table 3).

[Table 3 about here]

Our forecast is as follows: China needed some 2.64 million S&Es in 2005 and will require 3.85 million S&Es in 2010. China's 2015 and 2020 demand requirements for S&Es are 5.9 million and 8.9 million respectively. China needed 1.09 million full-time equivalent (FTE) S&Es engaged in R&D activities in 2005, and this demand will increase to 1.75 million FTE S&Es in R&D in 2010. This forecast is significantly higher than that by Chinese S&T policy analysts when they prepared the medium- and long-term plan for S&T development (2006-2010) based on data up to 2001. According to that forecast, China was predicted to have between 743,000 and 1.13 million FTE S&Es involved in R&D activities in 2005 and between 848,000 and 1.75 million FTE S&Es in 2010 (Li and Yu 2004).

Our forecast of demand for the years of 2015 and 2020 used Model 1 in five scenarios. From analyzing these scenarios, we derived a range of S&Es involved in R&D activities for the years 2015 and 2020 and reached our forecast.

Forecast of Supply of S&Es

In forecasting the supply of S&Es, we have taken the following factors into consideration:

- retirement of the existing workforce: the statuary retirement age is 60 years old for male and 55 years old for female.
- on average, 88.7% of males aged between 16 and 60 years and 78.3% female aged between 16 and 55 years are in the labor force.
- 75% of those with master's degrees or above have become working S&Es.
- the 2005 placement rate for those undergraduates trained in science, engineering, agriculture, and medicine into the areas for which they have been trained will be the average of the rates between 2001 and 2004.[10] Thereafter, the placement rate will increase 5% annually until 2020.

Based on this data, we forecast that China only will be able to supply 2.38 million of S&Es in 2005 and 3.48 million S&Es in 2010. We could not forecast the supply of S&Es involved in R&D activities as they are counted only as FTE**.**

S&T Talent Shortage

The above forecasts imply that China's demand for S&Es between 2005 and 2010 will not be met by the current supply pool (see Table 3). However, the gap between the supply and demand will decrease over time, especially as current graduates move up the experience and learning curve. Our research suggests that the placement rates of science and engineering graduates gradually will improve from 15% in 2005 to around 30% in 2020. Under such conditions, and assuming that market and wage adjustments begin to affect, to some degree, choice of majors by college students, supply and demand could reach equilibrium.

Given the projected demographic shift that will occur around 2015 when China will have a larger population in the 55-60 age group than that in the 18-22 age group, it is expected that the supply of S&E graduates could flatten out and perhaps even start decreasing. While this is not inevitable, given the fact that a smaller and smaller percentage of graduates are majoring in science and engineering (still high by US standards), there could be a real impact on the supply side. This would be ironic in view of the huge numbers entering S&E fields – past and present.

The Unknown – The Chinese Diaspora

Theoretically, the Chinese Diaspora is a potential source of "brain gain," a reverse migration or return of overseas Chinese. China's efforts to lure their native sons and daughters back home after they have been trained overseas, including various programs targeting overseas Chinese mentioned above, has had some success. For example, the sitting number of university presidents and professors in Chinese universities are overwhelmingly returnees, though they are most likely to have been short-term visiting scholars rather than degree-holders (Li 2005). An increase in the number of returnees would counteract, to some extent, the tendency for Chinese "high fliers" in research and other professions to go and remain overseas. But, it still remains to be seen whether more high-level talent will make a permanent move back to China.

## Quality Assessment

S&T Workforce and Productivity

Of the current 2.25 million S&Es, 340,000 have master's degrees or above, indicating a gradual improvement of the S&T workforce in terms of education and output. For example, in terms of publications indexed by the major international citation system, China ranked No. 5 in 2004, representing a significant improvement in terms of number of publications during the past 15 years.

