1 *Human resources, technological innovation, and economic growth*

It has become a well established fact that a nation's economic growth depends heavily upon its overall talent base. The size, quality, and utilization of a country's human resources determine, to a great degree, its prevailing level of technological sophistication as well as its future technological trajectory. Under the broad umbrella of human resources, the role of scientific and technical personnel probably is the most critical; accordingly, the term – "human resources in science and technology" (HRST) – has become accepted internationally as one of the key metrics for assessing a nation's real and potential technological strength(s). In the aftermath of the Cultural Revolution (1966–1976) and the debilitating impact of that movement on China's innovative capabilities, Chinese leaders have come to understand and appreciate the need to develop and harness a large pool of highly skilled human resources to promote, support, and sustain the country's technological progress, economic growth, social development, and national security. It is this drive to create and deploy a well-trained, highly competent scientific and technical talent pool that stands out not only as one of the hallmarks of China's modernization program, but, in all likelihood, also the key variable that will determine the nature of China's competitive positioning in the coming years.

This book examines the contribution – real and potential – of China's talent pool to the enhancement of that nation's science and technology (S&T) capabilities. Our approach begins with a review of relevant schools of thought regarding the role of high-end talent across three dimensions. The first dimension addresses the relationship between human resources and economic growth. Treating human resources as form of "capital" and through careful economic analysis (though this is not the place to go into great detail about pertinent economic theory and associated econometric models), this perspective highlights the fact that human capital has a positive impact on economic growth through productivity gains for a society and economy as well as wage increases for individuals. Since the end of the Second World War, if not earlier, in the economic history of the world, developing as well as developed economies have been left with no choice but to follow a path of human resources-reinforced economic growth.

The second dimension looks at the pivotal role that talent plays in supporting rapid technological innovation. As Schumpeter and others have shown convincingly, innovation is an important engine of economic growth. Even more important, innovation has the potential to reshape the prevailing global economic and technological landscape. This is especially true for late-comer economies which seek to catch up and perhaps even leapfrog ahead. Without an ample-sized cohort of well-trained scientists and engineers who can carry out research and development (R&D) activities and turn research into new, commercially viable products and services, their future prospects may be quite limited.

The third dimension, still unfolding, relates human resources and globalization. The emergence of a so-called "global talent pool," if there is one, is the direct consequence of the "flat" world in which large numbers of highly mobile talented people are able to choose where they want to work and live as traditional notions of employment give way to more footloose, virtual models of job definition, job responsibilities, and performance expectations. In a globally flat world, employment is less and less tied to a fixed national or local space (Friedman, 2005). As the number of highly trained college graduates, especially in engineering and technology disciplines, has been growing significantly in the emerging economies such as China and India, an important transformation has been occurring, spurred on by adoption of more open, liberal economic and trade policies. In parallel with the changes in domestic policy that have been taking place in these emerging markets, an increasing number of multinational corporations (MNCs) have decided, for both strategic and cost reasons, to relocate their operations abroad for improved access to the growing number of skilled individuals as well as to rapidly expanding markets with large and increasingly affluent populations. By so doing, MNCs are hoping to capture the growing availability of talent on a worldwide basis and leverage those human resources globally to not merely maximize their financial returns but also strengthen their innovation capacity. The growing availability of these types of jobs may have helped to reverse the traditional problems of "brain drain" faced by countries such as China and India (Saxenian, 2006). However, in the meantime, ironically, there now is a growing apprehension about an "internal" brain drain problem that derives from the increasingly apparent tendency of "returnees" and domestic professionals to seek positions within the newly established R&D and engineering centers set up by MNCs in these countries and to forgo opportunities with domestic firms, universities, or R&D establishments. Thus, instead of a so-called "brain gain," there actually still may be problems for domestic organizations to attract "the best and the brightest." The growing intensity of the competition for talent is one of the defining features the globalized world of the twenty-first century.

This chapter will review the main core of intellectual thought surrounding each of the three areas. Each is important in helping us to better understand the Chinese case and to place the People's Republic of China situation in an appropriate global context. Of all China's vast resources, the talent factor may be the most strategically important to its overall development. Through our examination of current thinking on the role of talent, we also hope to highlight where the Chinese case may depart from the existing studies. In a word, we hope to bring about a better understanding of the logic of human resources development in China and lay a foundation for the discussions in the chapters to come.

