China: Innovation in a Centrally Planned Economy

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Abstract – Innovation has been identified as a key factor in sustained economic development. China has made significant policy changes in the past 30 years in an effort to improve the level of innovation, while maintaining policy institutions that ascribe to central planning and control. Our paper addresses key issues in the measurement of innovation capacity to provide an assessment of China's progress towards increasing innovation capacity.

I. INTRODUCTION

In a world where technological innovation plays a major role in the success of economies it would seem to follow that China's recent economic performance would reflect a high degree of success in their management of technological innovation. In this paper, we offer some insight into the state of innovation in China and discuss the major factors that have contributed to China's success.

Any analysis of China's recent economic success would not be complete without considering events of the last half century and the impact they have had on life and business in China. A shift in China's political policies has led to changes in institutions. These changes were intended to have a positive impact on technological innovation. We discuss the major changes, their intended impact and the measured impact.

After reviewing literature pertaining to measuring innovation it is clear that there is a wide range of approaches that have been defined. Rather than establish a new approach, we have concluded that the best approach for this paper would be to use a system analysis approach described by Liu and White [9].

A. Why Innovate?

What would motivate China's policy makers to want to improve technological innovation, especially when the necessary changes to institutions could threaten the level of control by the state? The answer is that the state recognizes that to achieve long term economic success, a country must achieve long wave economic cycles as observed by Nicoli Kondratieff [1]. Long wave economic cycles are fueled by new basic technologies creating new functionality.

Innovation is "…the creation and implementation of new processes, products, services and methods of delivery, which result in significant improvements in outcomes, efficiency, effectiveness or quality." [11]. With that

definition in mind, it follows that a country's capacity for improving economic performance is dependent on its capacity for innovation.

B. Conflicting Priorities

China sets about attempting to satisfy two diverse priorities. Maintain central planning while moving toward policy that reflects influence by market performance. Central planning is a means of controlling the means of production and distribution. In a centrally planned economy supply and demand, cost and price do not dictate the allocation of scarce resources. Instead, a committee is charged with deciding the allocation based on political policy. Workers in a planned economy focus on completion of activities that are required. Behavior consistent with the goals of the state and that conform to policy are rewarded. Decisions are made in a top down approach and growth is planned.

In contrast, a market driven economy must meet the needs of the market to be successful, as success is measured on the basis of economic outcomes. As the needs of the market change, or as new unmet needs are identified, innovation is required to reorient resources to meet the new market opportunity. Workers are generally encouraged to think outside the box and decisions are generally driven more from the bottom up. One might consider this type of growth more 'organic' because it occurs more naturally without direction or planning.

The question is; can an innovation system in a centrally planned economy be as successful as it would be in a market driven economy? If so, then China may find some advantage. If not, then more change in China's policies will be necessary. As China has made changes to policy over time to create a more market aware economy there should be some evidence of success if they are moving in the right direction. To detect evidence of success a means of measure would be required that would expose the performance of the underlying structures and systems on which the success depends. A sound measure of China's capacity for innovation would be one way to assess the potential for successful economic growth.

II. HISTORY & EVOLUTION OF THE CHINESE ECONOMY

China has experienced breathtaking growth over the last 30 years by almost any measure: GDP growth has averaged over 10% year; exports were more than double that rate from 2000-2005; and per capital income continues to march forward at a strong pace. The biggest driver for this growth has been foreign investment in manufacturing to take advantage of a plentiful supply of low cost labor along with tax and other incentives provided by the government [2-4].

Growth has been substantial enough to push China to number three, behind the US (1) and Japan (2), on the list of global GDP leaders. However, as China closes out another $1 trillion in GDP growth for 2008; finishing above $4 trillion for the first time ever; the big question is, can they sustain this growth?

Following macroeconomic theory we would expect firms with global reach to prefer manufacturing in the environment that is least expensive – ceteris paribus. Moreover, in many firms, the bulk of costs are associated with labor. Thus, access to low cost labor is a key advantage for China.

However, as economies expand, this growth tends to drive the cost of labor up. Several factors combine to produce this effect, including: more intense competition for the available labor, the accumulated skills and experience (value) of workers, inflation which raises the cost of living, plus diminishing marginal productivity as we exhaust the supply of our most efficient resources and must employ increasingly less effective resources.

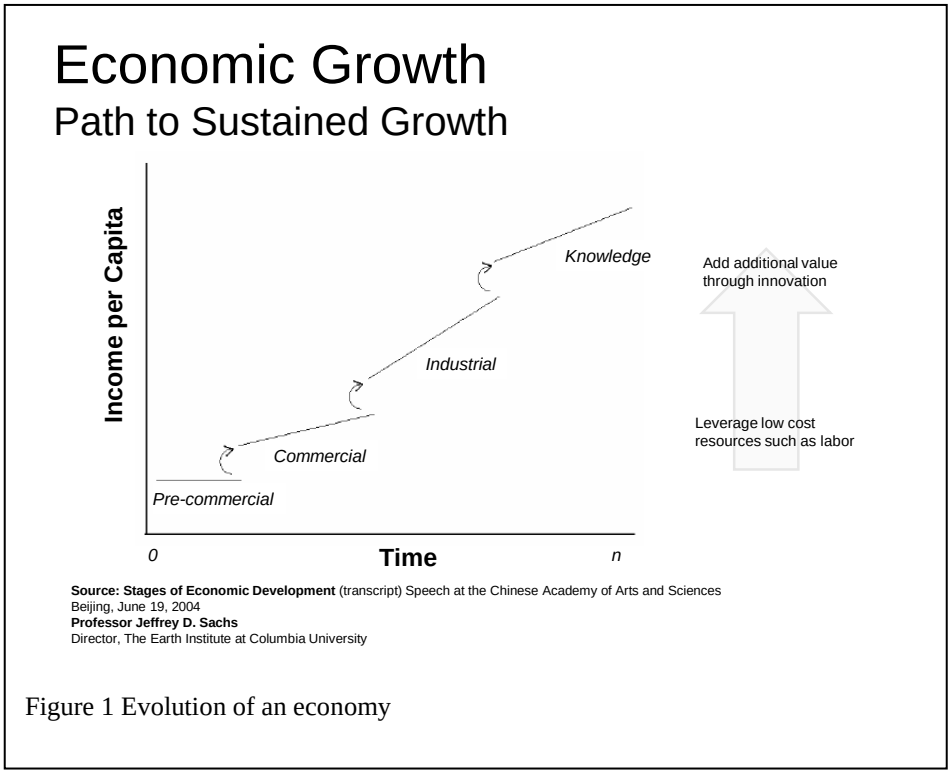

Figure 1 Evolution of an economy

We will examine the stage of growth for China in more detail later in this paper. For now, let's take a minute to explore China and recent history more closely. China is currently the largest country in the world in terms of population with a total of 1.3 billion people. The land area is 9.6 million KM giving ranking fourth in the world just behind the U.S. – in fact, China is very comparable in size to the U.S.

