A comparative study on S&T, Innovation & Development Strategies of China & South Korea Vis-à-vis India

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Executive Summary

Against the backdrop of rising S&T capabilities, knowledge intensity, and the steep growth rates of China and South Korea, a crucial question relevant for India has been whether it can learn from their experience. China has narrowed down the scientific gap and even managed to leave behind developed countries in specific technology groups. Similarly, the South Korean growth strategy has elevated Korea to the ranks of innovation leaders. What they have been able to achieve in the last few decades in terms of growth and development raises very important questions regarding the process through which they have been able to achieve this phenomenal growth. Though abundant literature exists to explain the South Korean boom, there are contrasting views on China with regard to its dependence on foreign technology, lack of participation in path breaking research by the industry, the sustainability of this development, etc.

This study was undertaken to look into the process that has enhanced dynamism and facilitated the build-up of S&T capabilities in China and Korea. The study has analysed the S&T policy framework of both China and Korea to identify the relationship between their achievements and policy architecture, in order to derive lessons for India.

However, some caveats need to be put in place before comparisons are made since the comparator countries are highly dissimilar, with Korea being a very small country and China a command and control economy. Though the growth trajectories are different, the rules of success that can be gleaned are reproducible. These are: targeted development and commensurate resource mobilization, continually evolving policies with strict enforcement and implementable instruments, a differentiation between success and failure, a will to acknowledge failures and efforts to correct them. The study draws more from the Chinese example, since India and China share a similar history (prior to Chinese reforms) in terms of inheriting a large unproductive research infrastructure far removed from the needs of the industry, education infrastructure incommensurate with the needs and size of the population, absence of an ecosystem for innovation, etc. If despite these constraints China has been able to transform itself by revamping its old unproductive structures, it could prove useful for India to learn from their experience.

Key strategies indicating the roadmap for using S&T

The following emerge as the key points that summarize Chinese and Korean initiatives to manage and co-ordinate their S&T aspirations towards industrial development and help leverage innovation in these countries.

1. State directed development with strong government intervention and clearly drawn vision.
2. R&D as a complement to competency building
3. Policy making and implementation
    - Overarching policy making
    - Coupling of S&T and economic policies
    - Enforcement in policy implementation

- Policy making is progressive with corrective supplements

4. Focus on priority areas with a target-centric approach and global targets
5. Continuously evolving structural and organization changes by dismantling old unproductive structures and replacing them with new structures providing opportunities to strengthen links
   - **Transformation in universities through expansion and upgradation of the education system to generate and augment human resource**
     - 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**
     - 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
     - Continuity in the change for the reorientation of research
   - **Creating an ecosystem of innovation through S&T parks**
     - Most successful parks are created around academia and government research institutions
     - Nurtured leading Chinese firms which have spun off from academia and GRIs
     - Manufacturing is the mainstay
     - Creation of intermediary structures for supporting commercialization and innovation
     - Have a mix of large, medium and small enterprises besides MNCs
     - Exhibit linkages amongst academia, GRIs and industry
     - Local governments have participated in infrastructure creation, governance and resource provision
     - The successful parks have become major contributors to industrial production
6. Accountability, governance, and regulation to ensure application of S&T for development
   - Clear distinction between performers and non performers for government support
   - Programmes and policies for outreach to firms
   - Concurrence among various policies to achieve targets
   - Shift in the government's role with the process of industrialization

Highlights of the execution with recommendations

The points raised in the study have important ramifications for India's strategy formulation. The experience of both China and Korea suggests strong government intervention and a targeted approach

in order to direct S&T to the desired end. Korea leveraged its growth strategy with that of catch-up and joined the OECD in 1996. China's catch-up strategy was not serendipitous, but was in fact an adroitly crafted strategy which was selective and focussed. It targeted high growth industries, exports, and enhanced the technological component of its exports. In doing so, it has mobilised its innovation infrastructure by revamping existing structures and creating new ones. China's major achievement is the revamping of its innovation infrastructure including universities, research institutes and industry.

China's growth strategy as reflected through its policy trajectory has unfolded in stages. China embarked on a series of policies and programmes to boost its S&T capabilities and catch up with the world. It has displayed an innovation plan in which strengthening of innovation has been strategized gradually with both a medium and long-term focus. The plan is specialization in select sectors, promote the innovation actors, pump in massive R&D investments and protect the domestic producers. Though China still has a long way to go in creating breakthrough technologies, its reliance on R&D in select fields is moving towards narrowing the knowledge gap with the leaders.

