Letter to the Editor

Will the science and technology gap between China and USA becomes narrower, wider, or stay in the same in 50 years' time?

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Submitted Feb 26, 2016. Accepted for publication Mar 07, 2016.
doi: 10.21037/qims.2016.03.04
View this article at: http://dx.doi.org/10.21037/qims.2016.03.04

It is acknowledged that currently USA overall takes a wide lead in science and technology ahead of China. Will the science and technology gap between China and USA becomes narrower, wider, or stay in the same in 50 years' time? This question recently occurred to me when a few reports in media claimed that China has become the 'globally second player' in research and development (1-3). Unfortunately, the data presented in these media were quite quantitative, mostly concerning the number of papers published, the number of graduate students trained, the amount of funds spent on R&D. The qualitative aspects of R&D in China have not been well studied. Back in 2011 Wadhwa noted that the engineer graduates in China were less skilled compared their USA counterparts (4). Wadhwa commented that '*our (U.S.) engineers can think outside the box… U.S.-educated engineers learn a broad variety of skills… The graduates of U.S. engineering programs are productive from the day they graduate… Our engineering education system… gives us a big advantage in productivity, innovation and entrepreneurship*'. Wadhwa argues that there was no shortage of engineers in USA overall. In a free economy such as USA, supply responds to demand. Using salaries as the indicator, in most engineering professions salaries have not increased more than inflation over the past two decades, and graduating more of the wrong types of engineers is likely to increase unemployment rather than create jobs (4).

Recently, the following three news headlines caught the author's attention. The first news was brought about by Space Exploration Technologies Corporation (SpaceX, www.spacex.com), headed by Mr. Elon Musk with the ambitious goal of creating the technologies to reduce space transportation costs and enable the colonization of Mars. It is headquartered in Hawthorne, California, USA. On 22 December 2015 SpaceX launched an upgraded Falcon 9 rocket from Cape Canaveral Air Force Station into low Earth orbit. After completing its primary burn, the first stage of the multistage rocket detached from the second stage as usual. The first stage then fired some of its engines to send it back to Cape Canaveral, where it achieved the world's first successful landing of a rocket that was used for an orbital launch (4). Stage two successfully deployed eleven communication satellites for Orbcomm (satellite, www.orbcomm.com). This approach dramatically improves the cost for access to space (5).

The second news came from London. Google DeepMind (www.deepmind.com) is a British artificial intelligence company founded in 2010 as DeepMind Technologies (renamed when acquired by Google in 2014). In October 2015, a computer Go program called AlphaGo, powered by DeepMind, beat the European Go champion Fan Hui, five to zero. The announcement of the news was delayed until 27 January 2016 to coincide with the publication of a paper in the journal *Nature* describing the algorithms used (6,7). As opposed to other artificial intelligences, which were developed for a pre-defined purpose and only function within its scope, according to Demis Hassabis, the founder of DeepMind, DeepMind has the aim that their system is not pre-programmed and it learns from experience. In addition, on 24 Feb 2016 DeepMind Health was launched, to work in partnership with NHS (National Health Service of UK) nurses and doctors to build and scale technologies to provide the better patient treatment (8).