The country is composed of 22 Provinces, 5 Autonomous Regions, 4 Municipalities, and two Special Administrative Regions. The 22 Provinces are governed directly by the central government; as are the 4 Municipalities that are large and strategic enough to warrant direct control. Autonomous regions are given greater legislative rights; like the ability to pick a local Governor; however, they are still under the control of the central government. Special Administrative Regions are given broad authority to manage their own affairs, including executive, legislative, and judicial powers; with the exception of diplomatic relations and national defense which are still managed by the central government. Both of the Special Administrative Regions (Hong Kong & Macau) operate under pre-existing capitalist economic systems.

Figure 2 Provinces in China

The east coast of the country extends along the Yellow Sea in the north, to the East China Sea, the South China Sea, which lead out to the Pacific Ocean providing plentiful access to sea ports for international trade. The western portion of the country is mountainous and sparsely populated. In between lies rich agricultural areas that are very rural in nature. China has traditionally relied on an economy that was dominated by agriculture. In fact, the majority of the population still found in rural areas; however, that is rapidly changing based on growth patterns in China.

The administrative functions of the government are led by the National People's Congress (NPpC). The members of the NPpC are elected and represent various constituents across the country. Although the stated goal is to represent "the people" the composition of the NPpC still does not provide a balanced cross-section of the country. More detail on the composition can be found in Figure 3 below.

The people are represented by the NPpC, the country does have a constitution that provides for certain individual rights, and the country has a system of laws, penalties, and a judicial system. This all sounds pretty typical from a "western" point of view; however, there is another, much more powerful, layer to this governmental structure in China. The country is actually run by the Communist Party of China (CPC). With over 73 million members it is the largest active political party in the world.

In theory, any Chinese citizen over the age of 18, who accepts the Party's Program and Constitution, is willing to work actively in one of the party organizations, carry out the decisions of the Party, and pay membership dues may apply for membership [4]. However, in practice membership is usually limited to those who are wealthy or influential, intellectuals, model workers, or soldiers. Once a person applies they are monitored for several years, their friends and associated are interviewed, and they have to attend classes on party policy and culture.

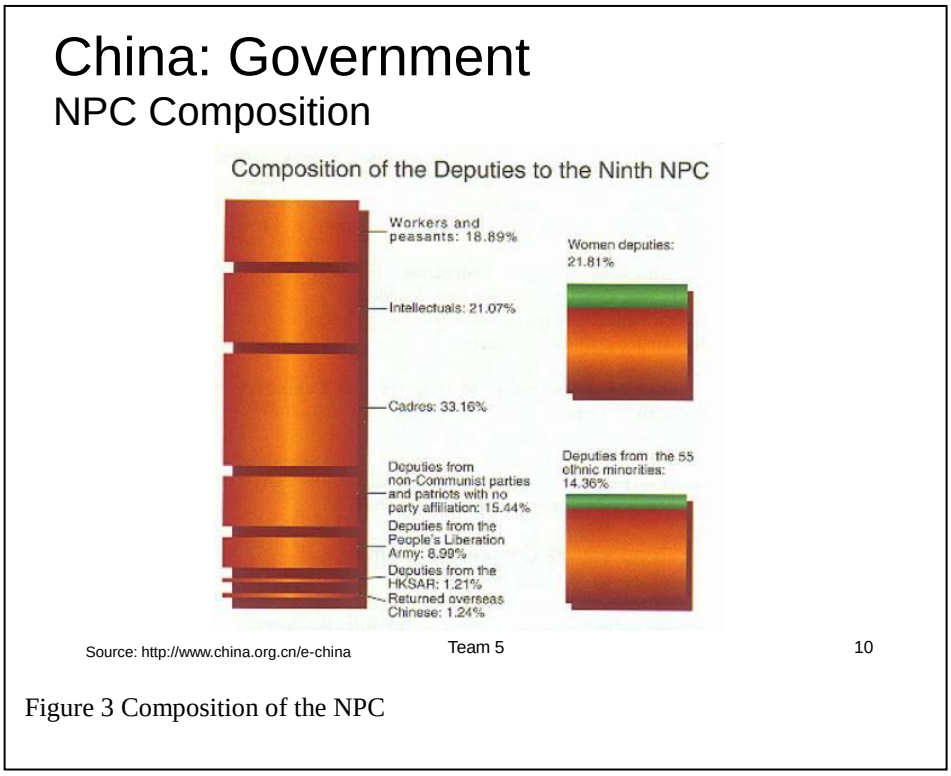

Figure 3 Composition of the NPC

Figure 4 Chinese Communist Party Roles

The direct result of these policies is that the 73 million members of the CPC represent only comprise 5% of the population and membership is far from representative of the population. For example, 80% of the CPC are men, 77% are over the age of 35, and 31% have a college degree. The upside down pyramid structure of the party concentrates leadership even further. The party is represented by the National Party Congress (NPaC – position authority over the National People's Congress) composed of ~2,000 party members which meet every 5 years to put together China's "master" five year plan. This plan is approved by the Central Committee (~200 members) who "push" the master plan down to the National People's Congress for adoption and implementation.

The power of the Party is even more concentrated in the Politburo (24 members) and the Standing Committee (9 ranking members of the Politburo) which drives all day-to-day decision making for the Party. The members of the Standing Committee meet frequently to decide matters of policy and much about their activity is shrouded in secrecy. Thus, the Party drives both the day-to-day and long-term policy making for the country; while the National People's Congress, and the agencies that it oversees, are responsible for implementing those policies.

The power of the Party is further solidified by the fact that the Chairman and General Secretary of the Communist Party (Hu Jintao); is "selected" by the National People's Congress to serve as President; and also serves as the Chair of the Military Affairs Commission, making him the de facto Commander in Chief of China's armed

forces. Since the National People's Congress, which he presides over as President, manages the judicial and administrative functions of government, Party control is very far reaching.

In addition, to the national Party, each region, province, or city has its own Party officials who monitor operations and progress within each region. The local officials are expected to implement policies and make decisions, but if the local party office disagrees, the Party official has the ability to pull rank.

