Dynamism in S&T and the role of S&T and Innovation policies in China: Lessons for India

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ISTIP (Indian S&T and Innovation Policy): First Study of its kind focusing on various dimensions of innovation activity in India; aiming at providing valuable inputs for S&T and Innovation decision making.

Contents

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1. Introduction

Both India and China have been projected as the economies scripting a new growth trajectory that can shift the centres of growth and development from developed world to the Asian region. China has been credited with developing significant capabilities in several areas of science, technology, and innovation in the last three decades. In equipping itself with developing capabilities, it has not only narrowed down the scientific gap but also managed to leave behind the developed countries in specific technology groups[1&2]. Although India has demonstrated ample strengths in few key areas such as space, atomic science and technology, defence related technological innovation, software and pharmaceuticals; it has not been able to match China's level of S&T advances particularly in the industrial sector.

This bulletin briefly discusses some of the policy issues related to S&T and innovation that triggered transformation and catalyzed developments in S&T in China and suggests broad lessons that can be learnt by India in terms of indicative guidelines. The analysis is drawn from a study done by NISTADS that looked into strategies of Chinese and South Korean S&T and Innovation Policies vis-à-vis India for understanding the policy dynamics and drawing lessons for India[2]. Although both the economies are different in terms of governance and require careful assessment, the essence of Chinese growth process and its strategization can provide a useful tool for learning not only for India but by other emerging economies as well.

The next section throws some light on the comparative performance of China and India though selected indicators followed by the delineation of Chinese roadmap for fostering S&T and catalyzing developments. The concluding section enumerates some of the broad suggestions as lessons for India.

[1] Preeg, Ernest H. (2008), `Technological Advances in Key Industries in China, Testimony before the U.S.-China Economic and Security Review Commission', July 16, MAPI.

[2] *CSIR-NISTADS (2012), A Comparative Study on S&T, Innovation and Development Strategies of China and South Korea vis-à-vis India*, Study commissioned by the Office of the Principal Scientific Advisor to the Government of India, June.

2. Some reflections on the performance of China and India in S&T and Innovation

In the following paragraphs, we will look at both China and India on the basis of some of the indices measuring innovation and knowledge through Global Innovation Index[3] (GII), Knowledge Economy Index as well as other standard output indicators such as publications, patents and high technology exports. GII, a measure of the suitability of conditions in an economy to sustain innovation, ranked China at 29th and India at 62nd place in 2011. The relative position of both the economies on the indices of human capital and research ranked China at 56th and India at 104th place. In terms of scientific outputs China was ranked at 9th and India at 60th place. Based on parameters related to Knowledge Economy Index[4], through economic incentives and institutional regime, education, innovation and Information and Communication Technology (ICT), China has improved its performance in the last fifteen years consistently on innovation and education vis-a-vis India.

Table 1: Knowledge Economy Index for China and India

Country	KEI	Economic Incentive Regime[5]	Innovation[6]	Education[7]	ICT[8]
China (2009)	4.47	3.90	5.44	4.20	4.33
2000	3.92	2.84	4.35	3.71	4.80
1995	3.93	3.24	4.07	3.62	4.77
India (2009)	3.09	3.50	4.15	2.21	2.49
2000	3.17	3.59	3.83	2.41	2.87
1995	3.56	3.47	3.70	2.56	4.50

Source: http://data.worldbank.org/data-catalog/KEI

The comparison of research performance as measured by the publications output of China and India shows that though India was ahead of China in 1990, China surpassed India in the period between 1990 and 1995 by doubling its publications. In 2009, while India's total count of publication stood at 57,785, China produced 5 times more.

Similarly, the patent outputs of China and India at the United States Patents Office in some of the specific technology groups from 2003 to 2009 places China ahead of India in nine out of ten high technology groups. While China scores in electronic components, telecommunications, office machinery and computers, electronics, nano and biotechnology, India is ahead only in pharmaceuticals. The interesting dimension of this analysis pertains to the actors of patent outputs which show that Chinese domestic firms and government research organizations are more active in comparison to Indian counterparts. However compared to China, India shows an increasing patenting activity by the Multinational Corporations (MNCs)

