Introduction to The Source of Innovation in China

In the 1990s China was minor player in the world of science and technology and application of new knowledge to business innovation. Chinese scientists and engineers contributed just 1.2% of the world's scientific publications in 1990, which placed China 14th in the ranking of countries by papers below countries with much smaller populations, such as Sweden and the Netherlands[1]. China enrolled 3.8 million undergraduate students – 5.6% of world enrollments, far below the country's 31% of the world's 1990 population. It graduated less than 2,000 science and engineering PhDs and sent a modest number of students overseas. The country's R&D spending was minuscule compared to the R&D budgets of the US, Japan, UK, and Germany, and smaller than those of many other advanced countries. Like Korea in the 1970s, China was an intellectual backwater. China developed its economy largely on the work of tens of millions of rural migrants employed in low wage manufacturing and construction.

Fast forward a decade and half to the mid 2010s and presto! you see a remarkably different China at the frontier of modern science and technology. In 2012 China graduated more bachelor's in science and engineering (and in all 4 year degree programs, for that matter) than any other country (table 1, line 1) – the result of the country more than doubling the number of colleges and universities from the mid 1970s to the mid 1980s[2] and of existing universities expanding their enrollments. From 1990 to 2010 the number of science and engineering bachelor's graduates in China increased 8.4 fold; the number of master's graduates increased 9.4 fold; and the number of PhDs increased 17-fold (table 1, lines 1-3). Whereas in 1990 China graduated 5% to 7% as many S&E PhDs as the US,[3] in 2010

1 National Science Board, Science and Engineering Indicators 2004, Table 5-35. The 2004 Indicators numbers are larger than those reported in the Science and Engineering Indicators 2002 volume.

2 Li, Haizheng Higher Education in China: Complement or Competition to US Universities? (p. 269 – 304), table 8.1 and 8.2. in American Universities in a Global Market Charles T. Clotfelter, editor May 2010 University of Chicago Press

3 See http://www.nsf.gov/statistics/doctorates/pdf/sed2000.pdf table 5, p 36 for 1990 US PhDs by field. Subtracting humanities, education, and professional from the total gives 23,228. National Science Board National Science Foundation, Division of Science Resources Statistics Science and Engineering Indicators 2004 Arlington, VA (NSB 04-01) [May 2004] footnote 12 estimates that 1,069 S&E doctoral degrees were granted to Chinese students within Chinese universities in 1990.(http://www.nsf.gov/statistics/seind04/c2/c2s4.htm. The 7% figure divides the number in Exhibit 2 by the US's 23,228. The 5% uses the smaller NSF estimate for China.

China graduated comparable numbers of S&E PhDs as the US.[4] Because many Chinese citizens earn PhDs in the US and other advanced countries, moreover, the country's contribution to the worlds' supply of new S&E specialists goes beyond degrees granted within China.

Line 4 of table 1 shows that as a result of a similar expansion in R&D spending China became the 2nd biggest spender among countries on R&D measured in purchasing power parity terms. China's R&D to GDP ratio surpassed that of the EU so that the OECD reported that China's total R&D would exceed that EU R&D by 2014.[5] Line 5 shows China also made a huge advance in the number of scientific papers to become the 2nd largest producer of scientific papers in the world after the US – the result of a 5.6 fold increase in the number of papers with China addresses from 2000 to 2012. Measured by the number of citations obtained or the impact factor of the journals of publication, the quality of China-addressed papers lagged behind that of the US and most other advanced countries but was improving.

Lines 6 and 7 show that China has also made extraordinary progress in number of patents. In the USPTO data China moved from negligible patenting address in the US to number seven in the list of non-US countries ranked by number of patents. In the WIPO data China was the number one patenting address in the world, due to huge numbers of patents granted in China. While this was due in large part to policy-driven incentives that produced many small patents of little value (judged by the fact that the patents were never brought to other country patent offices as well), it reflects China's focus on innovative activity.

Finally, China's production of high tech or high valued added industries also increased substantively. Between 1997 and 2012 China moved from marginal producer of "knowledge intensive

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4 China-US comparisons vary with how one treats Hong Kong and social/behavioral sciences. With Hong Kong counted as part of China, China produces more S&E PhDs than the US excluding social/behavioral sciences but fewer inclusive of social/ behavioral science. See http://www.nsf.gov/statistics/seind14/content/chapter-2/at02-39.pdf reports 32,649 US S&E PhDs inclusive of the social/behavioral sciences and 24,559 excluding them; and 31,410 China PhDs inclusive of social/behavioral sciences and 29,039 excluding them. China graduates from 10% to 18% more natural science and engineering PhDs than the US while it graduates 3.8% fewer in all S&E.

5 http://www.oecd.org/newsroom/china-headed-to-overtake-eu-us-in-science-technology-spending.htm

industries" goods and services to third place behind the US and Japan (line 8). China dominated world trade in information and communication technology products with nearly 40% of exports (line 9).

