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ABSTRACT

China in recent times has emerged as a world superpower in both economic as well as military power; this is a reality facing the rest of the world. China is a country of many contrasts because politically it is run by a central communist party but in economic terms it is a capitalist type of society and as such no other industrialized country has this type of governing model. China’s central government dictates and decides which industries are needed and pursues them vigorously: allocating resources, reducing bureaucratic impediments, even creating incentives for foreign partnerships to emerge. This type of management works well for well established enterprises such as manufacturing where repetitive and well-known principles govern its execution. In this report, we focus on the Research and Development (R&D) aspects of China’s growth and its emergence from an imitator to an innovator in the high-tech industry.

R&D on the other hand, requires a different approach. No predefined set of guidelines or approaches exist yet, and when created they need to change rapidly in order to accommodate new data. The work ahead is defined by work being done today, and often times are dependent on discoveries obtained through collaboration with other research institutions. This document will try to examine Patents and R&D expenditures by the Chinese government and compare those two factors versus Japan and South Korea, two other Asian countries which followed a similar path as they moved forward to become industrialized nations, in order to predict if China has moved to the forefront of innovation.

INTRODUCTION

China is the fourth largest country in the world with the total land area 9,596,960 sq. kilometers and is the world's most populous country in the world with over 1.33 billion people.[1] It is emerging as one of the world's most powerful countries in its economic, military, and technological growth and has recently surpassed Japan to become the second largest economy in the world and with growth rates of 9-10% annually. Table 1 below gives trends of macroeconomic indicators for China in recent times.

	2004	2005	2006	2007	2008
Real GDP growth	10.1	10.4	10.7	10.4	10.4
Inflation*	6.9	3.8	2.8	2.5	2.5
Consumer price index**	3.9	1.8	1.6	1.8	1.5
Fiscal balance (% of GDP)	0.0	0.2	1.0	2.0	1.8
Current account balance (% of GDP)	3.6	7.2	9.5	10.2	10.6

* Percentage change in GDP deflator from previous period.
** Changes in Laspeyres fixed base year index (base year 2005).
Source: National sources and OECD projections.

Table 1: China's macroeconomic indicators (from OECD website)

China's achievement in macroeconomic indicators has mainly come on the back of its industrialization and export-dependent growth. For example, it is the largest exporter of Information and Communication Technology (ICT) goods as of 2005 [Fig. 1].

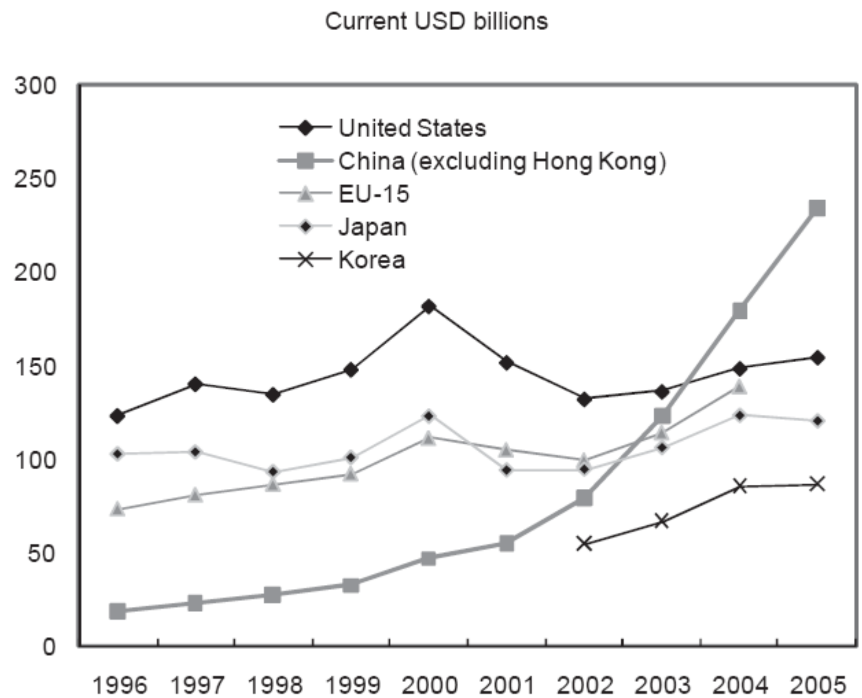

Figure 1: Export of ICT goods from 1996 to 2005(from OECD website)

However, China cannot continue to grow at its current rate forever without innovating, due to its current population structure which predicts a lower population growth and hence, has to innovate to improve productivity to maintain this growth.[2] Also, the "Made in China" label currently refers to cheap and flimsy products to most people around the world. To improve its image and to change the perception, China needs to move from imitator to innovator so that the "Made in China" label can be changed to "Created in China". Our research will analyze factors such as R&D expenditure and patents to determine whether China is moving in this direction or not.

This report is organized as follows: At first we look at the China's Innovation System framework to characterize the growth in R&D based on factors such as R&D expenditures and human capital as inputs and patents and publications as outputs. In this study we pick nano-technology as a representative to the overall high-tech industry and innovative technologies as such. This model is then applied to other similar Asian countries such as Japan and South Korea where we will look at their R&D expenditures as a percentage of GDP, and patents in the nano-tech area and their world-wide rankings for a comparative study. Based on different factors, we also come up with an overall ranking system to see the direction where China is headed on the innovation front.

INNOVATION FRAMEWORK MODEL

We used a framework similar to the NIS provided by the Organization for Economic Co-operation and Development (OECD) and have shown the framework in Figure 2.

*"NIS (**National Innovation System**) is the flow of technology and information among people, enterprises and institutions which is key to the innovative process on the national level. According to innovation system theory, innovation and technology development are results of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutes"*[3]. It is instrumental in measuring knowledge flows, comparing areas such as R&D expenditures, patents, production and trade in high technology products.

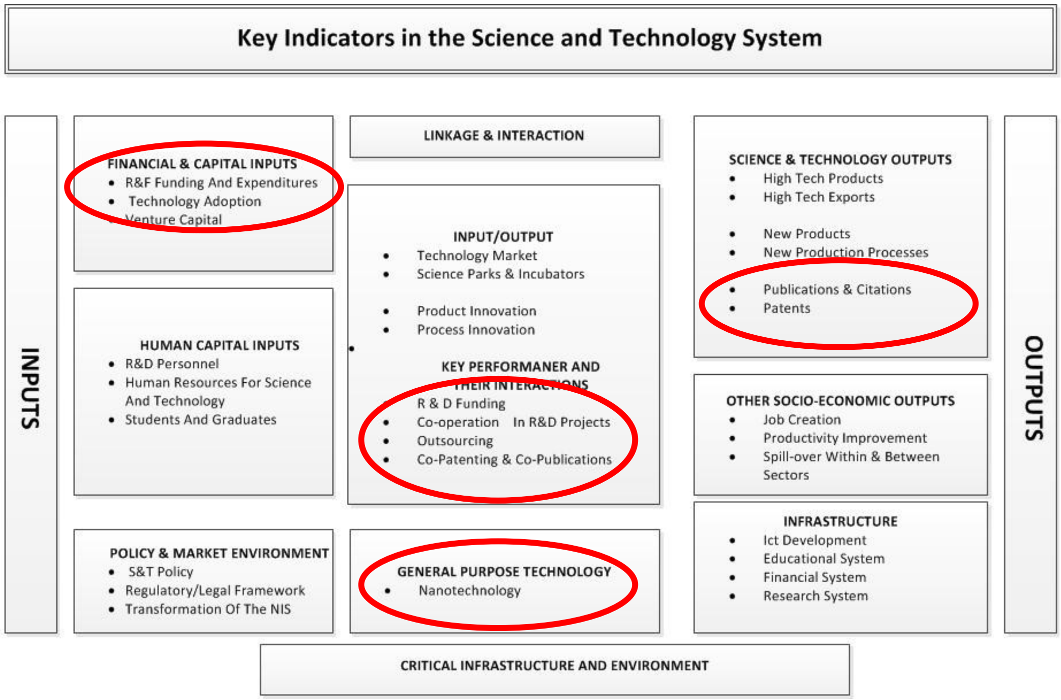

Figure 2: Model used by OECD to track innovation. [4]