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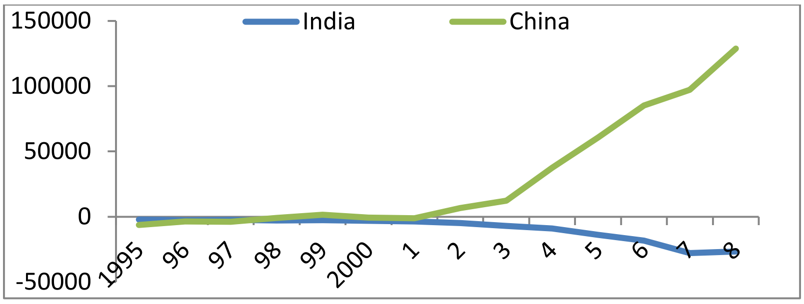
[3] *Global Innovation Index, 2011 (http://www.globalinnovationindex.org/gii)*
[4]*KEI reflects the suitability of the environment for using knowledge for economic development.*
[5]*Economic incentives regime includes simple average of normalized scores on tariff & non-tariff barriers, regulatory quality and rule of law.*
[6]*Average of normalized scores of total royalty payments and receipts, patent applications granted by USPTO, and journal articles.*
[7]*Average of normalized scores on adult literacy rates, secondary enrollment & tertiary enrollment.*
[8]*Average of normalized scores on telephone, computer and internet penetration.*

based in India for their global operations. India is emerging as a more preferred destination by MNCs for their R&D.

High technology exports which are used as an indicator of technological competitiveness reflect on the ability of an economy to derive value from activities which are R&D intensive. A comparison of balance of trade (in million USD) of both China and India with the rest of the world from 1995 to 2008 shows that while China had wiped out the deficit by 2001, India faced an increasing trade deficit in high technology export and import over the years (Figure **1).**

Figure 1: Comparative performance of India and China in high technology trade.



Source: Constructed from www.nsf.gov/statistics/seindio/appendix.htm

Although the exemplary performance of China in high technology exports has been criticised on account of the fact that the major contributors to these exports are MNCs and also that Chinese firms operate at the lower end of global value chains, yet it is seen that not only Chinese domestic firms have been integrated in to the global production system now but have gradually increased their R&D activities.

China has made S&T advances in the industrial sector and has enhanced its global rankings in selected fields. The overall output of Chinese publications in relation to the world output has recorded phenomenal growth and universities account for more than 80% of this share in areas such as astronomy, computer science, life sciences, engineering, material science, etc. The increasing output of papers published by the Chinese researchers is also accompanied by an increase in key citations in international citation indices in few key areas such as information technology (IT), life sciences including pharmaceuticals, medical devices and biotechnology, electronics, nanotechnology, environment, and energy.

Chinese universities rank amongst the world's top hundred in the fields of engineering technology, computer science, chemistry, and maths. More than 700 universities are currently engaged in research and commercialization. Seven of Chinese universities figure in the top 200 universities in the world QS (Quacquarelli Symonds) rankings.

The introduction of reforms and organizational restructuring in Chinese Academy of Sciences (CAS), the highest academic and comprehensive research institute has resulted in long-term impact on the performance of institutes and has led to a productivity growth of 12.5% from 1998-2005[9].

The issues that emerge from above revolve around Chinese route to development and strengthening of S&T capabilities, which need to be understood in terms of changes in economic, technological and industrial policies, institutional arrangements to accommodate all this, governance issues, and execution of policies. How has China strategised to address these issues? How the synchronisation of restructuring of various spheres of actions made?

In the next section we delineate the process that broadly laid the course of S&T development in China since the onset of reforms in the 1980s.

3. Roadmap of the execution of S&T and Innovation Policies in China

China's reforms in S&T have broadly emerged from the National S&T conferences held in 1985, 1995, 1998 and 2006 from which the strategic decisions evolved. These exercises helped in providing overall direction for orienting S&T and laying down the framework. The S&T focus between 1980 and 1991 was on catch up with the realization of a dismal performance of Chinese S&T following the Cultural Revolution (CR) in 1965. The reform measures implemented by the leadership included dismantling the old unproductive structures through restructuring of existing and creation of new institutions. There was a surge in measures related to the issue of the importance of human resource through the generation and augmentation of human resource between 1992 and 1997. Chinese policy making shifted its concerns to the National System of Innovation and the Knowledge economy from 1998 onwards.