Human resources and economic growth

A substantial body of scholarly and policy research has established the positive relationship between human resources or human capital[1] and economic growth. The use of the term "human capital" dates back to the American economist Jacob Mincer in the late 1950s (Mincer, 1958),[2] though the best-known application of the concept has been attributed to Theodore Schultz and Gary Becker, both Nobel Prize-winning economists who argued that "much of the unexplained

[1] For our purpose in the book, "human capital" and "human resources" are interchangeable.
[2] It is worthwhile to note that as early as 1890, Alfred Marshall noted that "the most valuable of all capital is that invested in human beings" (cited in Becker, 1993: 27; 1964/1994).

increase in productivity, wages, and economic growth recognized by economists could be explained by investments in human capital" (Brown, 2001: 5). Schultz, an agricultural economist, viewed human capital as a way of showing the advantages of investing in education to improve agricultural output, and by extension, to improve productivity and nation's wealth. According to him, there has been a "decline in the economic importance of farmland and a rise in that of human capital – skills and knowledge" (Schultz, 1980: 642). Schultz also demonstrated that the yield on human capital in the US economy was larger than that based on physical capital (Schultz, 1961).

The term "human capital" was coined by Becker (1993) because "people cannot be separated from their knowledge, skills, health or values in the way they can be separated from their financial and physical assets." Becker's seminal book, *Human Capital*, laid the foundation for the study of this subject area, whose importance has become more and more significant over the years (Becker, 1964/1994). In his view, "expenditures on education, training, medical care, and so on can be considered as investments in human capital," which, though intangible, may be further used to significantly enhance the economic prospects of a nation and the welfare of individuals (Becker, 1993). Though not replacing land, labor, or capital totally, human capital can be substituted for them to various degrees and be included in production.

In the 1980s, human capital, or more accurately, *the skills and knowledge that make labor forces productive*, along with technological change or innovation, were incorporated into economic growth theory. According to Robert Solow's (1956) neoclassical model of exogenous economic growth, output growth depends upon the growth of two factors of production – capital and labor – and upon exogenous changes in technology. This theory was quite useful in describing the growth experience of the USA and other industrialized nations, and helped economists to rule out some popular misconceptions about the causes of sustained disparities in growth rates, such as differences in tax codes and trade barriers. But for Robert Lucas (2003), also an economic growth theorist, technology, knowledge, and human capital – "all just different terms for the same thing" – hold the key to endogenous economic growth. He distinguishes the *internal* effects of human capital through schooling and the *external* ones, including on-the-job training or learning-by-doing, by pointing out that the latter is at least as important as the former in the formation of human capital and "even an important element in the growth of knowledge," because they "have to do with the influences people have on the productivity of others." According to him, a rise in human capital leads to a rise in national income with the level of income highly correlated to that of human capital (Lucas, 1988: 37–8).

It is Paul Romer (1986), however, who argues explicitly that knowledge is the basic form of capital and that economic growth is driven by knowledge accumulation. His model, also an endogenous growth one, includes four basic inputs – capital and labor, the two in Solow's theory, human capital, and technology – with the key being an adequate stock of human capital. He finds that "what is important for growth is integration not into an economy with a large number of people but rather one with a large amount of human capital" (Romer, 1990: S98). The development of new knowledge also follows the law of diminishing returns in production; that is, when a fixed input is combined in production with a variable input, say capital and labor, using a given technology, each additional unit of variable input yields less and less additional output, but investment in knowledge leads to increasing returns in marginal products. In other words, because of the spillover effects, or the *external* effects in Lucas's model, the stock of knowledge and embodied human capital determine the growth rate, and continuous investment into them can sustain the long-term growth of a firm as well as a nation. Indeed, in essence, Romer's research foresees the key drivers underlying the onset of the knowledge economy and the demand for talent in this new form of economy.

There is an extensive and rather detailed literature on rates of increasing return on education and training, primarily based on the human capital theory, beginning with the classical growth models developed in the 1950s and including the so-called endogenous growth models that are still widely applied in many current empirical studies. This literature mainly explores the direct quantitative relationship between investment in education and training *and* the level and growth in terms of per capita gross domestic product (GDP).