With its huge expansion of human capital, investment of resources in knowledge creation and manufacturing production competencies, China seems set to follow the path of its Asian neighbors Japan and Korea to become a giant in innovation in the global economy. Surprisingly, however, the most prominent indicators of cross-country innovation places China far lower than its position in education, R&D, or scientific publications indicates. The bottom lines of table 1 show that in 2014 the Global Innovation Index placed China 29th in innovation (line 10); the Global Competitiveness Report ranked China 32nd in its 12th Pillar Innovation measure (line 11); Bloomberg's Innovation Indicator placed China 22 out of 50 countries (line 12); while the National Association of Manufacturers, Manufacturing Institute, and Boston Consulting Group 2009 study ranked China 27th (line 13).

Looking into the future, experts and observers have debated whether China will attain the top ranks of innovation with its existing social and political structure or fall short. In the March 2014 Harvard Business Review three US-based China experts questioned whether China's government structure was compatible with "the true spirit of entrepreneurship".[6] In a May 2014 graduation address to US Air Force cadets US Vice President Joe Biden challenged the cadets to "Name me one innovative project, one innovative change, one innovative product that has come out of China,"[7] with the clear implication that he believed there were none. In February 2015, the Economist held an internet debate on the question" Is China a global innovation powerhouse?". Analysts who answered argued that government domination of the economy would stifle innovation. By contrast, in its 2013 China Innovation Survey, the consulting firm Strategy& argued that China was regaining its historical position as a global innovation power.[8]

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6 Why China Can't Innovate by Regina M. Abrami, William C. Kirby, and F. Warren McFarlan Harvard Business Review March 2014

7 Joe Biden is wrong. China does innovate May.29, 2014

8 http://www.strategyand.pwc.com/media/file/Strategyand_2013-China-Innovation-Survey.pdf

Ying-ying Zhang and and Yu Zhou's The Source of Innovation in China present compelling argument and evidence that China is indeed a substantive innovator, with special characteristics due to its low cost of labor, government-initiated innovation institutions, and developing private market in the digital era. They point out that innovation in China involves more than technological development to include effective use of available resources, such as low cost human labor, to meet the needs of China's big market as well as global export markets. Rather than solely imitating the operations of foreign enterprises, Chinese businesses adapted technologies, goods and services to Chinese conditions and to the global market. Zhang & Zhou's analysis of company cases shows the wide range of Chinese business responses to the economic realities. Their stress on the role of human resource management in moving firms from innovations that use China's low cost labor resources, from migrant labor to scientists and engineers, gives a fresh view of innovation beyond introduction of technological changes.

The picture in the book is, in my judgment, closer to the truth than the widely used indices that give China low ranking in innovation. The indices are misleading in two ways. First, the indices ignore the innovation involved in adapting advanced technology to China's market, which made Alibaba such a success, and in developing work practices to bring China's huge low wage rural work force to the center of global manufacturing. Second, they downplay the importance of scale in knowledge-based innovation. To the extent that innovation depends on the *total* amount of resources devoted to science, technology, and their application to business – the usual assumption for knowledge production -- indices based on *per capita measures* such as numbers of scientists, engineers, scientific papers relative to population understate the innovative capacity of highly populous countries like China relative to much smaller countries such as Switzerland or Sweden that invariably sit at the top of innovation indicators. The fact that China can readily deploy many times as many scientists and engineers as smaller "more innovative" countries means that it can make significant breakthroughs in science, technology and innovation that will escape them.

Skeptics of China's ability to innovate often point to the quality and structure of China's colleges and universities as an impediment to innovation, due to the role political shenanigans and guanxi in decisions about personnel and resource allocation. Buttressing these concerns Shanghai Jiao Tong University's 2014 Academic Ranking of World Universities ranked no Chinese universities in the top 100, just six in the top 200, and 32 in the top 500.[9] To address this weakness, the Chinese government has funded a diverse number-designated set of programs to improve the higher educational system: the 211 project to support the top 100 universities; the 985 project to transform the 40 top universities to world-class status; the 863 program to fund research and development of technology; and the 973 program to fund basic research. These programs and the natural tournament style competition among universities to be among the top will surely improve China's higher educational system in the next decade or so.

But even with lower quality universities than the US or EU, the scale of China's university system can produce substantial innovative talent and enable China to progress through substitution of large numbers of highly trained or innovative business persons for better quality. Define a successful innovator as the top person who starts a business in some sector. Assume that the quality of persons who try to start a business follows a given distribution. Even if the mean quality of China's potential innovators falls below that of some other country, the greater number of Chinese seeking to start a business could still produce the top person and successful innovator.