China inherited a Soviet model of S&T, which was plagued by basic defects and was a closed one in which the existing S&T system suffered due to a lack of horizontal linkages with education and business; inappropriateness of the structure to facilitate technology diffusion due to a lack of Intellectual Property Rights (IPR) or mechanisms of technology transfer; hindrances in private initiatives in scientific enterprises due to direct interventions from the administration, and the hampering of enthusiasm and creativity of R&D personnel due to the rigid structures of research institutes. The reforms by the Chinese Government involved a series of initiatives to catch up with the world and in order to achieve that a series of organizational and structural changes were introduced for revamping the S&T system. The strategy unfolded itself in a series of policies to transform the organizational structures in research institutions and universities through a judicious planning process to help address specific problem areas which needed focus.

[9] Zhang, D.Q., Banker, R. D., Li, X.X., Liu, W.B.(2011) Performance impact of Research Policy at the Chinese Academy of Sciences, Research Policy 40 (6), 875-885.

The following emerge as the key points that summarize the Chinese initiatives to manage and co-ordinate its S&T aspirations towards industrial development.

State Directed 'Targeted' development

The rise of S&T in China post reforms is matched by a highly interventionist role of the Chinese government, which has used S&T as a complement to economic transformation. The State has played a very strong role in directing S&T towards economic ends in China. The vision of S&T based development and the narrowing of the knowledge gap with developed countries formed the focus of policies in the 1980s. The execution of political aspirations manifested in the whole system of policy making and implementation also been supported by the tight governance of S&T. China's S&T and innovation policies have played an important role in its transformation as is evident in its transformed S&T infrastructure and S&T capabilities. The policy for the transition process did not focus on one or two things but on the entire infrastructure relating to S&T, education and innovation strengthening institutions as will be seen in the following paragraphs.

China can be credited with developing policy frameworks that were operationalised through a large number of policy instruments – the result of long deliberations involving a large number of experts. China has implemented a multifaceted S&T policy through strategic national programmes with the aim of boosting its S&T capabilities. Since the basic agenda of the Chinese Government post-reforms was to catch up with the developed countries and to reduce the gap between them, R&D efforts were intensified in select areas, and high technology R&D was used as a complement to competency building with a target-centric approach**.** This is manifested in the Chinese S&T and innovation policies, which covered the entire innovation infrastructure including research institutions, universities, S&T Parks, support structures, etc. Emphasis on the promotion of basic research, applied research, and high technology and innovation unfolded gradually in the subsequent strategic plans. Specific sectors and technology groups got consolidated because of connectivity and consistency in research priorities. The outcome of various initiatives was positive due to the timely implementation, rigorous monitoring and evaluation of the key policy initiatives.

R&D as a complement to competency building

Chinese investments in R&D as % of GDP were at par with India prior to 2000 but increased by 161% by 2011. China's increase has been more than 20% each year while India has hardly been able to push the figures up (Table 2). It has been seen in the trends in OECD countries that once the R&D/GDP ratio reaches 1%, it rapidly goes up to 2. In terms of gross R&D expenditure, China is now the second largest country behind only US. China spent $154.14

billion in 2009[10]. According to Battelle forecast, China's R&D spending will match and surpass US by 2023[11].

Table 2. R&D as % of GDP in India and China

	Years						
Country	1998	2000	2002	2004	2006	2008	2011
China	0.7	0.9	1.07	1.23	1.42	1.54	1.83
India	0.7	0.7	0.74	0.77	0.8	0.8	0.9

Source: National Bureau of Statistics for China and DST for India

China has invested heaviliy in R&D to enhance knowledge frontiers in select areas including high technology. The industries that were prioritised for exports were suitably supplemented with directed R&D. Thus the first step China took in preparing for a transition was the adoption of a 'target-centric' approach with global targets in select sectors and technologies that were in line with the prioritization in developed countries. China designed national programmes around the entire value chain from basic research, applied research, commercialization of research, and developing advanced high technology with the following features;

- ✓ **Well resourced national programmes with timely implementation**
- ✓ **Emphasis on entire value chain from basic research to innovation**
- ✓ **Rigorous evaluation of programmes**

The programmes are continuously monitored and evaluated. These programmes are mandated to be output oriented. The higher productivity in China can be linked to its 'publish or perish' strategy as the funding of all the national programmes is linked to outputs. Funding is withdrawn if the project does not produce a stipulated output. Continuous monitoring of the performance for quick corrective actions are an integral part of such initiatives.