Lack of High-Quality S&T Talent

Based on field interviews conducted in several Chinese cities, our research suggests that China still lacks an adequate pool of qualified talent (with respect to experience and behavior) capable of leapfrogging in S&T, education, and the economy. Frustration at the lack of major breakthroughs in scientific research and technological innovation is still ever present among Chinese leaders, who consistently have been looking to China's S&T system for signs of progress that the technological gap between China and the West/Japan actually is decreasing. This is especially the case in view of the huge emphasis placed on the ownership and control of intellectual property rights and technical standards in the global marketplace today. It is therefore no surprise to see the government emphasizing, on an increasing basis, programs to recruit Chinese talent from abroad as well as to enhance the quality of higher education, especially within China's most elite universities.

With the damage of the Cultural Revolution fading, we believe that the impact of the "brain drain" has become more serious. What has not been formally taken into consideration in our forecasts is whether the Chinese Diaspora will become a contributor to the motherland's talent pool, and if yes, how significant the impact will be.[11] The large Chinese Diaspora could be a significant benefit strategically and practically, especially in terms of transfer of knowledge and attraction of foreign capital for high-tech endeavors and local entrepreneurship. Many Chinese who have remained abroad still remain connected to China's S&T system, and often serve as a source of scientific and technical communication at the very least. In other cases, as indicated, Chinese scientists now based in the U.S. frequently run labs in China as a way to access high quality graduate students or engage in specialty research with grants from the Chinese government. While this type of contribution has its very positive aspects, it also has produced all sorts of conflicts and petty jealousies from among those who feel these “outsiders” receive special treatment while not having to deal with the challenges of working inside China’s R&D system.

The most serious problem facing China’s innovation system today is the experience gap for the current S&T talent pool. The key reasons for this gap may lie in the fact that those fresh out of university do not have the experience to handle the type of tasks that requires knowledge and skill sets beyond formal education. Based on discussions with many MNC executives as well as Chinese R&D managers, there is an apparent mismatch between the areas in which students have been trained and the jobs they are asked to perform. In addition, many students simply were not trained with proper skills and knowledge for the new jobs emerging in China. Last, but not the least, there is a pronounced concern about the lack of creativity and entrepreneurial behavior among those recently trained. This lack of creativity also reveals itself in discussions about the limited aptitude of recent graduates for risk-taking and the low level of failure tolerance inside the prevailing operating culture of the innovation system.

Higher Education

Key Chinese universities, with increasing funding from the government and other sources, can now afford to attract highly-qualified faculty members, mainly Chinese-origin, from abroad with higher salaries and significant research support. At Qinghua University, the School of Economy and Management, for example, has recruited a team of overseas Chinese economics professors from such institutions as the University of California at Berkeley, MIT, Columbia, and the London School of Economics as endowed professors to lead teaching and research. Some universities have started to recruit non-ethnic-Chinese scholars. As early as 2001, Qinghua's Department of Industrial Engineering appointed Professor Gavriel Salvendy from Purdue University as its chairman. Most recently, the Ministry of Education has appointed some non-ethnic-Chinese professors from abroad to its Cheung Kong Scholar Program. Now, the minimum requirement for new hires at key universities is a doctoral degree and the competition has become fierce. On average, 7% of Chinese professors have doctorates, with 20% at key institutions of higher education and more than half at Beijing and Qinghua universities.[12] This low level of doctorates among university faculty on the whole is one reason for the problems with the unevenness in the quality of higher education across the country. It also helps to explain why China, with such a large contingent of new graduates in engineering still is not able to leverage that seemingly large pool of talent for driving to a higher level of innovative behavior in economic and technological terms.