The following points summarize the salient issues and actionable points.

1. Visionary State Directed 'Targeted' development with appropriate policy concurrence between economic and innovation policies

An extremely important factor behind the rise of S&T in both China and Korea is the highly interventionist role of the government in directing S&T towards economic ends. Both countries, in order to reach the catch-up milestone, have complemented their economic policies with S&T policies to boost S&T capacity and innovation. The target of achieving global excellence within a specified time period by focusing on specific areas, sectors, and technologies has formed the basis of S&T and innovation policies. Both countries 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. Chinese S&T and innovation policies were steered around national programmes on S&T and the creation of an ecosystem for innovation. Similarly Korean policies too have targeted the development of national R&D programmes and promoting industrial R&D through fiscal and financial incentives.

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 but the performance falls below global levels of efficiency in the industrial sectors where firms have to face market dynamics. There is a need for a holistic national level strategic vision for industrial development and manufacturing, followed by reforms in policies, strategies and structures. It would be pertinent to complement economic policies with suitable innovation policies for building S&T capabilities for a sustainable industrial development. The changes in the S&T policies along with appropriate industrial policies should be accompanied by necessary changes in the policy for human resource. This can be achieved by linking a powerful central coordinating agency connected with the concerned ministries affecting innovation. The ensuing power structure therefore can connect economic and S&T policies to enhance the efficacy of S&T towards economic growth.

2. R&D as a complement to competency building with a target-centric approach

Both China and Korea have pumped in massive R&D investments to ***enhance knowledge frontiers in select areas including high technology.*** The basic agenda of China's post-reforms period was to catch up with developed countries and to reduce the gap by focussing on select streams. The industries that were prioritised for exports were suitably supplemented with directed R&D. ***Thus the first step that was taken by both the countries in preparing for the 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 across the entire value chain from basic research, applied research, commercialization of research, and developing advanced high technology***. Similarly, the Korean approach too was to set global targets and focus on few sectors and technologies to speed up the process of industrialization and have global footprints in those few chosen sectors/ technologies. Later, the gradually reducing product basket by the industry led the Korean Government to reformulate its policy on basic research. Therefore the latest strategic programme – '577' initiative – has targeted global leadership in select areas of technology with a target of R&D expenditure of 5% of GDP on 7 focus areas. Following features define the national level programmes in China as well as Korea;

- **Well resourced national programmes with timely implementation**

  Both the countries have undertaken a series of well resourced national programmes to enhance their capacities and capabilities in S&T. The programmes have been provided with optimal investments and have been implemented timely. These programmes are mandated to be output oriented.

- **Emphasis on entire value chain from basic research to innovation**

  One of the highlights of the national level S&T programmes is that their jurisdiction has been the entire value chain from invention to innovation and from basic research to developing advanced high technology.

- **Rigorous evaluation of programmes**

  The programmes are continuously monitored and evaluated. 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. Korea, in particular has made a clear distinction between performers and non-performers and used finances to discriminate them. Continuous monitoring of the performance for quick corrective actions are the mantras of the regime.

The improved ranking of China in selected fields can be attributed to its target-centric approach. The overall output of Chinese publications in comparison to the world has recorded a sharp increase from 26% in 2000 to 85 % in 2009. Chinese achievements in clean energy, supercomputing, nanotechnology, advanced materials, etc. have not emerged accidentally. These are the outcome of consistent and sustained initiatives over a long period of time. For instance, in nanotechnology China

has now outpaced the US in terms of the output of publications. Similarly IT, which has influenced several industries due to its broad range of applications, has remained a consistent priority in China. In supercomputing again the growth is consistent. In clean energy China is gradually outpacing US through a comprehensive strategy by focussing on research as well as manufacturing. The emphasis on clean energy is discernible in almost all the major national programmes. A well developed, long-term strategy of consistent and increased investments in clean energy has enabled China garner clean energy supremacy over its rival countries which though might have been the pioneers in developing the solar PV, wind, nuclear power technology but the ensuing gains have been strategically collated by China. This is a sector where China is trying to erect barriers to prevent foreign firms from making inroads to promote and protect the interests of its domestic producers.