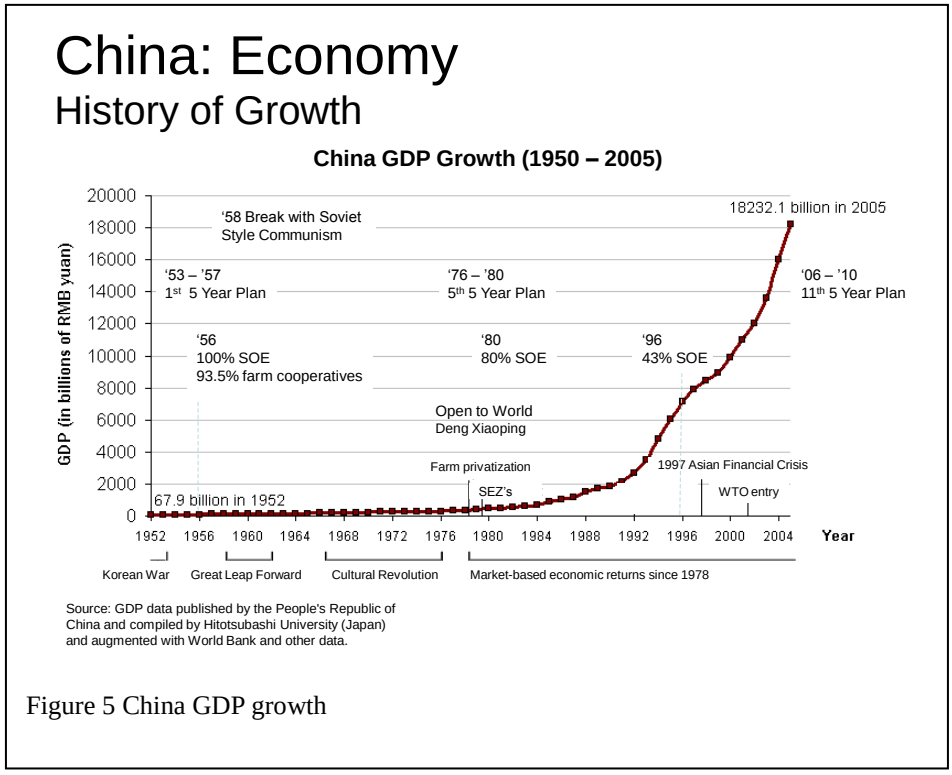

Figure 5 China GDP growth

The Communist Party consolidated control of China in 1949 and set about establishing a Soviet Union style centrally planned communist system. The role of any economic system is to manage the allocation of scarce resources. The hallmark of this type of economic system is public (state) ownership of all business and then the creation of very detailed plans to guide resource allocation, production, and pricing. China, with help from the Soviet Union, was able to implement their first five-year plan by 1953, nationalize existing business enterprises, and re-organize 94% of all agriculture into farm cooperatives by "convincing" farmers to "voluntarily" donate their land to farm cooperatives.

The Soviet Union provided guidance, advice, and sold China equipment and machinery to help build productivity; however, by 1958 China was ready to break with Soviet style communism and established the second five-year plan which aimed to increase agricultural efficiency and build manufacturing muscle at the same time.

Volumes have been written about "The Great Leap Forward", as this plan was called, and the millions of lives that were lost as a direct result of its policies.

This paper will not explore the details of this unfortunate time in Chinese history or the Cultural Revolution that took place from 1966 to 1976. Instead we shift our attention to 1978 where Deng Xiaoping ushered in the reforms that led to the modern economic miracle we see today.

In 1976 China published the 5th five year plan which called for steel output of 60 million tons, oil output of 250 million tons, 10 oil and gas fields, and over 120 other large projects. This plan required over ¥70B government investment – more than China had invested in total over the last 28 years (china.org.cn). These were soon found to be impossible targets; so in 1978 the Communist Party Central Committee, refocused the plan to a primary goal of modernization under the principles of readjustment, reform, rectification and improvement. These reforms called

Figure 6 Special economic zones in China

for the privatization of farms, agriculture, and many state owned enterprises; opening up to the world for outside investment; and controlled "market-based" reforms that would pave the way for foreign owned enterprises operating in China.

One of the primary tools used to make this transition was the special economic zone (SEZ). From 1980-1984 China established five special economic zones: three in Guangdong Province, one in Fujian Province, and the

entire island of Hainan. In 1984 another 14 cities were opened for foreign direct investment (FDI); these incentives were expanded to more coastal areas in 1985; additional economic zones were also formed. Early SEZ's were concentrated along the coast where international trade would be most likely to take root; but the government has continued to open up additional regions including all the capital cities of inland Provinces and Autonomous Regions.

The primary purpose of SEZ's was to create jobs, acquire technical knowledge, and attract foreign direct investment (e.g. allow others to finance the modernization of industry and knowledge acquisition). A number of incentives were provided to firms in SEZ's including: access to low cost labor, favorable tax treatment, greater independence for international trade, business friendly rules and policies, and the potential for additional government subsidies.

As we can see now, this set of policies has been a tremendous success resulting in an average annual growth in GDP of more than 10%; and export growth that can easily top 20% in some years. One other effect of these policies has been to create a deep chasm between the incomes of rural (agricultural) residents and urban residents. The income differential, and the demand for low cost labor in newly industrialized areas, has pulled

Source: Handbook of International Economic Statistics, Feb 1999

Figure 7 Flow of capital and labor

millions of residents from rural to urban areas in search of work. The migration has been significant enough so that if it continues at the current rate the number of urban residents will pass the number of rural residents by 2015 [13]. To compensate the government re-invests in inland regions through agricultural and banking.

As discussed earlier, as economies expand, growth tends to drive up the cost of labor. Several factors that were discussed earlier combine to produce this effect.

Professor Jeffery Sachs (Sachs: 2004) from Columbia University outlines a model that ties stages of economic development directly to income per capita. The basic idea is that as the cost of labor increases firms must add additional value to justify the higher wage rates (and standard of living).

The lowest level on this scale is the Pre-commercial period where economies exist in isolation without outside trade. The Pre-commercial economy gives way to a Commercial economy as Pre-commercial economies link to outside economic centers and begin to trade. The Commercial stage can then usher in an Industrial economy as we gather production capital and equipment and begin to manufacture goods – starting simple and getting increasingly more complex in our capabilities. The final phase of evolution is a Knowledge economy where unique new intellectual property is created and deployed to offer additional value well beyond that associated with low cost labor and production.

While there is a natural evolution between these phases with proper execution, there is certainly no guarantee that an economy will advance to the next stage. It is possible for countries to get stalled anywhere along this growth path. Of course, for rapidly growing countries such as China, this give rise to another risk; if an economy cannot advance to the next phase then they may be left in a position where rising labor costs erode all of the competitive benefits previously associated with their market. If the economy is powered by exports and foreign direct investment – like China – then international firms may migrate to other geographies where low cost labor still exists. Thus, it also become critical for countries in this phase of development to develop a strong domestic economy, and build strong trading partnerships by increasing imports, in parallel with an export oriented growth engine.