Finally, by sending some of its best and brightest students to study in world-leading universities, China has assured that those students will be at the forefront of scientific and technological advances. Many of them will, to be sure, do much of their work overseas, but even if those students remain overseas, China will benefit from flows of information from them to their family and friends back in China along “ethnic knowledge networks”. The close ties in higher education and scientific work

9 Other well-known rating systems give roughly comparable ratings, with however some idiosyncracy: the London Times ranking, for example, places British universities higher in its rankings than does the Shanghai rating.

between China and the US, in particular, should be a valuable input into China's innovation system.[10]

The bottom line for innovation is the introduction of new or improved products or processes. Absent a statistical database on the number and economic value of innovations comparable to GDP accounts of expenditures, quantities and prices of goods and services, the best way to assess China's performance in innovations is to piece together a collage of information, as Zhang and Zhou do in this book. Surveys that ask companies whether they introduced new products or processes in the past several years and the proportion of sales from those products or processes provide useful information but are too far removed from actual innovations to substitute for a collage or real cases.

Looking at information about innovative companies beyond those in the main part of the book – from BGI's biotech genome sequencing[11] to Tencent's innovations in Internet communication to Xiamoi's production of low-cost smart phones to Baidu's Internet-enabled devices from its search engine to hardware to Phantom's energy-efficient lightbulbs and app-controlled EcoTowers monitors [12] – confutes the skeptics' fear that a society dominated by single party invariably stifles innovation. That China's government can and will make mistakes is certain. But China has gone too far down the path toward an open society along intellectual, business, and other dimensions outside of politics for anything short of Maoist insanity to prevent its scientists, engineers, and business entrepreneurs from innovating in China and eventually becoming leaders in global innovation. According to the 2014 China Innovation Survey 64 percent of the executives from multinational corporations in China rated some Chinese competitors as equally or more innovative in the China market while twice as large proportion of executives of Chinese firms labeled innovation as their top priority than executives of the multinationals.[13]As more Chinese firms extend their horizons from the huge China market to the even huger global market, either by buying non-Chinese innovative firms or by developing their own research facilities overseas, the firms will take

10 See R. Freeman and Wei Huang (2015) China's "Great Leap Forward" in Science and Engineering
11 Henny Sender, Chinese innovation: BGI's code for success" Financial Times, Feb 16,2015
12 Www.fastcompany.com/most-innovative-companies/2014/industry/China
13 http://www.strategyand.pwc.com/global/home/what-we-think/reports-white-papers/article-display/2014-china-innovation-survey, exhibit 1; exhibit 5

advantage of the greater openness in democratic governments, much as China overseas researchers do.

In 2014 Joe Biden may have a problem naming an innovative project or product from China, but he will probably be the last US Vice President to have such a problem. Barring economic or political catastrophe, innovation with Chinese characteristics has begun to come to the world economy and it will come more and more rapidly.

Table 1: Levels, World Rank, and Trends in S&E Resources and Innovation, China,

	Level, circa 2010	World Rank	Trend
1. Science-engineering Bachelor's	1,258,643 (2012)	1st	8.4 fold increase over 1990
2. Science-engineering Master's	191,048 (2012)	1st	9.4 fold increase over 1990
3. Science-engineering PhDs	27,652 (2012)	1^{st} (tied?)	17 fold increase over 1990
4, R&D spending	$16.6 billion, purchasing power parity	2nd	Three fold increase in real PPP $ from 2000 to 2012
5, Papers	116, 663 (2012)	2nd	Quadrupling share of papers from 2000 to 2012
6.Patents (USPTO)	5928 (2013), 6^{th} highest foreign country	7th	Up from 119 patents in 2009
7. Patents (WIPO)	652,777 (2013)	1st	Huge increase in China patent office patents, policy driven
8. Value Added, Knowledge intensive industries	$1.7 trillion (8.7% of world total)	3rd	More than tripled share of world from 1997
9. Exports of ICT Products	$0.557 trillion (39.5% of world)	1st	Up from 8% of world in 1997
10. Innovation (Global Innovation Report, 2014)	55.3 out of 100	29th	No changes from 2007
11. Innovation (Global Competitiveness Report, 2014) Pillar 12 innovation	3.9 out of 7	32nd	up from 46 in 2006-07
12. Innovation (Bloomberg, 2014)	--	22 of 50	
13. International Innovation Index, (NAM 2009)	--	27th	--

Source: OECD Main science and technology indicators
http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#
http://www.nsf.gov/statistics/seind14/content/chapter-6/at06-40.pdf
http://www.wipo.int/edocs/pubdocs/en/statistics/943/wipo_pub_943_2013.pdf
http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utl.htm

http://www.nsf.gov/statistics/seind14/content/chapter-6/at06-02.pdf
http://www.nsf.gov/statistics/seind14/content/chapter-6/at06-25.pdf

http://www.bloomberg.com/graphics/2015-innovative-countries/
http://www.globalinnovationindex.org/content.aspx?page=past-reports
http://www.weforum.org/reports/global-competitiveness-repo
http://en.wikipedia.org/wiki/International_Innovation_Index