OECD is a group of 34 countries mostly European, North American, Japan, and South Korea. The purpose of this group of nations is to help "improve the economic and social well-being of people around the world".[5] For the framework, as highlighted in Figure 2, we will use inputs such as R&D Funding, human capital in-terms of number of people enrolling in higher education, and for outputs we use the patents, publications in nano-tech field.

ANALYSIS OF MODEL

From the general framework provided by OECD the key actors in the Science and Technology include the financial and capital inputs such as R&D expenditures, human capital such as enrollment in advanced degrees, inputs from companies both domestic and foreign domiciled, etc.. Due to extensiveness of the research materials, we will concentrate on enrollment in advanced degrees, and R&D expenditures as the only inputs, and patents and publications as measurable outputs. Japan and Korea are used as a parameter for comparison due to their geographic proximity to China and the fact that both these countries followed a similar path. USA is used as a benchmark due to its current status as the number one country for innovation.

Researchers And Enrollment In Advanced Engineering/Life-Sciences

Researchers are professionals who are the fundamental element of creation of new knowledge, products, and processes. Such human capital is one of the significant factors that affect innovation. Hence government policies that drive up the number of skilled workforce and the number of people with advanced degrees is quite important in determining future innovation potential. The number of researchers in advanced engineering or basic science fields can be used as a good estimate of the innovation potential. In Figure 3 below, a comparison of the number of researchers (Full Time Equivalent, FTE) in China to the developed or industrialized nations is shown. China has grown by 100 % in the period from 1996 to 2005, and has reached the levels of those in the US and EU nearly after having surpassed Japan in this area.

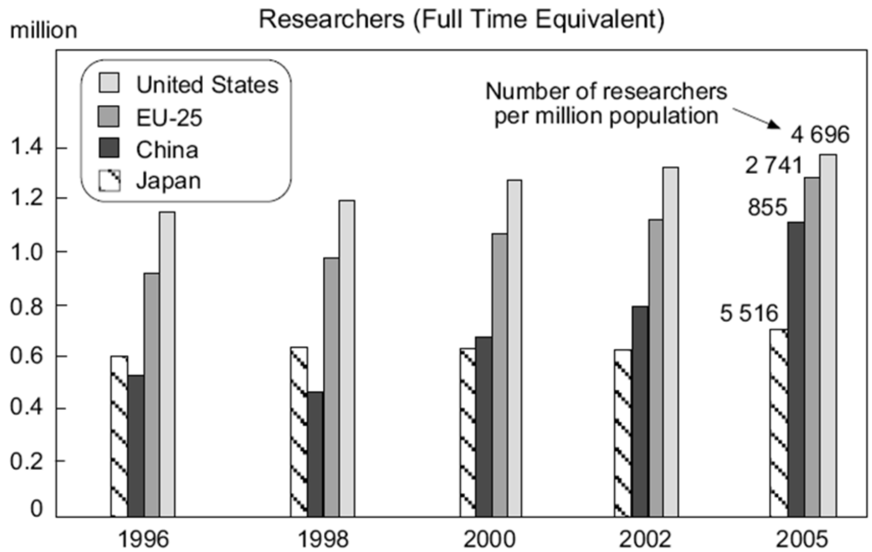

Figure 3: Number of researchers (FTE) from 1996 – 2005. [6]

Another way to look at the same data is the number of researchers per 1000 FTE(Fig. 4). This gives an estimate of the % of the working population involved in research activities. Seemingly, Japan has the greatest numbers of researchers per 1000 FTE followed by the U.S., Korea, and China relatively. This number may appear small for China because of the large population of China, even though in terms of absolute number of researchers, China is almost at par with the US and the EU, and exceeds Japan in this measure(Fig. 3). The annual growth rate of researchers in China was up to 10-15% approximately in 2000-2005[7] which was a impressive but still slower than the annual growth rate of R&D expenditure [8].

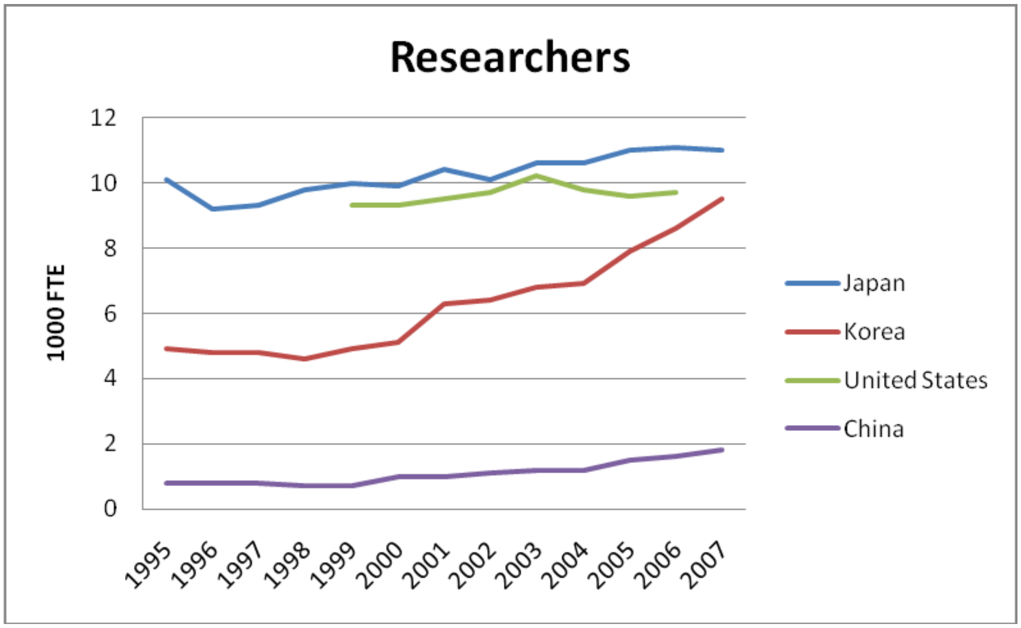

Figure 4: The numbers of researchers per 1000 employment full-time equivalent

In the ranking chart below, we have used the data from 1999-2006 from Figure 4 and compare the numbers of researchers in China with the rank of one with respect to others countries. For countries with number higher than 1, it means that there are higher numbers of researchers in that country.