Policy making and implementation

Another very crucial point that summarises the whole process of policy dynamics in China is that policy planning is extensive, comes under one body and is amenable to continuous monitoring. The enforcement of policies is facilitated by the amount of power vested in the concerned central authority, which enjoys decision making powers to influence issues related to education, S&T, research personnel, finance, commerce, regulation, so on and so forth[12]. It can therefore play a binding role in co-ordinating

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[10] NSB (2012) National Science Board, Science and Engineering Indicators, Arlington VA: National Science Foundation, (NSF 12-01).

[11] Battele (2011) Global R&D funding forecast by Martin Grueber and Tim Studt, R&D Magazine, December 16, *www.rdmag.com*

[12] China's S&T Management, with its highly centralized structure, vests the administrative control in the Ministry of Science and Technology (MOST), with several other agencies being responsible for other support policies. The MOST is the central authority that directs all S&T activities. It not only launches programmes but also ensures their smooth functioning besides

the decision making. Therefore the decisions of 'what to do', 'how to do' and 'by when to do' are settled by one body which is powerful and well supported. Secondly, the **implementation of policies** is ensured through better orchestration, integration, and concordance. Thirdly, the process of policy making is supplemental in nature, which is gradually consolidated over a period of time. For instance, the withdrawal of the government from unconditional research funding in China and its initial failure was countered by supplemental policies over a period of time. The lack of initial success in China in creating markets for technology was followed by a structural transformation of research institutes into enterprises, supported later by the 'Torch Programme' through the creation of innovation fund and the creation of S&T parks. The focus of research in the research institutions was sharpened by the 'Knowledge Innovation Programme'. The changes were later supported by IPR laws and by having their own standards. If despite the recurrent changes, the results were not found to be very encouraging then the indigenous innovation policy came to support the industry in areas where indigenous research has been undertaken. Usually China begins such experimental exercises on a limited jurisdictional scale and then takes it to other areas once it succeeds.

Continuous monitoring with accountability for actions and their end result is an important aspect of governance of policies. Thus, whether it is assessment of a policy or a programme, its evaluation on the basis of the success or failure and subsequent changes has surfaced in most of the policy initiatives in China. One of the reasons for continuous structural changes is learning from failures. This is an important component of policies and programmes.

Policy formulation and implementation

- ✓ Overarching policy making
- ✓ Coupling of S&T and economic policies
- ✓ Enforcement in policy implementation
- ✓ Policy making is progressive with corrective supplements
- ✓ Continuous monitoring of policies
- ✓ Distinction between performers and non performers for government support

ensuring the strengthening of R&D and technology development. The MOST is also the main body involved in providing funding for S&T activities all over China. The basic national strategies, guidelines, policies, laws and regulations, priority setting, creation of structures, etc are regulated by the MOST. It even prepares the national long term, mid-term and annual plans for civilian S&T. This includes the identification of areas which need more systematic focus and ensuring an emphasis on those different stages of innovation which need to be looked into. Another pillar of S&T system in China is the National Natural Science Foundation of China (NSFC), which funds peer reviewed basic and applied research in the domain of natural sciences.

Appropriate structural and organization changes in institutions

China has subjected its institutions involved in innovation including universities, research institutions, firms, supporting institutions to ruthless restructuring. The changes are manifested in the transformation of the research institutes and universities, creation of university parks, and S&T Parks. China has not only made efforts in restructuring the existing institutions and creating new ones but has also created new governance structures to facilitate both R&D institutions and higher educational institutions on one hand and enterprises on the other. Some of the structural and organizational changes include the following:

Transformation in universities

Universities have emerged as important actors in the Chinese Innovation System. China adopted a proactive approach to deal with the generation and augmentation of its human resource by implementing a large number of policies and programmes. While university modernization remained a key issue to revitalize human resource, changes in curricula, autonomy in administration, incentive plans, and growth strategies with the participation of local governments were some of the others. Universities were transformed from being centres of education to those of research and commercialization. More than 700 universities are presently engaged in research and commercialization. Chinese universities participate vigorously with regional governments to promote regional development; and regional universities undertake more of industrial projects. The provision of support structures for technology transfer has also helped in strengthening the links. China has enabled its universities to go in for commercialization by creating their own production centres to offset the limitation of lack of demand from the industry and facilitate the application of knowledge.