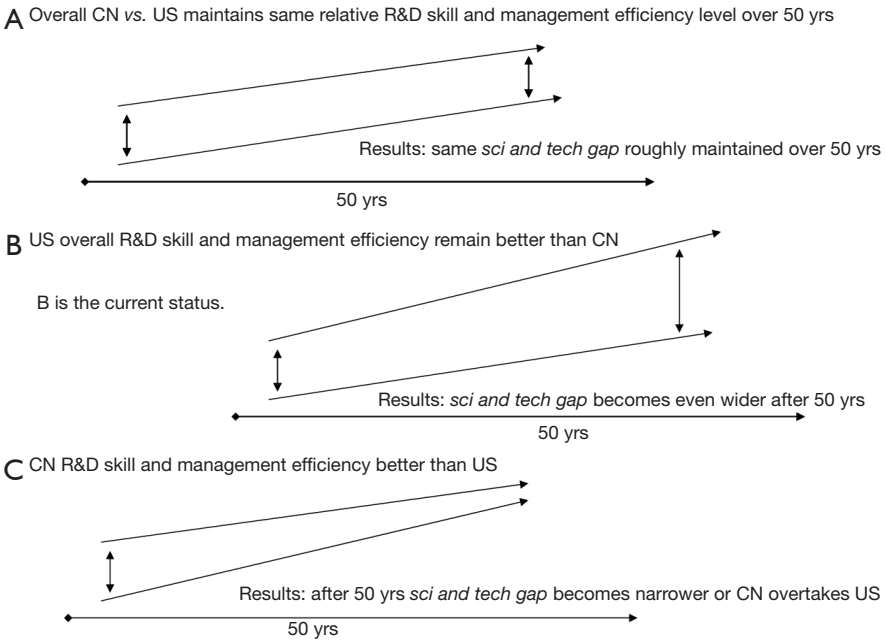

Figure 1 A simplistic presentation for the next 50 years. Prepared by Yi-Xiang Wang (2016-2-13). R&D, research and development; yrs, years.

While the above two news were from the industry, the third new hailed from academia. Gravitational waves are ripples in the curvature of space-time which propagate as waves, travelling outward from the source. Predicted in 1916 by Albert Einstein on the basis of his theory of general relativity, gravitational waves transport energy as gravitational radiation. Various gravitational-wave observatories have been in operation. On February 11, 2016, the LIGO Scientific Collaboration (www.ligo.org/) and Virgo Collaboration (www.ego-gw.it/) teams announced that they had first observation of gravitational waves from a pair of merging black holes using the Advanced LIGO detectors (9-11). That was 100 years after Einstein's prediction!

Why as the second player of R&D, China could not involve in similar exciting studies at all? I made a simplistic projection of science and technology gap between China and USA in the next 50 years, which shows unless there is a major improvement in R&D skills of Chinese scientists and management efficiency, the most likelihood is that the science and technology gap between China and USA will become even wider, or at best stay the same (*Figure 1*).

The most worrying sign is that 40 years after the ending of culture revolution in 1976 and with the massive governmental investment in research and the return of overseas Chinese scientists back to China (*Figure 2*), it looks major improvement in R&D skills and management efficiency is not happening in China (*Figure 3*), though China has been a quite decent passenger in the wagon of global technological advancement mainly driven by the west. However, the university and research institution's academic posts have been mostly filled recently, and unless scientists in China will make significant contribution to the Chinese society, the year-by-year increase of R&D spending will not be sustainable. According to the observation by Murray, '*history has worked out, the ages rich in giants have also been rich in near-giants and the rest of the significant figures…*' [review in (14), page 249]. This *giants spring-up* phenomenon is not happening in China yet. In fact, it has been reported that the academic atmosphere is becoming more bureaucratic (15), and the institutional structures have become more centralized. Scientists and technologists are being attracted to utilitism, while there is less idealism and romanticism. Even the validity of State First Class Prizes For Natural Science has been highly disputed in recent years (16,17).

Of note, the technology breakthroughs from SpaceX and DeepMind are both from industry, however, the R&D spending in Chinese corporations remains low (*Figure 2*). Another example promoted my pessimistic prediction is the relative development track record of two industrial