Country	1999	2000	2001	2002	2003	2004	2005	2006	Average	Scale
Japan	10	9.9	10.4	10.1	10.6	10.6	11	11.1	10.5	8.8
Korea	4.9	5.1	6.3	6.4	6.8	6.9	7.9	8.9	6.7	5.6
The US	9.3	9.3	9.5	9.7	10.2	9.8	9.6	9.7	9.6	8.0
China	0.7	1.0	1.0	1.1	1.2	1.2	1.5	1.6	1.2	1

Table 2: Ranking of countries based on number of researchers per 1000 FTE

From Table 2, the result shows that the numbers of researchers in China is very low compared to Japan which has almost nine times, almost six times for the U.S., and eight times that of Korea. China still lacks way behind Japan, Korea, and the U.S. and needs to increase the numbers of researchers to increase the number of R&D personnel.

R&D EXPENDITURES

Similar to building human capital, R&D spending is another key measure that can be used for comparing innovation systems. The conventional wisdom is that the greater the amount spent on R&D, the greater the growth in innovation. From a R&D expenditure input we postulate that if China is at the level of these other nations, then China has moved from an imitator to an innovator.

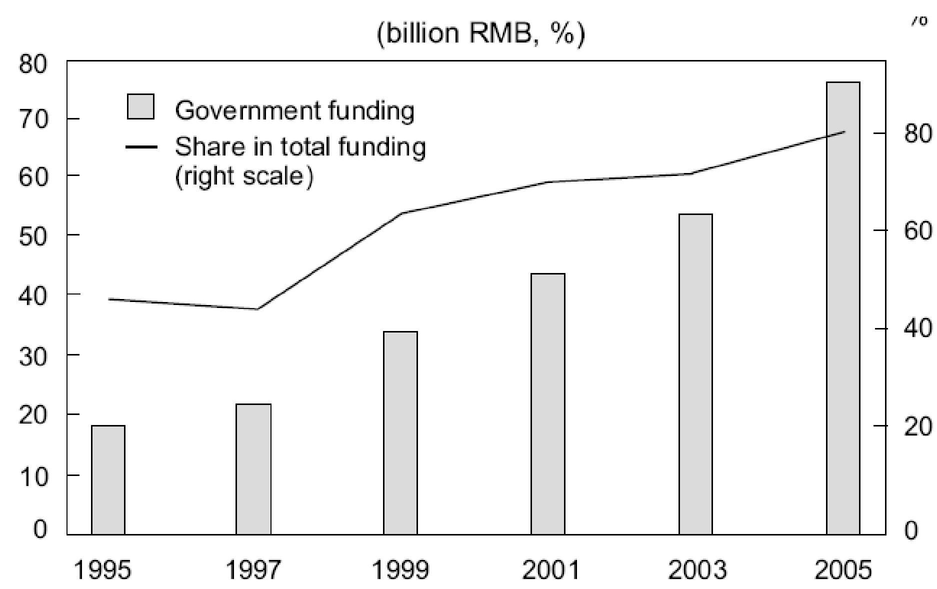

Figure 5: Government funding of Research Institutes (billion RMB)

Research and Development expenditures are a significant factor in high-tech industry. China has paid special attention to R&D and has entered the world of R&D with a decade of strong economic growth.[9] From Figure 5 above one can observe the growth in government funding towards research institutes which indicates that the government has been allocating funds towards the goal of transitioning from imitator to innovator.

Using the simplified model we will look at R&D spending in China, and compare it with the expenditures of Japan, Korea and other industrialized nations such as US and EU as in Figure 6.

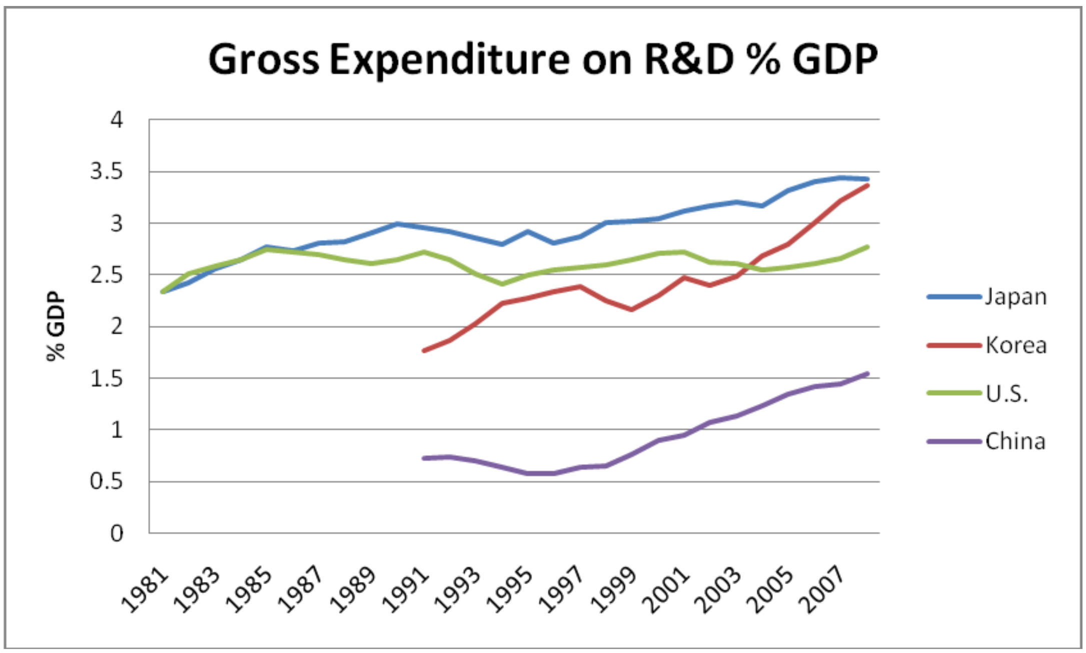

Figure 6: R&D as Percentage of GDP (from OECD)

In less than a decade, China has made a stunning investment on R&D compared to U.S., Japan and Korea and has become one of the world's biggest R&D spenders.[10]

R&D expenditure in term of GDP %, (R&D intensity) has grown rapidly since 1995 and has more than doubled since 1995 from 0.6% to 1.2% in 2004 which is even faster than its GDP growth rate at 9%-10% annually.[11] Compared to the U.S., Japan, and Korea in 2000-2008, China's R&D as GDP percent increased from 0.9% to 1.54% (71% increased), the U.S. increased from 2.71%-2.77% only (2% increased), Japan increased from 3.04%-3.42% (12.5% increased), and Korea increased from 2.30%-3.37% (46% increased). In China, industry finances approximately 70% of total R&D spending, up rapidly from 58% in 2000 and for the U.S., it is about 65% and for Japan and Korea, it is about 75%, respectively.