A number of programmes have been launched for the generation of manpower, modernization of universities, repatriation of Diaspora, and so on and so forth. Some of these initiatives such as the One Hundred Talent Programme; the Cheung Kong Scholar Programme; the Hundred, Thousand, and Ten Thousand Talents Programmes; the Chunhui Programme, etc., have targeted human resource augmentation through repatriation Project 211 was launched to revamp the higher education system by strengthening around 100 educational institutions and key disciplinary areas. The 985 Project targeted transformation in a limited number of universities to make them world class. By 2004, around 40 universities had been roped in for the transformation. Targeted investments coupled with incentives for performance through the 985 project has enabled all the universities covered under the project to rank among the best in China.

China's feat in education is laudable not only because it has increased the number of institutions and changed the focus of universities from education to research; but also because it has succeeded in creating an ecosystem that is supportive to innovation. The commercialisation of university research was aided by the incentivisation of university faculty. Through a provision in the Chinese version of Bayh Dole Act, universities can retain the rights to inventions created with government funding. Financial help through the Torch Programme, dynamic environment in the science parks and high technology zones, support structures of the parks, other policy incentives, etc. have helped in creating dynamism in these parks.

Human Resource Initiatives

- ✓ Expanded investments in education particularly the higher education
- ✓ Changing focus of universities from education to research and commercialization
- ✓ Revamping of education infrastructure
- ✓ Research consolidation resulting from select sector approach
- ✓ Target of making select universities global
- ✓ Repatriation of global faculty
- ✓ Autonomy and accountability in the universities

Transformation of Government Research Institutes (GRIs)

The Chinese reforms process addressed the inefficiencies in the research system through a planned process that entailed measures related to taking away the assured funding; creating Technology Markets; bring in structural changes in the existing institutions on the basis of their activities; sharpen the focus of research institutions through mergers and creating new institutions; make them participate in research in priority fields; make concrete attempts to help them enhance the skill base through several national programmes to attract the best; enhance the commercialization by encouraging them to own or float spin-off enterprises; create S&T parks; make the IP laws favourable to this; so on and so forth. The policy of creating research institutions affiliated enterprises and spin-offs, creation of S&T parks, innov-fund, support structures for technology transfer have all helped build links between research and industry. The Chinese Academy of Sciences (CAS) has not only transferred its mature technologies to various domestic industries but also created high-tech enterprises of its own. Subsequently, the reorganization of research through the making of the Knowledge Innovation Programme (KIP) by the CAS has led to China's enhanced rankings in research in few key areas**.**

Initiatives for enhancing relevance of research institutions

- ✓ Ruthless restructuring/creation of new institution
- ✓ Focus on select streams with global targets
- ✓ Enhancement of human resource
- ✓ Initiatives to enhance links between research and industry

Strengthening the ecosystem of innovation

An innovation ecosystem comprises of universities, research institutions, intermediary service providers and the interconnections amongst them. China had a large number of research institutions, universities and production houses prior to reforms, but the system suffered from a lack of linkages among innovation actors, deficient intermediary support services, and poor translation of research into applications. The efforts in transforming these research institutions and universities were accompanied by the creation of an ecosystem that enhanced the connectivity of elements comprising the innovation ecosystem. China has enabled its key organizations in academia and government research institutions through a process of gradual transformation to create knowledge and encouraged the creation of production centres from them to offset the limitation of lack of demand from the industry and facilitate the application of knowledge. The ability to bring together R&D resource residing in CAS, top universities, leading Chinese firms, MNCs and their R&D centres, availability of talent pool in the huge geographical structures has facilitated manufacturing and industrial development.

A total of 53 states level Science & Technology Industrial Parks (STIPs) were set up under the Torch Programme emphasizing the high-tech industrialization of China. These have been assisted by both central and state governments through the provision of physical infrastructure, services, and preferential policies such as tax exemptions. Many of these STIPs have high tech innovation centres which keep them dynamic and sustainable. These have achieved high growth rates and have emerged as vibrant clusters by creating industrial aggregation advantages. China has demonstrated the emergence of a larger congregation of firms in science parks which are spin-offs, affiliated enterprises to universities and research institutes, or established by scientists and researchers. China has strategized its long-term intellectual property with clearly stated goals and the implementation procedure spelt out — something that is very crucial for the competitiveness of emerging technologies. The indigenous innovation policy of China, which is based on a public procurement policy, is designed to favour sectors in which domestic firms indulge in R&D. The designated areas reserved for public procurement are the ones where China has made concerted efforts in R&D initially in research institutes and academia. Although the level of technological capability efforts in China has not reached the level of OECD countries, what is important is the emergence of a new set of enterprises from the GRIs, academia, and other private ventures that are not only R&D intensive in terms of R&D expenditures but are important in terms of creating a new landscape of innovation which is marked by the presence of links among the several actors of innovation. Enterprises have taken a lead role in producing R&D outputs such as patents, both in terms of applications and also as patent owners. Technology transfer from foreign sources has reduced in comparison to transfer from domestic sources.