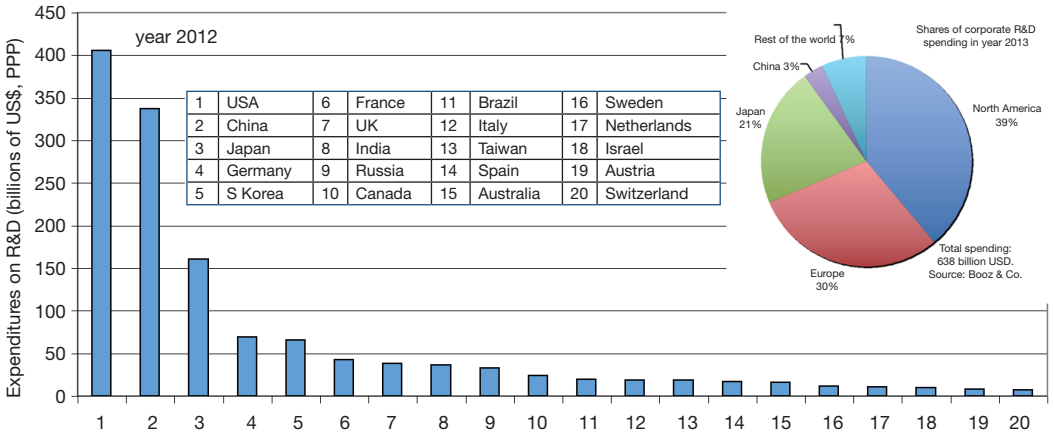

Figure 2 The top 20 regions with R&D spending in year 2012. The corporation R&D spending is shown in the insert. Available online: http://data.worldbank.org/; http://stats.oecd.org/. R&D, research and development. Note the comparative small share of corporate R&D spending by Chinese companies (12).

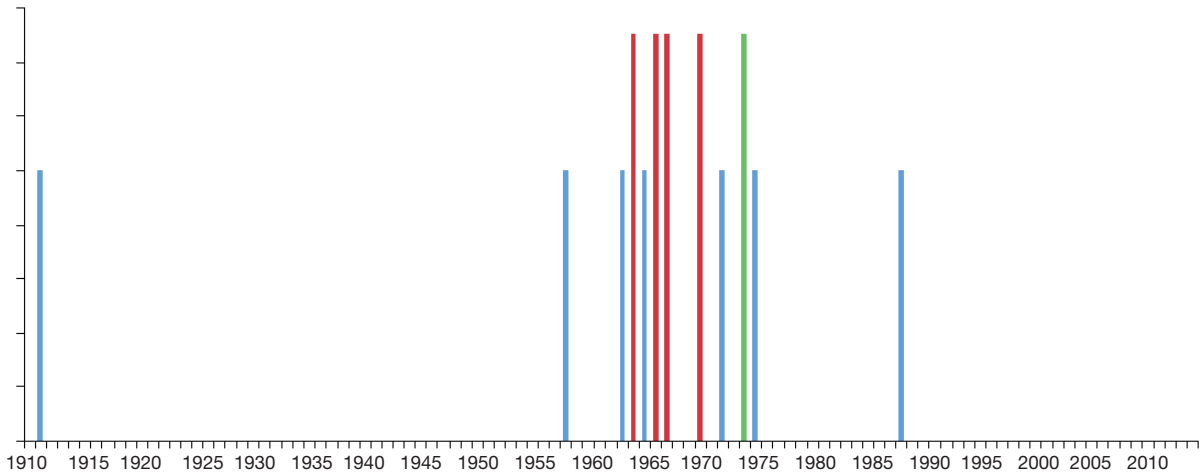

Figure 3 Concentration of major medical achievements toward later 1960s and early 1907s coincided with some technological successes in China. Y-axis is in artificial units. Blue-lines: top seven medical achievements in China mainland since Xinhai Revolution (1). (I) Wu's mask for plague prevention [1910]; (II) culture of chlamydia trachomatis in the yolk sac [1957]; (III) limb re-plantation [1963]; (IV) chemical of insulin [1965]; (V) Artemisine [1972]; (VI) arsenic trioxide (As2O3) [1974]; (VII) all-trans retinoic acid [1988]. Red-lines: (I) first successful test of nuclear bomb in China [1964]; (II) first successful test of nuclear-bomb carrying earth-to-earth missile in China [1966]; (III) first successful test of hydrogen bomb in China [1967]; (IV) first successful launching of satellite in China [1970]. Green-line: Longping Yuan's hybrid rice culture [1974] (13).