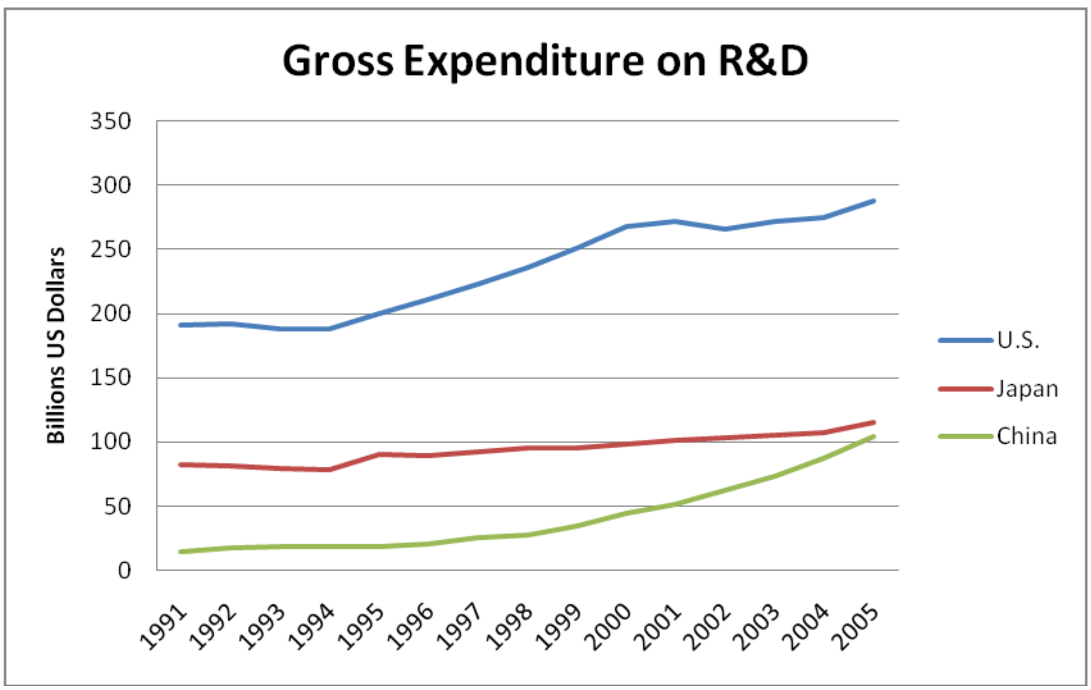

Figure 7: R&D Expenditure as Billions US Dollar, PPP

China has been spending a huge amount of money since 1995 on R&D at a rapid annual growth rate more than 18% and continues to converge with others while Japan and the U.S. spending grew more slowly at annual rate 2.7% in 1995 – 2003.[12] In 2005, China took the third place in world R&D expenditure with a annual growth rate more than 18% in 2000-2005.[7] By 2010, China continued to spend more on R&D due to its strong R&D growth and strong economics.[13] In 2011, China is sitting at the second place and is expected to spend $153.7 billion over Japan but still lower than the U.S.[14]

China's R&D expenditure in terms of R&D intensity as well as in terms of absolute dollars (PPP) spent on R&D, has had an impressive growth especially in 2000-2008 compared to the U.S., Japan, and Korea. However, China still lags behind most of developed countries in term of R&D intensity [10] which makes it look like it has just started to become an innovation-driven country. In the next several years, according to the midterm and long-term plan for a national innovation system and a series of strong innovation policies, China expects to spend more money to achieve R&D expenditure to achieve 2.5% of their GDP by 2020[10] which would be translated into a tripled R&D investment for the next decade to around $300 billion.[15] For China to achieve this target, they need to raise the annual growth rate of the R&D expenditure as percentage of GDP to at least 10-15%.[8] With strong innovation policies and their strong economic growth, it seems like there is no stopping for China to achieve the goals to be an innovation-driven nation in the world by 2020.

In the rankings below, we have used the data of the R&D expenditure as percentage of GDP from 2000-2008[Fig. 6] to show the R&D intensity in China compared to the U.S., Japan, and Korea. We have given China a scale of 1 and when other countries have the number more than one, it means China is still behind in R&D intensity.

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	Average	Scale
Japan	3.04	3.12	3.17	3.20	3.17	3.32	3.40	3.44	3.42	3.25	2.67
Korea	2.30	2.47	2.40	2.49	2.68	2.79	3.01	3.21	3.37	2.75	2.25
The US	2.71	2.72	2.62	2.61	2.54	2.57	2.61	2.66	2.67	2.63	2.16
China	0.9	0.95	1.07	1.13	1.23	1.34	1.42	1.44	1.54	1.22	1

Table 3: Ranking of countries based on R&D Expenditures (PPP Dollars)

From Table 3, the result shows that China's R&D intensity still lags behind the U.S., Japan, and Korea more than 2 times and China also ranks the last among the other countries. Even though China is the world's second R&D spender, China only spends approximately just 1.5 percent of their GDP. China will need to increase the R&D intensity and also R&D personnel in order to increase a large-scale in R&D activity.

PATENTS AND PUBLICATIONS

Patents and intellectual property (IP) are significant indicators of future success for the countries and enterprises that produce the IP. International estimates from the World Competitiveness Yearbook or the Global Competitiveness Report, often regard the patent data as a competitiveness indicator for a nation [16]. The Global Competitiveness Report (2009-2010) declaimed in 2009 by the World Economic Forum, states the Growth Competitiveness Index (GCI) of China ranked at 29th position among 133 major emerging economies. Among the indicators incorporated in GCI, the number of granted utility patents in the United States (US.

Patent Office) is probably the most direct and objective measurement for a country's innovation capacity [17]. We compare the number of patents submitted by the countries (to USPTO) mentioned above, and analyze the trends to understand their strengths in innovation-capability.

Our literature review is based on patent analysis in country level and in nano technology level. These patent analyses in different levels usually resort to patent counts or citation frequencies; nonetheless, these simple statistical numbers are not sufficient for evaluating the whole performances of a nation or a corporation. In this study, we have set up a ranking system, considering both patent quantity and quality by comparing with competitive countries like Japan and Korea and combining them in order to evaluate the competitiveness of China.

Also, the statistical analysis of number of patents in this report mainly includes the following sectors: comparing such numbers from top twenty six countries during 2004-2008; comparing Chinese patent number of nano technology fields, from the period of time from 2004 to 2008. Looking only at the number of patents alone can be rather imprecise as it fails to take into account of the value of each individual patent. Hence it is necessary to find the other indicators to cover the shortage of number analysis partly. The other indicators we look at in this section include: a) Patent statistics by field of nano technology, b) patent filings across 3 patent offices viz.(USPTO, JPO and EPO), and c) patent Intensity per R&D expenditure.

Nanotechnology

Nanotechnology refers to multifaceted technologies which covers a broad area of technologies on the nanometer scale rather than a single technological field [18]. The category of the nanoscale science includes energy, medicine, microelectronics, water and environmental remediation, communications technology [19]. Nanotechnology has been on a rapid growth and expansion path, and the country which has more patents in nanotechnology field indicates it not only has ability to handle high precision technology but also can diffuse this technology among various different industries.

Since China started “National Nanotechnology Development Strategy” in 2000 (2001-2010) [20], it has been getting significant improvement in nanotechnology field. Korea, as well as China, has been starting their “21st Century Frontier R&D Program” since 1999 [21]. Due to the resource and the strategy of these national programs, China and Korea have accumulated abilities to develop nanoscale science. By comparing the number of filed nanotechnology patents, we can get an idea of the achievements of these countries.

In order to make sure that our study in patent field is non-judgmental, we have applied data from the most authoritative patent offices among the world such as the USPTO (United States Patent and Trademark Office), JPO (Japan Patent Office) and EPO (European Patent Office) which hold the mass of the world's patent and applications [22].

Trends in resident patent filings per research and development expenditure

Research and development (R&D) expenditure and patent filings are highly correlated. Countries with a high level of R&D investment tend to have high resident filings to R&D expenditure ratio (patent intensity). The Republic of Korea, Japan and China have a high patent intensity.