The availability of funding in select sectors and technologies for the entire chain of innovation has, as a matter of policy, helped China direct its research on a few focussed areas. The process has simultaneously encouraged competition among universities, research institutions, and industry for research funding in select areas.

One important point we wish to make is that the intermediary structures to support and promote innovation are part of a national strategy and are set up with a declared objective of promoting innovation. Attempts for looking in to the non-functionality of any policy initiative for correction forms an integral feature of any policy instrument. The nurturing of ecosystem of innovation in China is through the following;

Strengthening of innovation ecosystem in the STIPs

- ✓ Most successful parks are created around universities and GRIs, nurturing firms spun off from universities and GRIs. The successful parks have become major contributors to industrial production. Manufacturing is the mainstay of these parks and they house large, medium, small firms and MNCs. The parks exhibit linkages amongst universities, GRIs and industry.
- ✓ Creation of intermediary structures for supporting commercialization and innovation
- ✓ Local governments have participated in infrastructure creation, governance and resource provision
- ✓ Support given to incremental innovation
- ✓ Indigenous innovation policy in China to promote and support its domestic firms

Organization and Management of R&D and Technology

The emerging new technologies are multidisciplinary in nature. Their introduction requires high R&D investments, creation of new organizations, advanced skill sets, appropriate regulatory frameworks, vibrant ecosystems, new firms to absorb the new research results, so on and so forth. China has succeeded in bringing out necessary changes in the organization and management of R&D associated with the introduction of new technology as is seen in case of nanotechnology. For instance, nanotechnology as a field of priority in China, surfaced in the beginning of 1990s and the subsequent growth in the field can be attributed to defining the R&D areas, massive R&D investments, mobilising advanced skills locally and through repatriation, developing instruments critical for nanotechnology research, emphasis on creating new materials, creating nanotechnology parks, availability of funding along the entire chain of innovation, creating standards, appropriate machinery for risk governance, etc[13].

4. Lessons for India

China has slowly and systematically narrowed down the scientific gap with developed countries and also overtaken them in certain technology groups. What China has been able to achieve is not merely through increased R&D but also because of a focus on manufacturing and by creating conditions that encouraged learning and leveraging. In terms of the lessons that can be learnt from this analysis, the causality of dynamism of S&T in China points at targeted development and commensurate resource mobilization, continuously evolving policies with strict enforcement and implementable instruments, a will to acknowledge failures, and efforts to correct them. The points raised in the study have important

[13] Bhattacharya, S., Bhati, M. (2011) China's emergence as a global nanotech player: Lessons for countries in transition, China Report, 47(4). 243-262.

ramifications for India. Some of the issues that require careful assessment and actionable strategies are the following;

India too has shown impressive achievements when it has targeted and directed development in selected sectors such as space, atomic energy and defence related technological innovations. However, there is a need to strengthen the industrial sector where firms have to face market dynamics. There are ample policies, strategies, and policy instruments but the implementation and regulation requires strengthening. Although many initiatives have been taken in India to boost S&T and innovation, the outcomes can become more visible by following measures that affect the process of building S&T capabilities;

First, India trails behind China in its spending on R&D. India's expenditure on R&D as a percentage of GDP stood at 0.9% in 2011. In contrast, the figure for China during the same period stood at 1.83%. While the industry dominates R&D in case of China with more than 70% share, the government continues to be the major spender of R&D in India, spending around $3/4^{th}$ of the total R&D expenditure.