There is no doubt that investment in education is an individual's decision, as labor market earnings increase for individuals with more education as a result of gaining productive skills through schooling (Becker, 1993). Indeed, the human capital theory has been used to explain why individuals decide to make investment in education and on-the-job training. In particular, according to Becker (1993), high school and college education in the USA "greatly raise a person's income, even after netting out direct and indirect costs of schooling, and after adjusting for the better family backgrounds and greater abilities of more educated people." Such a claim, together with the assumption that school changes a student's life and perspective, suggest that independent of socioeconomic status, family dynamics, or the skills and knowledge that students possess prior to schooling, it is largely what takes place inside the classroom that contributes to increased earnings once students enter the labor market. Econometric estimates and quantitative analyses at the micro-level further explain a large portion of an individual's annual or monthly income by their level of education and work experience, and consistently show a statistically significant and positive financial gain of an individual's average years of education – even after controlling for other factors such as the parent's level of income or education. And, the economic payoff of higher education, in terms of the increased wages over lifetimes, is enormous. In the USA, for example, a college graduate earns about two-thirds more than a high school graduate in their lifetime (US Census Bureau, 2006).

However, "human capital accumulation is a *social* activity, involving *groups* of people in a way that has no counterpart in the accumulation of physical capital" (Lucas, 1988: 19). Further, returns to society and the economy as a whole may be even higher than those to the investing individuals if their colleagues are inspired by the new knowledge. This is because schooling that improves productivity and earnings at the individual level can plausibly be translated to increased growth at the national level. Consequently, *external* effects can lead to total returns exceeding the sum of the returns to those individuals who spent more time studying. In fact, it is the rapid accumulation of human capital that has driven rapid economic growth, and empirical evidence confirms this linkage. Not only has almost one-fifth of the increase in GDP between 1948 and 1973 in the USA been attributed to the expansion and enhancement of the American education system, the contribution of education to productivity rose from 25 percent to more than 30 percent between 1973 and 1981, even when productivity growth began to falter (Brown, 2001).

Moreover, it has become a recognized global phenomenon that accumulation of human capital leads to sustained economic development.

Robert Barro, for example, uses educational attainment as proxy for human capital to explain cross-country differences in economic growth rates.[3] He finds that the educational attainment of a country’s adult population is significantly and positively related to that country’s subsequent growth rate of per capita GDP. In particular, his findings imply that human capital and physical capital investment tend to work together, both being associated with faster national growth conditional on initial income. The channels of effects involve the positive effect of human capital on physical investment, the negative effect of human capital on fertility, and an additional positive effect on growth for given values of investment and fertility (Barro, 1991). In a similar manner, Benhabib and Spigel (1994) present cross-country evidence that the growth rate of total factor productivity depends on a nation’s human capital stock.

The success of economic “catch-up” by the USA, Japan, and newly industrialized economies further illustrates the importance of human capital development. The East Asian economic miracle is largely attributed, among other things, to the region’s sustained levels of investment in human capital over a long period. We can identify an “education miracle” behind the economic miracle (Haq & Haq, 1998) or describe economic development in East Asia as human resource-led development (Behrman, 1990). For example, to catch up with the advanced economies in the West, Japan, as a latecomer to industrialization and modern economic growth, invested heavily in education, especially in its early development stage. During the one hundred years between 1890 and 1990, Japan witnessed an increase in its citizens’ average schooling from 1.3 years to 11.5 years with an annual increase of 2.2%, but most dramatic increase occurred between 1890 and 1940 when the annual increase reached 3.3%, while the annual

[3] The average years of education of the population aged 25–64 is a proxy for the measurement of human capital. Apparently, all countries increase their average years of school over time. Enrolment rate, attainment rate, and quality also are important, though difficult to measure. Experience and further training will certainly also raise human capital. “Years of schooling” as a measure of human capital could be misleading as it treats years of schooling at different levels and different disciplines within the same level of education as the same. Other possible measures include attainment rates and enrolment rates. Quality of human capital is also difficult to measure. For a discussion on the measurement issue around human capital, see Bergheim (2005).

increase between 1890 and 1910 in particular was 4.4% (Godo & Hayami, 2002).

Massive development in the human capital stock through investment in education also has contributed to the economic take-off in South Korea. As a result of emphasizing education for decades and acting accordingly, Koreans raised their average years of education from 7 years in the early 1970s to around 13 years in 2003, faster than the rate of economic growth (Bergheim, 2005: 14). Singapore's industrial training system, under government's guidance, is now considered one of the best in the world for high-tech production (Lall, 2001: 159–61). In general, in these types of vibrant economic settings, a 10 percent rise in human capital leads to a 9 percent rise in GDP per capita over the long run (Bergheim, 2005: 9).[4]

However, Jones (1995b) finds that over a period of time the growth rate of the United States' economy has not responded to the steady increase in the number of scientists engaged in R&D and other measures of research intensity. To explain this, he proposes the economy's growth rate is proportional to the rate of growth of population, that is, increasing the size of the talent pool has a scale effect on the level, but not the growth rate, of per capita GDP (Jones, 1995a). This accommodation to the more broadly held view about the synergies between growth and human resources development only serves to highlight the fact that a country's talent base becomes increasingly important over time and that importance does not recede even as industrialization proceeds ahead or the transition to a knowledge economy begins.