So, how is China doing? In order to answer this question we used income per capital estimates associated with stages developed by Professor Shinichi Ichimura (Ichimura) at Kyoto University in Japan, combined them with the outlined earlier from Sachs (Sachs: 2004), and then used actual per capita income numbers provided by Thomson Reuters (Thomson Reuters: 2008) to map China in this model.

What we discovered was that the incomes in China are extremely bifurcated between urban and rural residents. However, using this scale, both were well below the levels required to establish a knowledge based economy. In fact, rural residents straddle the Pre-Commercial or Commercial stage (extremely early stage); while

urban residents appear to be early in the industrial stage – these figures are well below both the $10,000 threshold presented by Ichimura and the $48,000 of a mature economy such as the United States. This model would suggest that a move from Industrial to Knowledge based economy by China is premature at this point.

This leads to one key distinction between planned economies such as China and market-based economies such as the United States. In a market based economy a more organic growth process takes place and the market tells business (through losses or rewards) when the transition is required; in a planned economy the government needs to project and plan for transition. A market-based system runs the risk of time lag as market signals are incorporated into operating plans; a planned system has the advantage of leading the charge at the risk of missing the mark completely.

So, if we look at the composition of GDP and labor today what other clues can if offer? China currently generates only 11.3% of GDP from agriculture, yet 43% of labor is employed in that sector. In addition, we know from our earlier discussion that agriculture (predominantly rural) incomes lag those of urban residents by almost

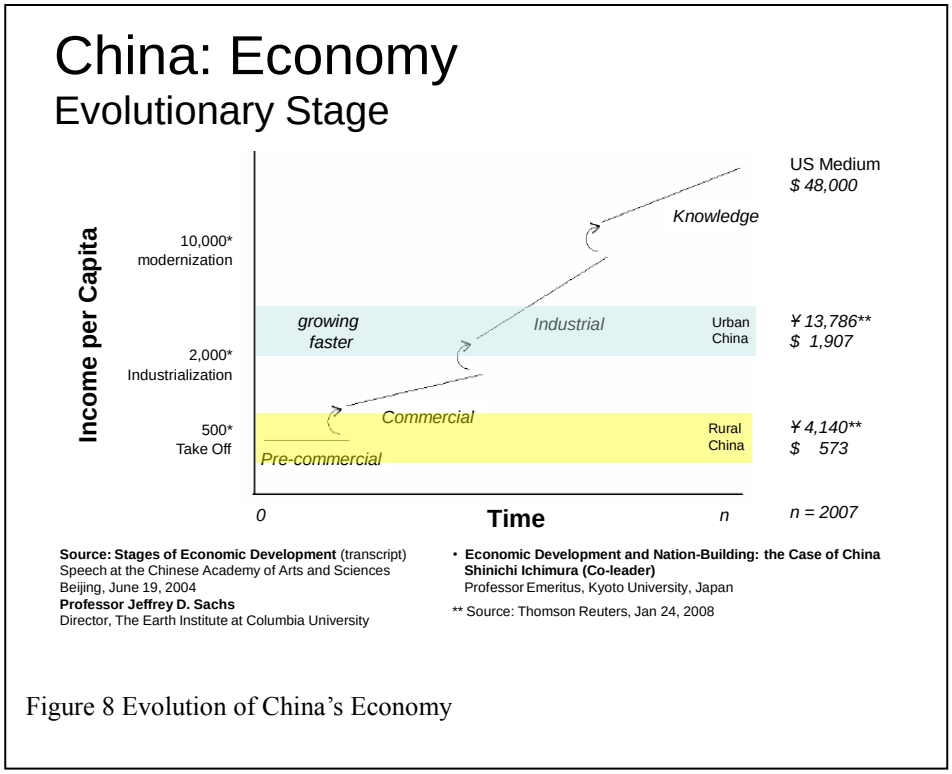

Figure 8 Evolution of China's Economy

300%. This continues to pull rural residents to urban areas (despite travel restrictions) creating a host of infrastructure issues.

In addition, because of China's one child per family policy started some 30 years ago, China also has one of

the fastest aging populations in the world which will put additional stress on social systems such as medical care and create the need for some type of national retirement plan or safety net. These elements must all be addressed if China is to maintain a "harmonious society" and the Party is going to maintain its way of life.

Figure 9 Changes of focus on 5 year plans

Of course, the natural way forward in this situation for a planned economy is the 11th five year plan (2006-2010). The 11th plan contains a number of different platforms; however, we will see that many of these mirror the themes that we have covered here.

The plan outlines a "new socialist countryside" which seeks to narrow the gap in income between urban and rural residents, invest in production technology and capacity, and create a social security system. The plan also seeks to upgrade the industrial structure by focusing on high-tech (knowledge based) industries, modernizing heavy industry, enhancing the energy industry, the supply chain for raw materials, increase the use of information technology, and looking for ways to modernize and increase value-add for light manufacturing. In support of these initiatives the central government wants to invest in science and education; further develop the services industry; and try to maintain a balance across regions while building a "harmonious socialist society".