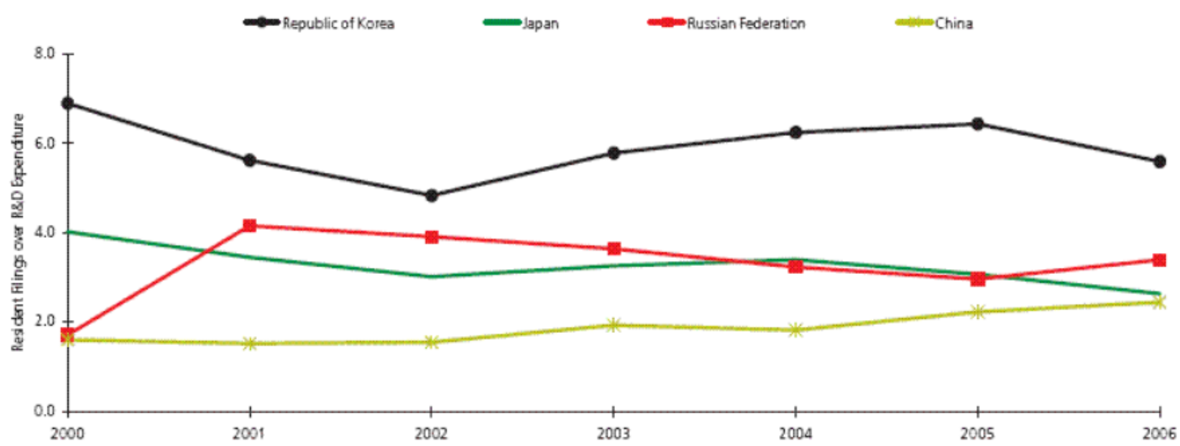

Figure 8: Resident filings per research and development expenditure[23]

As in Figure 8, from 2000 to 2006, the patent intensity ratio (resident filings per research and development expenditure) of China and India has increased slightly, which is mostly due to the higher growth rate of resident filings relative to that of R&D expenditure.

China's Achievement among Three Main Patent Offices

The achievement of China in nanotechnology field among three patent offices has been discussed based on two aspects: patent numbers and the annual growth rate. Again, we choose Japan, Korea for comparison and the U.S. as a benchmark.

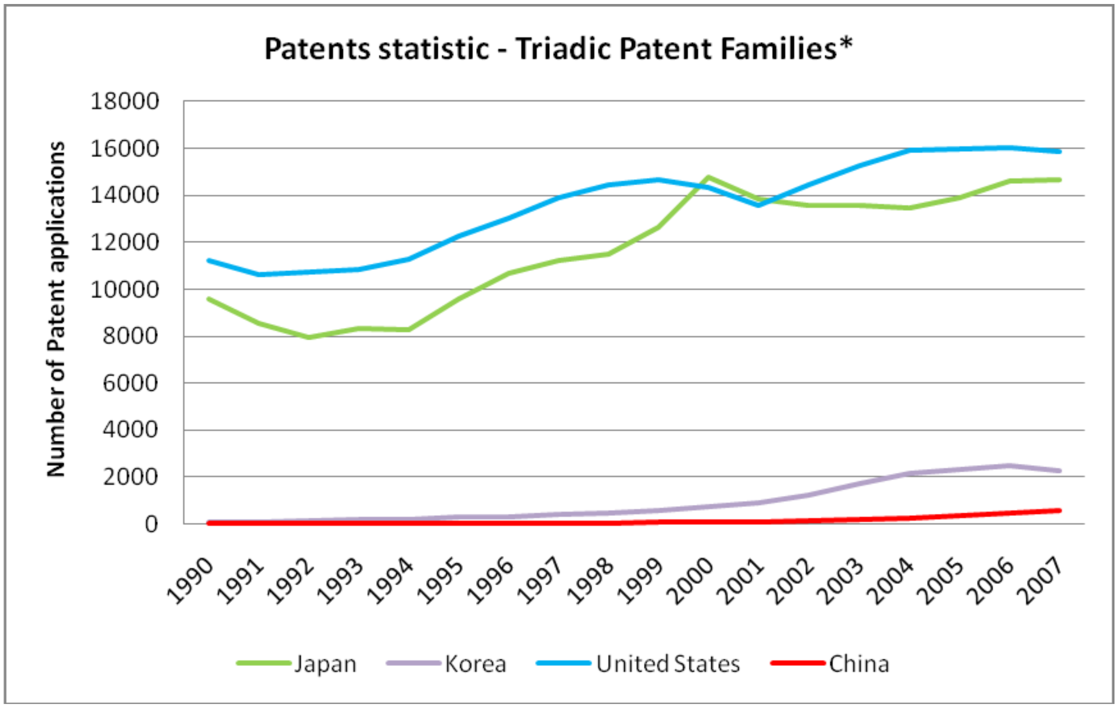

Figure 9: Nano Technology Patent Applications among Triadic Patent Office [24-26]

From Figure 9, United States and Japan have majority of nanotechnology patents among triadic patent families. Overall, U.S. has more nanopatents among triadic patent office than Japan. Korea's nanopatents number had been apparently increasing since 1998. For China, its patent number has started to increase in 2000. This is also apparent from the growth rate. U.S.'s annual growth rate of patent numbers was 1.3%, while Japan's was -0.2% and Korea's was 26.9% during 2002 to 2007. China had the most impressive growth rate which was 98.6% since 2000.

Considering the patent information we got from JPO and EPO is not up to date, we decided to do further analysis based on USPTO's data. For this study will used two indicators to analyse

China's performance of nanotechnology patent field in USPTO; patent counts and; world ranking of number of nanopatents.

Figure 10 below shows the trend of patent numbers among the U.S., Japan, Korea, and China during 1990 to 2009 in USPTO database.