China's climb in global publication rank is most commendable when compared to that of India. *India was ahead of China and Korea in 1990. China surpassed India in the period between 1990 and 1995 by doubling its publications. And by 2009, China's publications became 5 times that of India. Korea, on the other hand, was far behind both India and China during the 1990s but came steadily closer to India's publications output by 2009. The performance of China in high-technology exports and Patents too reflects similar outcomes though Korea has outperformed China in patent outputs. While industry's performance in China in patent output shows a steady growth, it has become almost static in case of India.* The case of domestic research organizations show a grimmer picture as though three fourth of R&D is accounted for by the government in India, there is a decline in patenting by them.

India trails behind China and Korea 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 same in the case of China and South Korea during the same period stood at 1.83 % and 3.74 % respectively. While the industry dominates R&D in case of China and South Korea with more than 70 % share, the government continues to be the major spender of R&D in India with around 3/4th of R&D expenditure.

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. 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. It would be important to establish India at least in a few areas where front-runner countries are engaged in R&D, in order to become competitive in the long run. Non-technological means of sustaining innovation alone will not be sufficient. There is a need to develop technological means of enhancing innovation capacity. India has not been able to cross the R&D to GDP ratio beyond 1% for a long time, despite the repeated policy indications of doing so. It becomes all the more necessary to direct research as the government is still the major spender for R&D, and thus investments should go to sectors where industry has shown some manufacturing strengths.

3. Policy making and implementation

Another very crucial point that emerges from the study is that the **whole process of policy making** in China and Korea 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. It can therefore play a binding role in co-ordinating 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 and one can discern step by step augmentation 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 research in 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.

In India, the sectoral policies are evolved at the level of sectoral ministries such as IT, telecommunication, energy, heavy industry, science agencies, etc. The sectoral industrial policies emanate from the concerned ministries; and research and academia are directed by their parent ministries. There is a need to strengthen the co-ordination among these in terms of planning and enforcement.

4. Appropriate Resource mobilization

The jurisdiction of S&T policies has been the entire innovation infrastructure targeting research institution, universities, S&T Parks, support structures, fiscal and financial instruments, legislative issues, etc. The subsequent structural and organizational changes have been made in the institutions involved in innovation. These include:

4.1 Reforms in the higher education sector

Revamping human resource through generation and augmentation, targeting global excellence in selected universities and prioritized sectors and formation of global universities, initiatives to attract repatriation of skilled manpower for both universities and research institutions for augmenting the human skills, enhancing the stock of PhD manpower, etc. have been few of the initiatives adopted by both China and Korea. This coupled with the availability of funding in select sectors and technologies for the entire chain of innovation has, as a matter of policy, helped China to direct its research on a few focussed areas. The process has simultaneously encouraged competition amongst universities, research institutions, and industry for research funding in select areas. More than 700 universities are

currently engaged in research and commercialization. Chinese universities participate vigorously with regional governments to promote regional development; and regional universities undertake more industrial projects.

The highlight of the Korean system of human resource generation is continuous upgradation of the higher education system and measures to enable universities to be participants in research. While the introduction of the NURI (New University for Regional Innovation) in 2004 was initiated to strengthen the higher education system outside Seoul, the Brain Korea project is targeted at creating a knowledge base in strategically important areas by fostering world class researchers through world class graduate schools. Both the countries have adopted various measures to bring back the diaspora to augment the skill base.

These measures related to human resource upgradation and infrastructure has led to 6 Chinese and 5 Korean universities emerging in the top 200 universities in the world.

Adequate systemic reforms are required in India to transform the education system in general at and higher education system in particular. India does not have a single university in top 200 global universities, even though Indian faculty enriches universities the world over. India has increased the number of IITs but faculty remains a key problem. Although some of the newly created IITs are making attempts to upscale their infrastructure, offer better remuneration and research opportunities, create better housing facilities, and reach out to PhDs and post doctorates, there is a need to address this at a larger scale. There is a shortage of PhDs in the engineering and software/IT sector, where there is a vast gap in the requirements and availability of PhDs. It would be useful to draw some lessons from China and Korea which have tackled this through a number of university upgradation and modernization programmes.