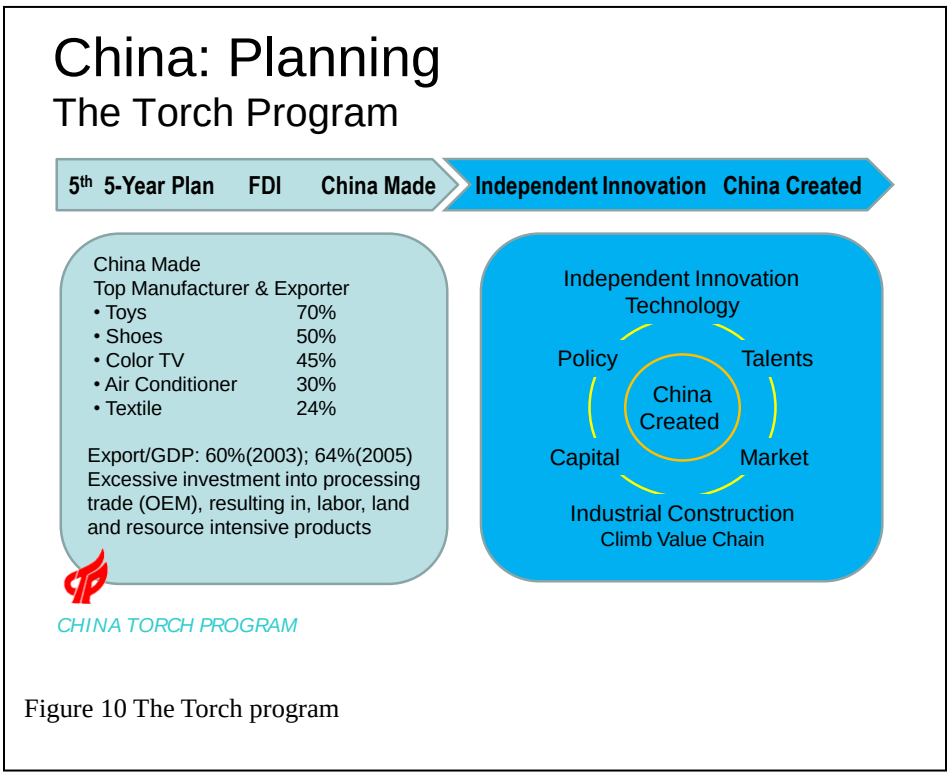

Figure 10 The Torch program

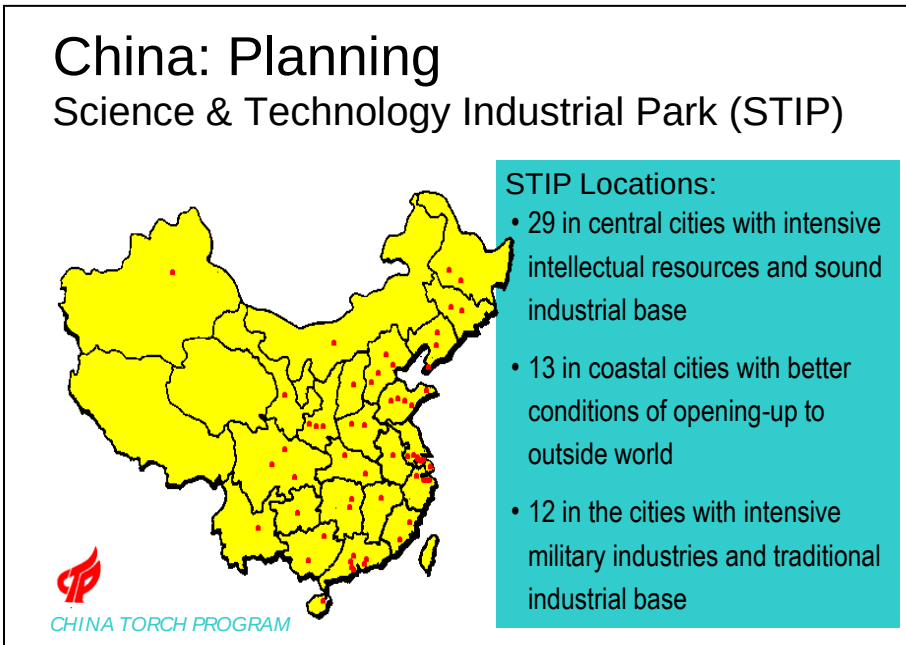

Figure 11 Science and industrial parks

One example of how this type off planning works in practice can be found in the Torch Program. The

Torch Program seeks to plant the seeds (technology, talents, policy, capital, and markets) that will become the foundation for greater innovation and a knowledge based economy in China. One of their largest initiatives is to create Science & Technology Industrial Parks (STIP) that will encourage research, development, and commercialization in target industries. They have now created 54 of these centers. However, in keeping with the policy of narrowing the gap between urban and rural residents more than half of these parks are either in interior areas or outside the traditional industrial base. This is counter to the way we might see this same program implemented in a market-based economy. However, it does underscore the importance the Chinese government places on a new economic transition based on less imitation; and more driven by innovation, knowledge, and value-add.

III. MEASURING INNOVATION

What is China's capacity for innovation? A variety of different approaches to measure innovation capacity are possible. The following are a few approaches we considered.

A. Using Indices

According to Porter and Stern [12], international patenting with U.S Patent and Trademark Office is the single most useful measure of innovation. Whilst this attribute, international patenting, might be an output that could be easily measured it might be argued that not all corporations, such as members of the European Union, would find patenting with the U.S Patent and Trademark Office (USPTO) an economically viable option, not just in terms of the costs involved but because of reasons of geography and/or socio-political circumstances. The Economist, in its 2009 Intelligence Unit Report sponsored by Cisco, agrees with Porter and stern on the importance of international patenting but with a slight difference in the scope of the definition. The Economist defines international patenting as any patent registered with U.S Patent and Trademark Office, European Patent Office (EPO), and Japanese Patent Office (JPO) [5]. Other researches also showed patent can be used as an indicator of R&D capacity [6, 14]. Figure 12 shows the number of patent granted by the US Patent and Trademark Office from 1991 to 2003. The Economist's international patent is a triadic patent and it is a patent that has "been applied for at EPO, the JPO, and

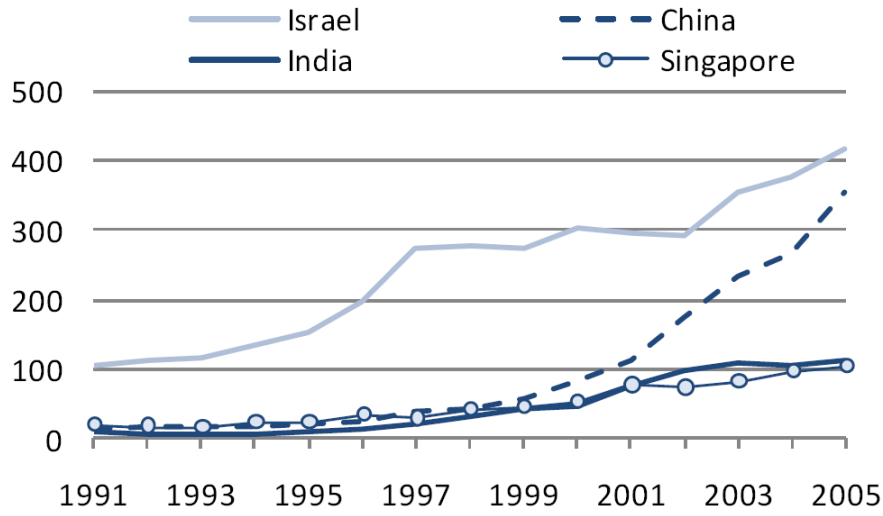

Figure 12. Patents granted by the U.S. Patent and Trademark Office, 1991-2003

Source: OECD, Patent Database, June 2008

granted by the USPTO to protect the same invention".