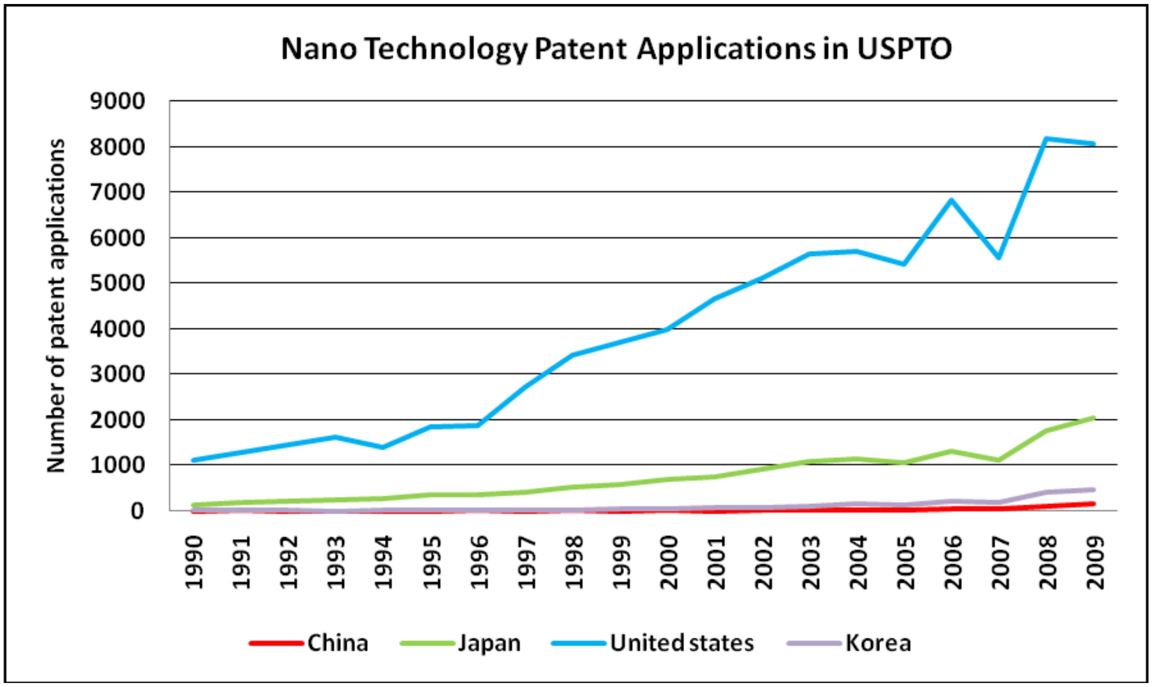

Figure 10: Nano Technology Patent Applications by different countries in USPTO [24]

From the information in Figure 10, United States is the bellwether of USPTO and has majority of nanotechnology patents in its own patent office. There is an obvious gap between Japan and the U.S. although Japan still has the second largest number of nanopatents. As successors, Korea and China have improved since 2002 even though they fall behind Japan and the U.S. patent numbers.

On the other hand, from 2002 to 2009, U.S. annual growth rate of patent numbers was 7.2%, Japan's was 15.3%, and Korea's was 59.9%. China has had an impressive growth rate of 604% since 2002.

World Ranking Analysis

Besides analyzing variation of patent numbers among China, Japan, Korea and the United States, we have also calculated their world ranking by filed number of nanopatent in USPTO and come up with the chart below for 2001 to 2009.

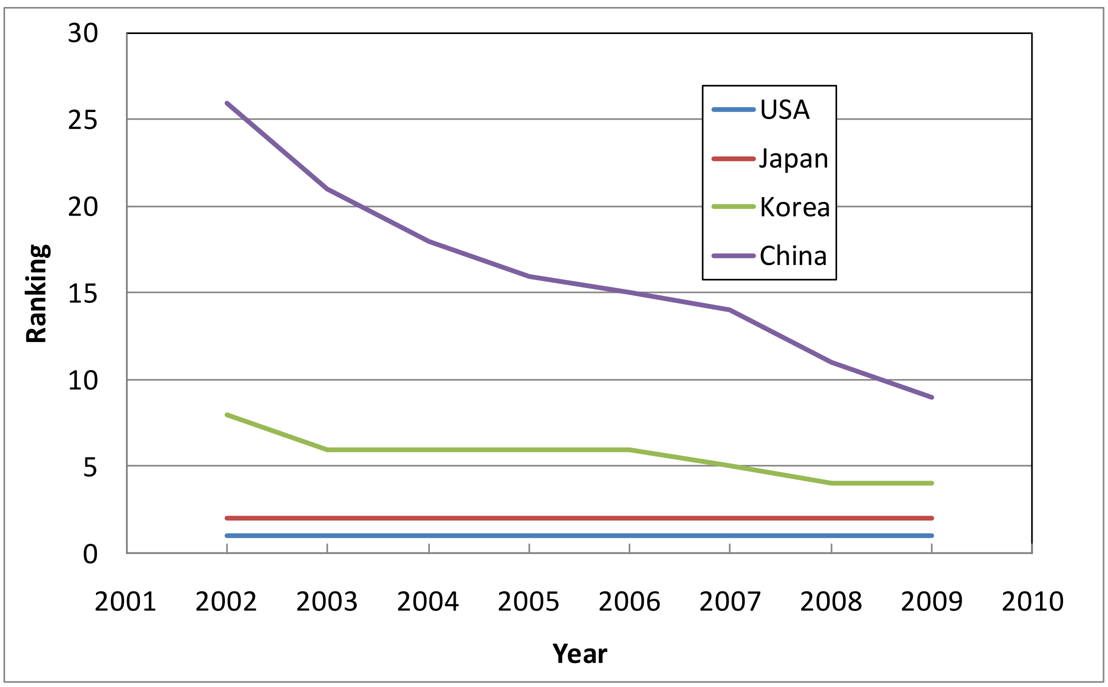

Figure 11. Ranking of countries globally based on # patents in nano-technology (lower rank is better)

U.S. is in the pioneer status while Japan always occupies the second position. Korea's performance is notable. Being compared with the U.S., Japan, and Korea, China has relatively small patent numbers. However, impressively China is the only one country that continues to upgrade its ranking among 26 countries. Its ranking started from the 26th in 2002 and then made significant improvement to hit the 9th in 2009.

PUBLICATIONS AND CITATIONS IN THE NANO-TECHNOLOGY AREA

Given the dynamic development and expansion in nanotechnology research, it is useful to continually reassess international scientific performance. In so doing, we have tried to distinguish quantity and quality, the latter of which is often measured through citations.

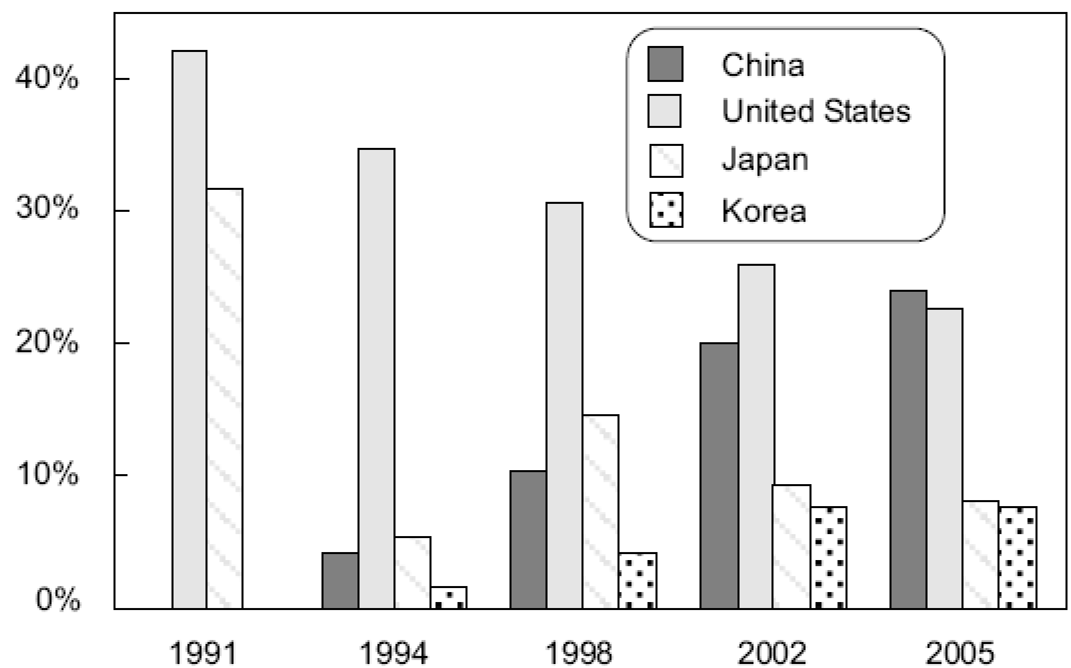

Figure 12: Share of countries in production of articles in nanocomposite sub-area[27]

As can be seen from Figure 12, the number of articles has grown from 4% to 23% in China while US has been steadily decreasing. Japan has also been on a downward trend while Korea seems to have made progress. This chart clearly indicates that China has laid emphasis on nanoscience and nanotechnology.