China's higher education system has shown marked improvements, especially at key institutions. Many schools are now internationally acclaimed. The high level of enrollment of Chinese undergraduates in the world's leading graduate programs in the US and Europe reflects evidence of the quality of Chinese universities, especially in terms of math and science. Between 1999 and 2003, Beijing University and the University of Science and Technology of China in Hefei were the two largest baccalaureate origin institutions of U.S. doctorates in physical science (558 and 461 doctorate recipients, respectively), surpassing both MIT and UC Berkeley by well over 100 doctorate recipients. In engineering, for the same period, Qinghua University was the largest baccalaureate origin, with more than twice as many graduates earning

U.S. doctorates than the largest U.S. origin institution, MIT (863 versus 344) (Hoffer, Selfa, Welch, and et. al. 2004:Tables 32 and 33).

Having said this, China's key universities as a whole are still not on par with, and in fact, lag far behind, many of their counterparts in developed countries as well as in some Asian countries and regions, including Hong Kong and Taiwan. According to the academic ranking of world-class universities by China's Shanghai Jiaotong University (based on four criteria – quality of education, quality of faculty, research output, and size of institution) in 2005, Qinghua and Beijing universities, China's most prestigious, ranked somewhere between 153 and 202 and between 203 and 300 in the world respectively, although there has been a trend of upward mobility for both schools.[13]

Furthermore, as implied above, the quantitative increase in gross enrollments in China's higher education system in recent years has been at the expense of quality improvement or control. Apparently, a diploma from Qinghua and Beijing universities is significantly different from one awarded by a little known college in an interior city. To maintain the pipeline and throughput, graduate schools have an incentive to train ever-increasing numbers of students so that they perform the work on research grants that bring money into universities and attract new professors. However, it is quite common that one professor has ten doctoral students in China. Concern about the quality of graduate education also comes from the trend where students from key universities go abroad for advanced study, leaving those from non-key universities to fill the slots at the key domestic schools. In other words, in a growing number of instances, the higher the level on the educational ladder, the lower the quality of students. This could jeopardize the long-term sustainability of China's high-quality talent growth.

## Conclusion

Our forecast of the future demand for S&T talent in China has captured the projected changes and shifts in the nature of Chinese economic growth – away from FDI-dependent growth, to higher levels of informatization in economy and society, and ultimately to more emphasis on indigenous efforts to drive scientific and technological advance. The demand for S&Es was most likely around 2.64 million in 2005 and will increase to 3.85 million in 2010. However, in all likelihood, based on our analysis, China only was able to supply 2.38 million S&Es in 2005 and only will be able to supply 3.48 million S&Es in 2010. Therefore, China will face an S&T personnel shortage quantitatively, although on paper it is able to produce more than enough students in science, engineering, agriculture, and medicine to supposedly meet the demand for the S&T talent and replacement of the retired S&Es.

The projected talent shortage will derive, largely, from the fact that China is not able to place its young graduates in science and engineering into jobs in the fields for which they have been trained and into regions where talent is in greatest demand. Talent continues to move east, while demand for talent in the west is not being met – which negatively affects the growth trajectory of these lesser developed regions. While the number of Chinese having tertiary education has increased significantly, quality issues will continue to plague the Chinese workforce and could constrain the country's further economic growth in terms of indigenous innovation and technological advance. The shortage of experienced S&Es in China plus the lack of appropriately skilled talent will have implications for China's long term economic growth and the global redistribution of S&T human resources. Our forecast models expect that the demand for S&Es in the PRC, most likely, will come from new types of higher value-added FDI, growing manufacturing-driven high-tech exports, enhanced market forces regarding wages, and

China's indigenous innovation efforts. Quality aside, a perception that the country is facing a talent crisis could signal to MNCs to slow down their new investments in China and thus reduce their potential contributions in terms of continuing to drive the growth and deepening of China's high-tech exports and also high tech industrial development.