On the other hand, patents do not necessarily lead to products or services that find their way to the market, so they do not always contribute to innovation. While there has been an increase in patents obtained by companies in China, it is not clear whether the patents were granted to China based multi-national enterprises or by Chinese companies. With these issues in mind, patents alone are not a reliable measure of innovation capacity.

B. Rank

China's rank in the world provides some perspective on the impact of their history, geography, natural resources and other factors that influence economic performance. A country's rank in the world is a snapshot of performance, but it does not yield significant depth to our understanding of the reasons behind the rank. Rank may change due to changes in other members of the data set. A country's rank in the world is measured by organizations like the United Nations Industrial Development Organization (UNIDO), the Organization for Economic Co-Operation and Development (OECD) and a variety of others such as China's rank in the world in Income Per Worker and Total Factor Productivity as shown in Table 1.

Table 1 China rank in the world

	1960	2000
Income Per Worker	103	71
Total Factor Productivity	105	76

Source: UNIDO Viena 2005 and UNIDO 2007

C. Trends

Trends in economic performance can be helpful in analyzing the impact of policy and other factors when the factors are well understood and outside influences can be fully accounted for. The difficulty arises with the selection of factors to be considered. In the case of China, as a latecomer to the global technology sector, their role

in business has changed over time. In the early 1990's China provided low cost labor as their primary contribution to foreign owned companies. As the business environment changes, the underlying cause for economic performance also changes.

D. Policy Analysis

Analysis of the underlying innovation policy framework involves consideration of the government bodies, organizations and stakeholders and their impact on innovation [**Error! Reference source not found.**]. Beginning in 1978 the policies in China started moving to open its economy to global markets. This shift in policy and subsequent emphasis on developing support for innovation provides an opportunity to study the impact of specific initiatives as shown in Table 2.

Table 2. Chinese reform policy for public S&T institutions: 1978–2004.

Period	Policy actions target	Policy actions
Reformation of Planning Practice (1978–1984)	Recover and develop the R&D system and integrate it into the planned economic practices.	Rehabilitation and improvement of R&D institutions after the damage during Culture Revolution (1966–1976). Integration of R&D activities into the 6th National Five-Year Plan (1980–1985).
Performing the S&T activities in the ‘‘Market’’ (1985–1991)	Establish the horizontal and regular connection between S&T sector and enterprises.	Replace the former S&T funding method that is mainly through planned appropriation by the program projects competition mechanism. Diminish the government grants to force the R&D institution to establish cooperation with industry. Create a ‘‘Technology Market’’ to legitimize paid transactions for technology and set up the agencies to support the transactions. Promote the autonomy of R&D institutions and mobility of the S&T Personnel. Attempt merging the R&D institutions into enterprises. Support the spin-off enterprises.
Bridging S&T activities closely to ‘‘Socialist Market Economy’’ (1992–1998)	Run non-basic research R&D institutions as run enterprises.	Endow the R&D institutions the comprehensive economic autonomy as the same hold by normal enterprises. Encourage spin-off activities through promoting science park and incubators. Continue the merging strategy.
Large Scale	Transform nearly all of the	Transform the R&D institutions into

Transformation of R&D institutions (1999 till now)	government owned R&D institutions.	enterprises, non-profit organizations, intermediary organizations or merged them into universities.

Source: Organization, program and structure: an analysis of the Chinese innovation policy framework

E. System Analysis

The institutional and microeconomic environment play an important role in determining the effectiveness of a national system of innovation, the capacity of which is a country's ability to produce commercially competitive innovations on a global technological scale [5, 7, 8, 12]. This ability is demonstrated by the sophistication and size of scientific labor force, array of investments, policy choices of government and private sector that affect incentives for innovation, and productivity in R&D efforts. Therefore, any national innovation system must necessarily identify factors that enable the system to innovate at local, national and global levels. According to Porter and Stern [**Error! Reference source not found.**] there are, however, basic conditions that form a foundation for a nation's innovation infrastructure: pool of scientists and engineers; excellence in R&D and government funding; protection of intellectual property; the extent of tax-based incentives for innovation; degree to which antitrust enforcement encourages innovation-based competition; and openness of the economy to trade and investment. Porter and Stern further assert that whilst such a foundation is necessary, the ultimate test of national innovativeness rests with the "companies that introduce and commercialize innovation" and recommend clustering these companies to provide for linkages and to ensure presence of high-quality and specialized inputs, local competition, sophisticated local demand and local presence of related and supporting industries.

To analyze China's innovation system, we plan to use a framework proposed by Liu and White [**Error! Reference source not found.**]. This framework considers fundamental activities that are required for innovation with respect to system structure, dynamics and performance. In their paper on comparing innovation systems, Liu and White identify fundamental activities of the innovation process as shown in Table 3.

Table 3 System Analysis Metrics

Activity	Metric
Education	Research papers from Universities
	Graduates with technology related degrees

R&D	Patents
	Research papers from Research Institutes and Business
	Number of R&D personnel
	R&D Expenditure
Implementation	Number of business entities actively producing products
	Revenues generated
End-use	Consumption of goods and services
	Per capita income
	Per capita savings
	Value of exported goods vs. value of goods produced
Linkage	Science and Technology outsourcing
	Number of institutions focused on such things as technology transfer.

Robust educational activities, like graduates in technology, research papers that contribute to product or process improvements and long term science activities contribute significantly to a country's capacity for innovation. Research and development facilities that are engaged in work on products, services or fundamental investigations provide a source of new opportunities for implementers to implement. As implementers, manufacturers and businesses deliver new products and services, end users or consumers are needed to keep the process flowing. Finally, linkage activities facilitate the flow of value between institutions that specialize in the fundamental activities. Linkage may appear as mutual agreements between entities, resource transfers and even employment organizations that assist in directing talent to business needs. If all of the fundamental activities are well supported in a country, innovation should also flourish.

IV. ANALYSIS

Although the Chinese economy is moving from strong central controlled to market driven economy, the center planning is still playing a strong role in both economic development and S&T development. To examine how successful the innovation system under such central planning, we have collected data in the following categories: R&D expenditure, patent and S&T publications, education, and personal income, which are metrics that apply to the innovation system framework we adopt in this study.

A. R&D Expenditure

Figure 13 displays China's R&D expenditure in $US and as a percentage of GDP from 1991 to 2004. It is clear that the total R&D expenditure amount is increasing especially after 1998. For year 2006, the R&D expenditure and percentage of GDP are 37.7 billion US dollars and 1.42% GDP, respectively [10].