A similar trend can be seen in the graph below. The increased funding for R&D seems to have been quite efficient in terms of scientific publications, allowing China to end an old debate about its cultural aptitude for scientific work by becoming a scientific power that ranked fifth in 2005 in the SCI (Science Citation Index), after the United States, the United Kingdom, Germany and Japan, with a share of 6.5% of the world's publications, compared to only 2% less than a decade earlier. Clearly, in nanotechnology, China is already quite close to the United States in terms of number of publications. [Fig 13] This evolution of China's scientific production gives some indication of the progress toward innovation

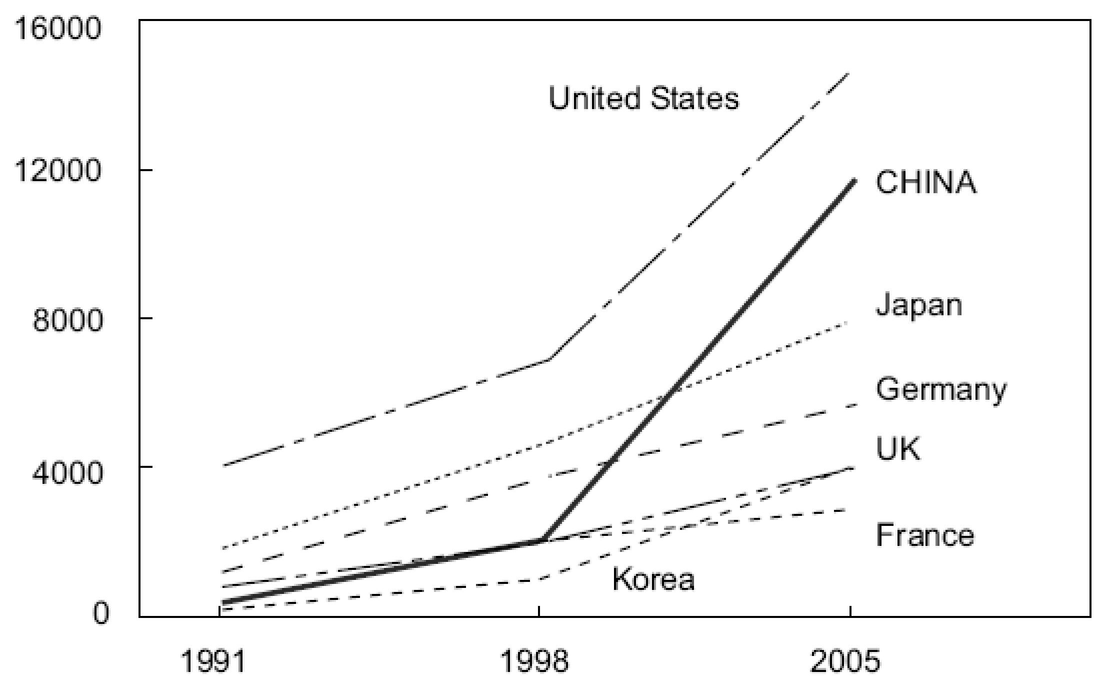

Figure 13: Nanoscience / Nanotechnology article production by country[27]

Firstly, this skyrocketing trend is partly due to increased incentives to publish. PhD students are now expected to publish at least one article in a journal listed in Thomson's Science Citation Index; for more experienced academics, publication records are more and more used to determine funding. Secondly, quality does not seem to keep pace with quantity. Citation rates and other indicators of quality remain relatively low; scientific fraud has even become a serious concern. At the same time, the national figures conceal strong performance by some individual universities.

Summary

In sum, no matter the combined statistic data from triadic patent offices or the data from USPTO, the result shows if we count the growth rate of patent numbers and the world ranking improvement since 2002, China has made an amazing achievement in the nanotechnology patent field when comparing to the United States, Japan, and Korea. It shows that China is on the way to progress.

The achievements of China in nanotech field are not sufficient for commercialization and further application. But, the impressive growth of China's performance in nanotechnology domain is an indicator of the beginning stage of the emergence presently, and signs of progress from imitation to innovation.

COMPARATIVE ANALYSIS WITH COMPETITORS (JAPAN & KOREA)

As we have noted throughout the analysis, China still lags both Japan and South Korea in terms of output. China has become one of the top countries when it comes to R&D expenditures, or total amount of financial input to R&D Functions. The biggest problem facing China is its output. China needs to improve its Quality of Patents. The raw numbers of Patent applications is on par with the top countries. The number of patent grants however is relatively low.

CHINA'S RECENT INNOVATIONS

China has been continuously striving to innovate to change from a sustaining to sustained development. One of the more visible phenomena of China's ascension in the innovation capability is the number of foreign companies that are setting up R&D Labs in China to tap their skilled workforce and personnel. Figure 14 below shows the impressive growth of China towards innovation.

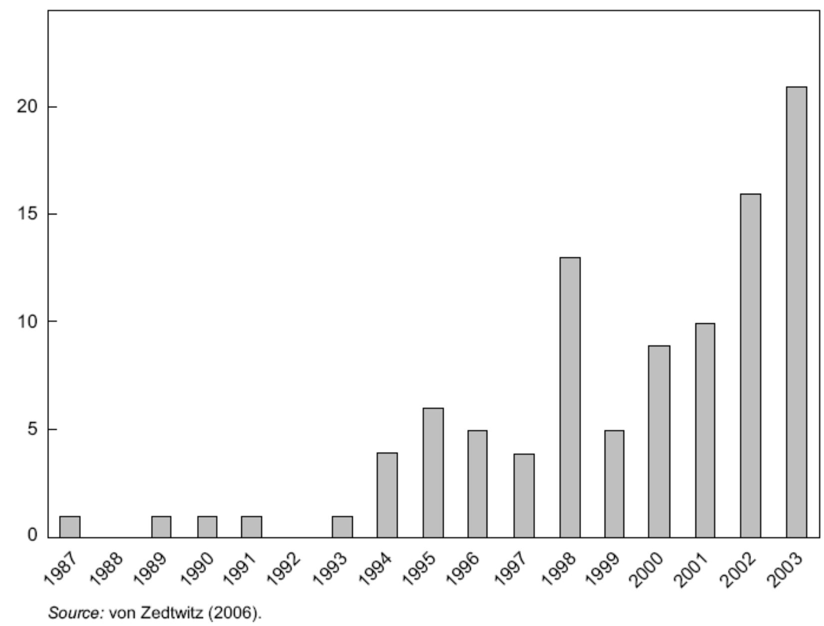

Figure 14: Number of new establishments of foreign R&D labs in China

Not only are the foreign companies setting up high-tech labs, but the Chinese government is also ramping up its high-tech industry. Below are some examples from the high-tech computing and communication equipment areas which are clear indicators of this movement from imitation to innovation.