The overall demographics of China's current S&T workforce indicate a comparatively young cohort, though it is seemingly quite well educated. It also should be noted that an increasing number of China's leaders at the national and local level have science and engineering backgrounds, and a growing number have had overseas training experiences in their respective fields. China's Minister of Education, for example, Zhou Ji, received his PhD from the State University of New York at Buffalo. Vice-Minister Shang Yong, from the Ministry of Science and Technology, was a Visiting Scholar at Harvard's Kennedy School of Government. Returning to the broader view of the Chinese talent pool, among the 2.25 million S&Es deployed in 2004, half are so-called "new entrants," having graduated during the past ten years; approximately 350,000 have graduate education credentials. For those working in civilian R&D institutions in 2004, 71.6% were under 45 years old. This "youth" trend is going to remain over the next 15 years.

For the group aged between 18 and 22 (ready for college education), however, there is going to be a decline appearing after 2010. Most important, this group will be surpassed in number by the age group of S&Es in the 55 to 60 years old category (approaching retirement age) around 2015. In multiple respects, this important demographic shift could prove to be greatly disadvantageous in terms of the growth of Chinese talent pool beyond 2020. China may have started on the path to becoming a richer society, but it is more likely to become an "aged society" before it truly becomes a wealthy society.

Most critical for the long term, China's talent challenges have been exacerbated by the absence of a "culture of creativity" that could allow China's S&T community to leapfrog ahead in S&T, education, and the economy. In many ways, the level of frustration regarding the shortcomings of China's innovation system is growing – even as the government has initiated various policy measures that favor talent enhancement. This suggests we are likely to see even more attention paid to the talent issue at the highest levels. Perhaps the best indicator of this sensitivity about creativity and innovativeness was the announcement by the National Bureau of Statistics, China's highest data collecting and processing organization, that it was going to create a series of indicators to track the country's progress towards becoming the type of "innovative nation" as described in the various recent documents coming from China's State Council as well as the Chinese Communist Party.

In the final analysis, China's ability to leverage, to the fullest extent, the innovative potential of its talent pool will necessarily depend on the changing nature of the operating environment in which scientists and engineers find themselves. While there clearly is some degree of change proceeding ahead in terms of greater transparency and higher tolerance of risk and failure, the fact remains that there still are many barriers to overcome before the full capabilities and skills of the domestic talent pool can be realized. In this regard, in the coming few years, the greatest threat to the government's S&T plans may have less to do with the issue of an "external brain drain," and more to do with the increasing evidence of an "internal brain drain." In the case of the latter, unfortunately, Chinese companies and research units may find local Chinese talent steadily moving into new positions with new, high-value-added foreign manufacturing operations or foreign R&D centers rather than into domestic organizations because of the prevailing differences in operating culture, business environment, and career potential. Taking a lesson from Taiwan, it is clear that over time an appreciable number of these persons will move out of the foreign sector and become a future source of local technological entrepreneurship and indigenous innovation. Right now, how quickly this will occur, however, remains to be seen. In the meantime, there will continue to be multiple inhibitors in place – a culturally and politically as well as socially – that will continue to moderate the capacity of China to capture the full potential of its talent pool, irrespective of the supply-demand equation.

**Bibliography**

Qian Du and Weiguo Song. 2004. "The Definition of S&T Talent and the Related Statistical Issues" (in Chinese), *China's Forum on Science and Technology*, No. 5.

Diana Farrell and Andrew J. Grant. 2005. "China's Looming Talent Shortage," *The McKinsey Quarterly*, No. 4.

Thomas B. Hoffer, Lance Selfa, Vincent Welch, Jr., Kimberly Williams, Mary Hess, Jamie Friedman, Sergio C. Reyes, Kristy Webber, and Isabel Guzman-Barron. 2004. *Doctorate Recipients from United States Universities: Summary Report 2003*. Chicago, IL: National Opinion Research Center.

Cheng Li. 2005. "Coming Home to Teach: Status and Mobility of Returnees in China's Higher Education," in *Bridging Minds across the Pacific: U.S.-China Educational Exchange, 1978-2003*, edited by Cheng Li. Lanham, MD: Lexington Books, pp. 69-110.