Second, India needs to strengthen higher education to counter some of the problem areas such as low investments, low gross enrolment ratios to higher education, inadequate allocations of public resources to higher education, infrastructure, faculties, research opportunities, and an inadequate number of PhDs in the engineering and software/IT sector (there is a vast gap in the requirements and availability of PhDs). Systemic reforms are required in India to strengthen the education system in general and the higher education system in particular. It would be useful to draw some lessons from China which has tackled this through a number of university upgradation and modernization programmes.

Third, Indian public research institutes in the 1980s suffered from problems similar to China. Although a number of initiatives have been taken in India since the 1980s to enhance their effectiveness, the concurrence between economic and S&T policies needs consolidation. It is extremely important to re-invigorate research institutions though structural and organizational changes to enhance their effectiveness and competitiveness on one hand; and create well resourced newer institutions on the other. The need for complementing the existing skill sets in research institutions with newer skills cannot be underestimated. Repatriation of foreign trained Indians has not been strategized in a manner that can help India augment its skill shortages, be it in academia or research institutions.

Fourth, the infrastructure for innovation in India needs to be strengthened. There is a domination of technology generation organizations but these are not supported by adequate organizations to support and promote innovation. Local level support reflects a lack of participation from the local governments. Although a number of initiatives have been taken in the last two decades, these do not match the initiatives undertaken in China. Commensurate structural and functional changes are required in the organizations involved in S&T and innovation including the infrastructure for innovation. Given the fact that India has made impressive achievements in sectors which were targeted; and there are systemic problems confronting India's innovation and higher education system; it becomes imperative to have a target-centric strategic vision that is built on existing strengths, along with the transformation of innovation and higher education system.

Fifth, there is need to strengthen the organization and management of R&D in India. The planning for R&D most often pertains to disbursement of funds to existing institutions with existing manpower which quite often is not even really geared to look beyond compartmentalized disciplines in S&T. The focus is still R&D and its subsequent application towards industrial development though now gradually being attempted in say nanotechnology is not the mainstay of policies in general. Streamlining, organization, and management of R&D in emerging technologies like biotechnology and nanotechnology requires strong R&D and production synchronization

Sixth, there are sectors which have shown tremendous growth potential such as software/IT, pharmaceuticals, biotechnology, automotives, textiles, etc. These sectors can enable India to achieve global competencies. For instance, Indian software development skills are utilized by foreign global firms for high value added activities but a strategy that can hone Indian strengths for high value added activities by Indian firms is needed. In the pharmaceutical/biotech sector, India has manufacturing strengths and R&D skills residing in firms, research institutions and academia. The need is to look for a niche where India can set global benchmarks supported by R&D. For establishing India on a global map, it is important for the highest growing sectors to be given adequate attention for R&D. Directing research is all the more necessary as the government is still the major spender for R&D in India, and therefore investments should go to sectors where industry has shown competitive manufacturing strengths. Though enhancing innovative capacity across a whole range of sectors, institutions, and regions may not be feasible; it is possible to strengthen them selectively through ruthless restructuring—the way that it has been done in China. The strategy for India should therefore target mega programmes, built around sectors where India has built manufacturing strengths and to consolidate them with R&D. Resource mobilisation can be channelized in accordance with targets by reorienting academia, research institutions, and industry to consolidate the ecosystem of innovation. Although many initiatives have been taken in India to boost innovation, the outcomes can become more visible with following measures that affect the process of building S&T capabilities.

Some Policy Initiatives for enhancing the effectiveness of S&T for industrial development

- ✓ Strengthening the strategic focus and target-centric approach in the industrial sector
- ✓ Focussed and targeted R&D for innovation
- ✓ Optimal investments and timely implementation of initiatives
- ✓ Commensurate structural and functional changes in the organizations involved in S&T and innovation including the infrastructure for innovation.
- ✓ Strengthening links amongst R&D, innovation, and production systems.
- ✓ Vigorous measures related to human resource generation and augmentation
- ✓ Streamlining organization and management of R&D in the emerging technologies like biotechnology, nanotechnology requiring strong R&D and production synchronization.
- ✓ Development of efficient geographical clusters

Note: The bulletin is based on a study on`A comparative study on S&T, Innovation and Development strategies of China and South Korea vis-à-vis India' Study commissioned by the Office of the Principal Scientific Advisor to the Government of India, CSIR, NISTADS, June, 2013. Project Team-Sandhya, G.D., Nath, P., Mrinalini, N. Bannerji, P., Bhattacharya, S., Mandal, K., Dey, D., Rawat, P., Kumar, A.

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