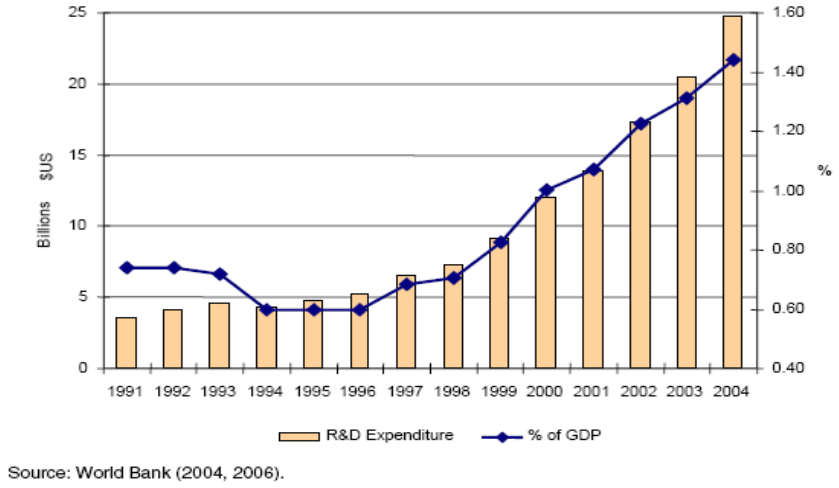

Figure 13. China R&D Expenditure and percentage of GDP from 1991 to 2004

Although China's total R&D expenditure has been increasing annually, it is worth to compare with other countries. Figure 14 shows the R&D comparison with a selected group of countries in year 2006. It is clear that China, in both total R&D expenditure and a percentage of GDP, is still behind the majority of developed countries.

In 2006, R&D expenditure of United States was $US 343.7 billion versus $US 37.7 billion of China, which is only 11% of United States' R&D expenditure.

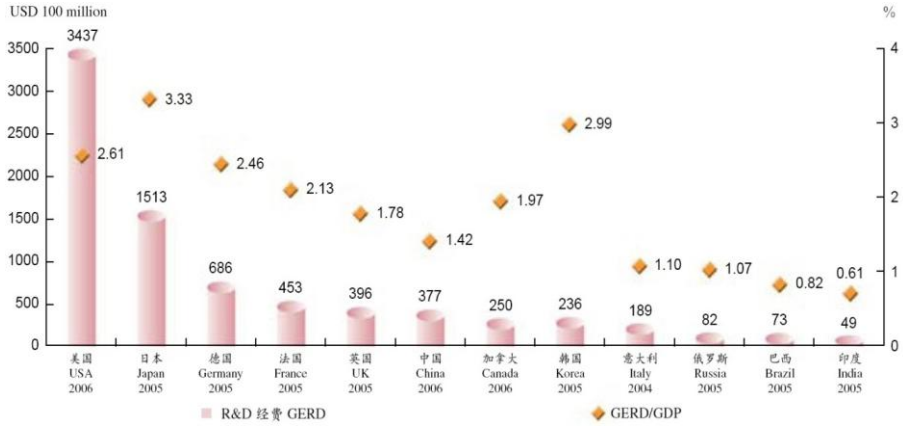

Figure 14. International comparison of Gross Domestic Expenditure on R&D (GERD) and GERD/GDP (2006) Source: Ministry of Science and Technology of China Statistic Data Book (2007)

Table 4 provides the breakdown how this $US37.7 billion or 300.31 billion Chinese Yuan is used in used in different sectors such as research institutes, business, higher education, and others. It is worth noting that 71% of

Table 4 2006 China R&D expenditure by sources of funds (billion Chinese yuan)

Sectors	Research institutes	Business	Higher Education	Others	Sub-total
Government	48.12	9.68	15.15	1.26	74.21
Business	1.73	194.60	10.12	0.92	207.37
Abroad	0.26	4.18	0.38	0.02	4.84
Others	6.61	5.00	2.03	0.25	13.89
Total	56.73	213.45	27.68	2.45	300.31

Source: Ministry of Science and Technology of China Statistic Data Book (2007)

the total R&D expenditure is attributed to business and 91% of which is coming from business sector itself.

B. Patent and S&T Publications

Figure 15 provides the patent applications filed and patent granted by State Intellectual Property Office

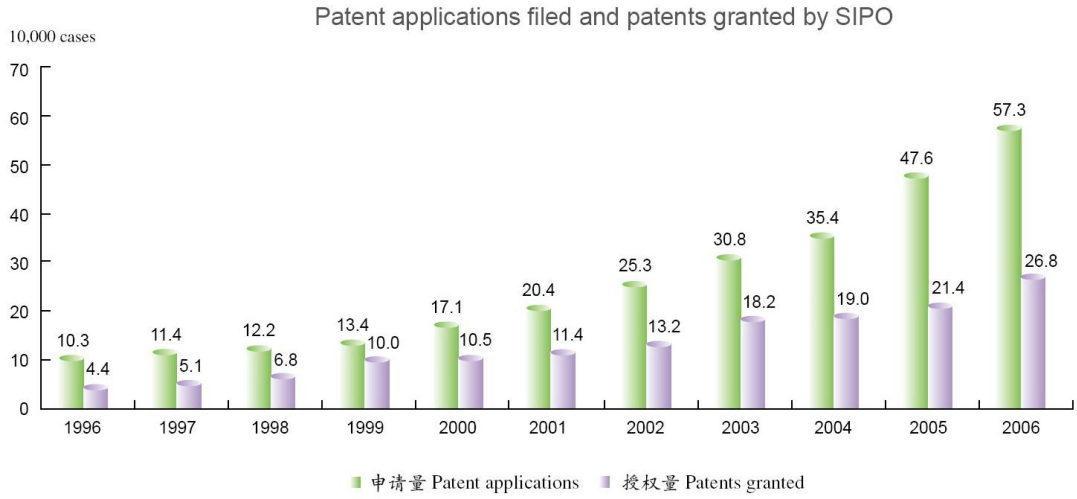

Figure 15 Patent applications filed and patent granted by State Intellectual Property Office (SIPO) of China Source: Ministry of Science and Technology of China Statistic Data Book (2007)

(SIPO) of China between 1996 and 2006. Table 5 shows the Chinese S&T papers by type of institution from 2001 to 2006. It is clear that both number of patents and number of S&T publications are increasing every year, which indicates the national level of activities in research and invention are growing.