Xiaoxuan Li and Jie Yu. 2004. "A Forecast on the number of R&D scientists and engineers in China" (in Chinese), *Science Research Management*, Vol. 25, No. 3, pp. 124-130.

OECD. 1995. *The Measurement of Scientific and Technological Activities: Manual on the measurement of Human Resources Devoted to S&T ("Canberra Manual")*. Paris, France: OECD.

Melissa Pollak. 1999. *Counting the S&E Workforce—It's Not That Easy* (Issue Brief, NSF 99-344). Arlington, VA: Division of Science Resources Studies, National Science Foundation, May 3.

Sylvia Schwaag Serger. 2006. "China: From Shop Floor to Knowledge Factory?" in Magnus Karlsson (ed.), *Internationalization of Corporate R&D: Leveraging the Changing Geography of Innovation*. Stockholm, Sweden: Swedish Institute for Growth Policy Studies, pp. 227-266.

Wang Zhile (ed.). 2005. *2005 Report of Multinational Corporations in China* (in Chinese). Beijing: China Economic Press.

Dominic Wilson and Poopa Purushothaman. 2003. *Dreaming with BRICs: the Path to 2050* (Global Economics Paper No: 99). New York: Goldman Sachs, 2003.

**Endnotes**

---

[*] Research on which the paper is based was partially supported by a grant from IBM. We would also like to thank Bojan Angelou, Bilguun Ginjbaata, and Howard Harrington, who helped to analyze the data. We appreciate as well the many colleagues in China who have provided guidance, access to sources of data, and their insights.

The research is a part of the Levin Institute's project, Global Talent Index™.

[1] Nevertheless, it is easier to pinpoint the problem than to solve it. For one thing, even though the talent issue has been on top of the agenda of the Chinese leadership, there is no an inter-ministry coordinating agency to tackle the urgent talent challenge.

[2] http://www.sts.org.cn/tjjg/documents/2005/051012.htm (accessed November 7, 2005).

[3] Increasing enrollment at universities was one of the measures that China adopted after the 1997 Asian financial crisis to stimulate domestic consumption. It has raised the educational level of Chinese as a whole.

[4] The increasing enrollment of graduate students may to some extent be due to the difficulty of college seniors finding jobs.

[5] According to Serger, the number of active foreign corporate R&D centers is between 250 and 300 (2006).

[6] According to the data released by China's Ministry of Personnel, employment rates for 2005 graduates varied from 96% for doctoral candidates to 82% for short-cycle course graduates and from 85% for humanity and social sciences and science graduates and 90% for engineering graduates. All these statistics count those who enter domestic and foreign graduate schools. Attending graduate schools would not only postpone several years for the students and government the situation of unemployment but also create a better pool of students to be chosen from.

[7] However, it should be noticed that increase in the enrollment of China's higher education since 1999 has to some extent hedged the coming drain of college-bound youth. See http://edu.china.com/zh_cn/1055/20051118/12862674.html (accessed on November 30, 2005).

[8] The difference between the U.S., European countries, Japan, China, and India in human resources lies in their respective demographic compositions. Given that the Indian population profile is younger than that of the Chinese, India might have high likelihood to sustain it economic growth. For a discussion on that, see *Business Week*, August 22/29, 2005, p. 55.

[9] BRICs refer to such countries as Brazil, Russia, India, and China.

[10] Our analysis indicates that China has had low and inconsistent record in placing undergraduates in science, engineering, agriculture, and medicine. But we expect this placement rate to be improved gradually.

[11] According to the criteria of China's S&T statistics, those who spend 10% of the time in S&T related activities and have the right credentials are supposed to be counted. But we don't know whether that is the case for S&Es from overseas who work part-time in China.

[12] http://ypa.zju.edu.cn/Article/ShowArticle.asp?ArticleID=1410 (accessed on November 22, 2005).

[13] http://ed.sjtu.edu.cn/rank/2005/ARWU2005_TopAsia.htm (assessed August 15, 2005).