China's **Tianhe-1A supercomputer** is created by the National University of Defense Technology (NUDT) and located at National Supercomputer Center, Tianjin, China. It is a GPU-based supercomputer which is equipped with 14,336 Xeon X5670 processors and 7,168 Nvidia Tesla M2050 graphic process units (GPUs). It offers half the size of regular computers at the same performance and 50% faster in term of performance than the world's top supercomputer at 2.507 petaflops, measured by the LINPACK benchmark, which makes it the fastest computer in China and in the world today[28].

Tianhe-1A is considered as a significant achievement for China and it has made China become a competitor in the world of supercomputer development. China uses it as a powerful tool mainly for scientific research, such as geology, meteorology, oil exploration and the aviation, automobile and chemistry industries[29].

Figure 15: Tianhe-1A

Another example is China's first photonic telephone network is a practical quantum communication completely built in Hefei, capital city of Anhui province, China by Prof. Pan Jianwei and his team research group at University of Science and Technology of China (USTC) in April 2009[30].

Quantum communication provides the complete secure which traditional communication cannot provide which means that it can provide great possibilities for information security field such as national security and finance. Moreover, it can be applied for everyday use as it can be expanded on the commercial fiber network.

This successful research has made China become the leader in the field of practical quantum communication and it indicates that quantum privacy in your own home may not be a too distant prospect and the industrialization of quantum communication technology has already come to China [31].

THREATS TO THE IP ECOSYSTEM

Most countries in the top echelons have very strong IP protection laws and enforcement institutions. China needs to increase its use of IP laws and prosecute offenders. The lack of IP protection and enforcement makes many transnational companies wary of sharing it most precious inventions. This has caused an isolation of their high technology industry. Most advanced corporations set-up manufacturing capacity in China, but most of the R&D work, as well as the design gets done outside China.

China needs to develop a strong reputation for IP enforcement; this will create a more business friendly environment, where foreign companies will be willing to work with academia and local institutions and to share and exchange knowledge. Academic misconduct is a particularly pervasive problem in China, where it infiltrates the higher education system from the undergraduate ranks on up. Many universities have shut down their US programs in China due to this economic misconduct.[32] There has also been cases of PhD graduates who have launched an online business to sell academic papers, charging between 10 to 20 thousand Yuan for each paper.[33]

As part of China's national innovation agenda, the govenrment has noted to intensify the protection of core technologies to become a breakthrough in boosting their economic growth and have independent intellectual property rights so as to promote the development of the high and new technology industries. The newly rising industries can improve the independent innovation capabilities of China and thereby enhance their national core competitiveness.

RESULTS AND CONCLUSIONS

The government needs to provide more freedom to its citizens to fully empower its workforce to discover and explore new avenues of development. As a nation is well suited to manufacture and produce any material or product. When it comes to moving to the next step, which is to develop the next new product, there is still has many more years to go.

On the high technology field, China is spending like the innovators, however, the output of these expenditures are not at the level of other industrialized countries. China has 4X the population of the United States. If one assumes that intelligence is distributed randomly China has 4X the number of geniuses compared to the United States. China has 4X the number of capable people in its population. If China finds a way to find and educate its smart and brightest, China has a strong future potential. With time, China will become a power house in the knowledge field as well.

REFERENCES

[1] China Map, http://www.mapsofworld.com/china/

[2] "Invented threats", Economist Newspaper: From website:

http://www.economist.com/blogs/freeexchange/2011/01/trade_innovation

[3] NationalInnovationSystems, OECD. http://www.oecd.org/dataoecd/35/56/2101733.pdf

[4] Martin Schaaper, "Measuring China's innovation system, National Specificities, and Internationalcomparisons."

[5] Organization for Economic Co-operation and Development (OECD), from website:

http://www.oecd.org/pages/0,3417,en_36734052_36734103_1_1_1_1_1,00.html

[6] Estimates from China National Census data and education analysis; OECD

[7] OECD Science, Technology and Industry Scoreboard 2007

[8] Martin S. (OECD) (2009). "Measuring China's Innovation System National Specificities and International Comparisons".

[9] 2011 Global R&D Funding Forecast Magazine

[10] UNESCO Science Report 2010, The Current Status of Science around the world

[11] "China Rises to the 2nd Place in R&D Investment", From website:

http://www. appliancemagazine.com/news.php?article=11071&zone=0&first=1

[12] OECD Science, Technology and Industry Scoreboard 2005

[13] 2010 Global R&D Funding Forecast Magazine

[14] 2010 Global R&D Funding Forecast Magazine

[15] Douglas, G. (September 2010). *"The New Geography of Global Innovation"*. Global Market Institute.

[16] Xiao-ping Lei, Dar-Zen Chen, Mu-Hsuan Huanget al; "An Analysis for Chinese Patent Competitiveness, through the USPTO Database in 2008," Technology Management for Global Economic Growth (PICMET), pp. 1-10, 2010.

[17] Chen D. Z., W. Y. C. Lin and M. H. Huang; "Using Essential Patent Index and Essential Technological Strength to evaluate industrial technological innovation competitiveness," Scientometrics, Vol. 71, pp.101-116, 2007.

[18] Masatsura Igami and Teruo Okazaki; "Capturing Nanotechnology's Current State of Development Via Analysis of Patents," STI Working Paper Series, 2007.

[19] "Report Of Nanotechnology Strategy Group",Engineering and Physical Sciences Research Council, 2006.

[20] Can Huang and Yilin Wu; "Sure Bet or Scientometric Mirage? An Assessment of Chinese Progress in Nanotechnology," United Nations University –MERIT Working Papers Serious,2010-28, 2010.

[21] Jorg Mahlich and Werner Pascha; "Innovation and Technology in Korea," Physica-Verlag, Heidelberg, 2007.

[22] M. Ichikawa, "Towards a Global Patent System: The Japan Patent Office View," CASRIP Publication Series: Reconciling Int'l Intellectual Property, No 7, pp. 150, 2001.

[23] www.wipo.int/ipstats/en/statistics/patents/wipo_pub_931.html

[24] USPTO Patent Database, http://patft.uspto.gov/netahtml/PTO/search-adv.htm.

[25] JPOPatentDatabase, http://www4.ipdl.inpit.go.jp/Tokujitu/tjsogodben.ipdl?N0000=115.

[26] PATSTATdatabase http://gb.espacenet.com/search97cgi/s97_cgi.exe?Action=FormGen&Template=gb/en/advanced.hts.

[27] RN Kostoff et al(2007) Structure of the Global Nanoscience and Nanotechnology Research Literature.(http://www.dtic.mil/)

[28] Nvidia Tesla GPUs Power World's Fastest Supercomputer

[29] Tianhe-1A marks rapid growth of China's science and technology http://www.defence.pk/forums/china-defence/81140-tianhe-1a-marks-rapid-growth-chinas-science-technology.html

[30] USTC built the world's first photonic telephone network in Hefei http://physics.ustc.edu.cn/bencandy.php?fid=41&id=453

[31] First Quantum cell phone network been built in Hefei by USTCers http://en.ustc.edu.cn/news/201001/t20100118_1705.html

[32] USATODAY: Plagiarism epidemic shuts down U.S. program in China

[33] IBMTIMES: http://www.ibtimes.com/articles/104095/20110124/academic-plagiarism-on-the-rise-in-china-phd-on-sale.htm