Table 5 Chinese S&T papers by type of institution

Type	2001	2002	2003	2004	2005	2006
Total	203229	238833	274604	311737	355070	404858
Higher Education	132608	157984	181902	214710	234609	243485
Research institutes	29085	28779	30123	34043	38101	42354
Business	14452	16307	15489	13673	14034	13269
Medical institution	19736	25612	33242	35691	52331	91283
Others	7348	10151	13848	13620	15995	14467

C. Education

The bar graph in Figure 16 displays the number of students enrolled in Chinese universities; the line graph on the right side displays the growth rates of number of enrolled students and the growth rates of number of faculty. The growth rate of number faculty is far slower than the growth rate of students, which means the student-faculty

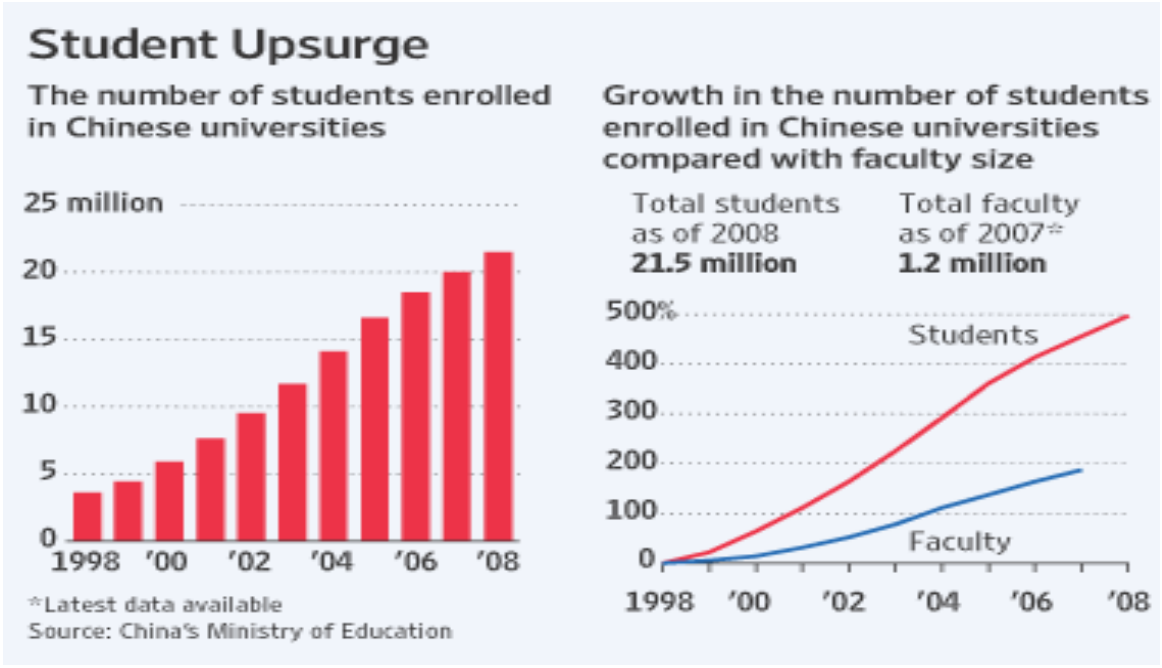

Figure 16 Chinese university enrolled student and growth rate of students and faculty 1998-2008

ratio has increased. As a result, the quality of students graduated from universities has been dropped. Students are not well prepared with skills required by the industry when they step out the door from universities.

D. Personal Income

Traditionally, China is a saving country due to various reasons such as culture and economic and social systems. During the period of the economic growth, China is still the highest in national saving, as shown on the right PERT chart in Figure 17, part of the reason is that individuals are saving for their own needs as the social reform eliminated the public medical and health insurance programs, government sponsored retirement programs, etc. Personal income has a relative steady increase rate, as illustrate on the left bar chart of Figure 17, because of the high saving rate, how to increase the domestic consuming capacity has been a challenge for many years.

Figure 17 Growth rate of per capita income in China and gross national rates

Source: The Boston Consulting Group

On the other hand, compared to other countries globally, the income level and total factor productivity of China are still far behind which is clear from Table 1. Both ranks have been moved toward the top but there is still a long way to go relative to other developed country such as United States that has a rank of 3 in year 2003 on both measures.

V. CONCLUSIONS

A. Economic Growth

In the past 30 years there has been an explosion of growth in China. A major factor in this growth has been foreign direct investment. Another major factor has been the change in policy to encourage business. China's low per capita income has provided an advantage in low cost labor. As the economy in China grows and the per capita income rises this advantage will be reduced. To remain competitive China will have to increase value in what they have to offer a global market. We think it will be crucial that China develop a robust innovation system to sustain growth.

In addition, to continue benefit from foreign direct investment and low cost labor advantage, expanding development from the urban area into the central and west rural area will crucial. How to raise the level of productivity and labor quality, and encourage the knowledge shift from the urban coastal areas to these less developed regions will require incentive policy and creativity from policy makers.

B. Innovation System Improvements

From our review and data analysis, it is clear that major innovation metrics demonstrate a steady growing trend. Graduation statistics indicate the education system in China is making significant progress. The number of teachers graduated and the lack of jobs for graduates may be a near term problem that can be overcome. Increased partnering with business and research and development activities is an important step towards needed improvements.

R&D expenditures have increased steadily over the past 10 years. Funding is mainly from business with is largely made up of foreign companies. Long term research projects are needed to establish a foundation for future invention and innovation.

Implementation has been one of China's strengths for many years. As the per capita income increases in China and the local market grows, they will need to locate resources for low cost labor to remain competitive.

Linkage activities have improved as the government has put initiatives in place specifically to improve the transfer of research to businesses and to improve productivity.

End-use has improved slightly over the years. Measures of education level, income and life expectancy indicate that the vast majority of the population is still relatively poor. The large population could constitute a

significant local market if they had the means to participate at a significant level in the economy. Improving the standard of living in urban areas and for the larger population of China is one of the largest opportunities to increase China's capacity for innovation.

C. Planned Innovation to Sustain China's Future Growth?

China has maintained a relative steady economic growth rate for the last 30 years especially over the last decade. Even under the most recent global economic downturn, the GDP growth is expected to be 8% in year 2009. Contributions of science and technological innovation have been increasing but it is still in relative small scale compared to developed countries. In addition, compared to the innovation model of bottom up with individual enterprise R&D/Entrepreneurial collaboration, China's innovation system is more top down structured with central planning on national science and technological activities. Government intervention has been very strong in the Chinese socialist system on economic policy and S&T development compared to other capitalist countries such as United States. To sustain long term economic growth, it is undoubted that innovation is the key. Without innovation, economic growth will be staged eventually. The question we posed at the beginning of this paper is: "Can an innovation system in a centrally planned economy be as successful as it would be in a market driven economy?"

Throughout the most recent global economic crisis, government interventions have been everywhere. "Top-down" controlling or planning has been playing a crucial role to save the global economy at least that has been the intention and action, which has an huge impact to R&D funding, human resources and other innovation activities. It looks like we may have an answer to our question. Or, it is too early to tell?

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