Talent and technological innovation

There is little doubt that the combined imperatives of competition and wealth creation in the knowledge-economy era demands a well-trained and highly skilled labor force, and, in particular, innovative scientific and technical personnel. Indeed, research has been

[4] The region also benefited from rapid accumulation of physical capital, an increasingly sophisticated internal and international division of labor, rapid demographic transition, and endogenous growth factors, including institutions and values. Nevertheless, investments in education seem to be central to the economic success of the East Asian economies (Wood & Berge, 1997).

conducted on the role of talent in creating, disseminating, and using knowledge and in driving and sustaining technological innovation.

In his Nobel Lecture, Schultz (1980: 648) points out, "it is important not to overlook the increase in the stock of physicians, other medical personnel, engineers, administrators, accountants, and various classes of research scientists and technicians." In particular, it was engineers and scientists and other highly skilled workers, not raw labor, who performed high-end R&D and innovative activities (Romer, 1990). And scientists tend to speed up the rate of innovation, reduce the cost of innovation in leading economies, and help latecomers to be more adaptive to technologies that were discovered elsewhere (Nelson & Phelps, 1966). In a word, S&T talent can effectively raise the growth rate in leaders as well as followers in economic development by way of technological innovation.

Technological innovation starts with an undertaking of R&D activities. If in the time of Isaac Newton scientific research was just a hobby of amateurs, and still was so in the era of Thomas Edison, nowadays it has become embedded in the behavior of successful organizations, be they universities, research institutes, or corporations. Therefore R&D often requires huge sustainable investment and support from both government and society. Moreover, the world of innovative activities is a domain that generally requires participants to possess higher educational credentials (doctorates in many cases), expertise, and years of experience. In other words, innovation requires skilled talent. The dominance of the USA in science and technology since the Second World War has, to large extent, been associated with its possession of a high-caliber talent base.

At the turn of the twentieth century, graduate education to train high-quality scientists and engineers started to flourish in the USA. During the Second World War, the USA benefited greatly from the influx of scientific talent such as Albert Einstein and Enrico Fermi, who fled Fascist governments in Nazi Germany and Italy; their contributions literally helped the Allies to win the war, especially their contribution to the development of nuclear weapons. After the war, American and European scientists and engineers gave birth to such high-tech industries as information technology and biotechnology, which today have become the pillars of the knowledge economy. Immigrants from India, China, and other countries with a strong tradition of prioritizing education, along with America's locally schooled and trained scientific workforce, have contributed greatly to US technological advance and strong economic growth (Wadhwa *et al.*, 2007).

Looking from the vantage point of the twenty-first century, it has become evident that competition within and across a global knowledge-based economy is essentially competition about innovation capability, which, in turn, is underscored by the growing competition for talent between firms, regions, and nations. One of the key measures of innovative strength is embedded in R&D activities, which may be viewed as a proxy for education and training in higher-level skills. While it is true that there can be no research without talent, and not much innovation without research, it is equally true that expenditure on R&D tends to be higher in countries with a high concentration of scientific and technical talent. Thus, Romer (1990) includes in his model of "endogenous economic growth" an R&D sector which uses valuable resources to produce more new ideas and bring about technical change. Simply stated, using the analytic lens provided by this class of endogenous growth models we can see that an increase in the stock of resources – financial and human – engaged in R&D activity is directly related to a permanent increase in the economy's growth rate.

Expenditure on R&D, however, also tends to be higher in countries which strive to catch up with the advanced economies. The "catching-up" and leapfrogging process requires a capacity to create new technology as well as a capacity for absorbing and adapting technology created elsewhere. This absorptive capacity is considered directly related to the human capital stock present in the catching-up country, which tends to be the product of an enhanced higher education and research system established through enormous investment and support – both public and private.

Because of the importance of human resources in driving the exponential increase in scientific and technological knowledge, the size of the talent pool in each country is explicitly linked to its indigenous technology level. In this regard, the higher education system shoulders the main responsibility for preparing and supplying the qualified technical, professional, and managerial workforce that is required to support national as well as regional and local innovation systems within each country. Of course, it is the quality, rather than just the quantity, of human resources that stands at the heart of innovation. In East Asia, a high level of human resource development