giants in USA and China, i.e., Google (www.google.com) and Baidu (www.baidu.com) respectively. Incorporated on September 4, 1998 with headquarter in Mountain View, California, USA, Google Inc. is an American company specializing in internet-related services and products. Sixteen months later, Baidu, Inc. a Chinese internet-related services company, was incorporated on January 18, 2000 with headquarter in Beijing. While Google has since then developed into a multinational technology company, developed (and acquired) Gmail, Google map, Google translate, Android, YouTube etc. products which I use a lot. Baidu remains pretty much a domestic company (18). While I use both English and Chinese languages, I rarely use Baidu. Among others, Google is also investing in quantum computing, driverless cars and vehicles. In October 2014, according to the Interbrand ranking, Google was the second

most valuable brand in the world (behind Apple) with a valuation of $107.4 billion (19). A Millward Brown report from the same year puts the Google brand ahead of Apple's at #1 (20). The paradox of large mainland Chinese internet companies like Alibaba, Tencent or Baidu is that they may only be successful domestically, since most of them are copies of existing foreign companies and they owe their success to government protection (18).

Government grants and subsidies are no guarantee of success, and may eventually be counterproductive [review in (21), page 265; (22)]. Silicon Valley's leading technologists are developing businesses that are so profoundly innovative that they create entirely new industries which change the way humans live and work. Radical ambitions require a certain defiance, disregard for authority and conventional thinking (18,23). And that is crucible for the irrefutable confirmation of Euro-America's leadership and domination of every major innovation in technology (18). It is the kind of success that every government has sought but cannot mandate (18). Naubahar Sharif at the Hong Kong University of Science and Technology recently noted: "All economies want to become a Silicon Valley. Very few are able to do it." (24). In the end, China cannot claim being one of the leaders in R&D unless China has vibrant and innovative industries (25).

Historically China did not have strong track record in doing high quality sciences. Using a statistical data base Dong *et al*. (26) concluded that the European area has been active in various scientific activities since 500 BC, and its scientific and technological achievements have always been outperforming China, and this is also reflected by the ancient architectural monuments scattered in the Eurasian Land. Similar accounts have been well illustrated by Charles Murray in his book 'Human Accomplishment: The Pursuit of Excellence in the Arts and Sciences, 800 BC to 1950' (11). As discussed above, there is no apparent sign yet that the scientific activities significantly deviated from the historical norm. In the foreseeable future, China is more likely to remain a learner (and therefore adapting herself) and a participant, instead of a leader in science and technology innovation. The traffic between China and USA will likely to remain mainly one-sided. One the other hand, the author expects the relative strength of USA *vs*. Western Europe in science and technology will remains more or less the same, due to the fluidly flow of human resources, capital, and the cultural and structural integration.

However, as one famous Arab proverb goes, "*The man who speaks about the future lies even when he tells the truth*." and it was said the truest rule of stock market it its unpredictability [review in (27), page 31], I hope I will be able to live long enough to see I was wrong this time.

Postscript

Since the manuscript was accepted for publication, more news has come out with DeepMind. On 15th March 2016 DeepMind announce that DeepMind's computer program AlphaGo won the match with Lee Sedol, a South Korean professional Go player of 9-dan rank, with the final score of 4-1 (https://deepmind.com/).

Acknowledgements

During the course of preparation of this manuscript, on this topic I interacted with colleagues from a number institutions, including, Tsinghua University, Zhejiang University, China; Yonsei University, National Cancer Center, S. Korea; Kyoto University, Japan; Sheffield University, UK; Guerbet Group, France; Harvard University, USA; and the Chinese University of Hong Kong, Hong Kong SAR, China. I thank these colleagues for their inspiring comments. Some agreed with my pessimistic view while others were more up-beating. Interestingly, those of Chinese heritage were more likely to agree with me.

Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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Cite this article as: Wáng YX. Will the science and technology gap between China and USA becomes narrow, wider, or stay in the same in fifty years' time? Quant Imaging Med Surg 2016;6(2):233-237. doi: 10.21037/qims.2016.03.04