4.2. Reforms in the government R&D institutions through organizational restructuring

The Chinese reforms were targeted at countering the inefficiencies in the research system through a planned process that entailed measures related to taking away the assured funding; creating Technology Markets; bringing in structural changes in the existing institutions on the basis of their activities; support through national programmes; sharpening the focus of research institutions through mergers and creating new institutions; making them participate in research in priority fields; making concrete attempts to help them enhance the skill base through several national programmes to attract the best; enhancing commercialization by encouraging them to own or float spin-off enterprises; creating S&T parks; making IP laws favourable to this; and so on and so forth. The outcome of the series of initiatives is not just enhanced research outcomes or linkages with the industry but an ecosystem in which the GRIs have a meaningful role to play.

In Korea, the GRIs were created in response to facilitate technological learning. The government policies on S&T emphasised the role of GRIs in fostering and building technological capabilities and in helping firms in absorption of imported technologies. The technological support, which the industry was lacking in at that time, was provided by the GRIs. Though after 2000, these GRIs have lost much of their relevance towards big firms. These are now supposed to play a bigger

role in strengthening the SMEs. Thus a continuous restructuring in the roles and goals of GRIs in keeping with their relevance to industries has defined their existence.

In India, it is extremely important to re-invigorate research institutions that have been created in a wide number of areas. There is a need for major structural and organizational changes to enhance their effectiveness and competitiveness on one hand; and creating well resourced newer institutions. 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. Although there are some indications of repatriation in industries, these are not parts of a broader policy paradigm.

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 it is done in China and Korea. Resource mobilisation can be channelized in accordance with targets by reorienting academia, research institutions, and industry to consolidate the ecosystem of innovation.

4.3. Creation of an appropriate ecosystem of innovation

One of the major factors instrumental in creating dynamism in China is the creation of an ecosystem exhibited by the S&T parks and university parks. The majority of them are created around universities and GRIs, and some around the existing centres of excellence from research and academia. The clusters are duly supported by intermediary structures such as innovation centres, productivity promotion centres, technology transfer centres, venture capital firms, legal services, etc. to enhance links in the 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. A large section of firms have emerged from the research institutions and academia. The ability to bring together R&D resource residing in CAS, top universities, leading Chinese firms, MNCs and their R&D centres, the availability of talent in the huge geographical structures has facilitated manufacturing and industrial development. The creation of S&T Parks/University Parks/Incubators has facilitated the creation of an ecosystem in China that is conducive to nurturing innovation. Their contribution to industrial output has gone up from 2% to nearly one third.

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. One important point we wish to make is that the intermediary structures are part of a national strategy and are set up with a declared objective of promoting innovation. 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 in the research institutes, academia and enterprises.

Similarly in Korea, a support system in the science parks comprises of intermediary agencies, consortium programmes, and programmes to support techno parks, which have been set up to enhance the innovation capacity of Korea. The noteworthy point is the co-existence of Regional Research Centres (RRCs) at a regional level. An important observation is that these RRCs specialize in those technologies that dominate the region's industry and are located in universities and aid co-operation between universities and SMEs. These arrangements have shown an enhanced co-operation between universities and SMEs.

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. The local level support reflects a total dearth and participation of local governments are in terms of implementation of central schemes and mobilization of resources. Although a number of initiatives have been taken in the last two decades but these do not match the initiatives undertaken in China and Korea. For instance, Software Technology Parks have done exceedingly well in exports. The time has come now to engage firms residing in the parks in high-end work with government support on research. For instance, participation of state governments in developmental projects is mainly in terms of the implementation of central schemes and mobilization of resources. It would be crucial to involve local governments in providing inputs on research and intermediary facilities and hold them responsible with greater stakes. Introduction of result oriented accountability rather than financial accountability with continuous structural changes can render more meaningful results.

5. 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. The Chinese and Korean cases show that these countries have succeeded in bringing out necessary changes in their institutional structures to carry forward the new technology dynamism as we have seen in case of nanotechnology in China and Korea. Both have created new institutions towards the development of this technology. Attention is also paid to the creation of standards, risk analysis, assessment and management centres to encourage wider acceptance of technology. Both the countries have developed science parks, high industrial zones and university-industry joint research centres that are functional entities leading to joint technology development, technology transfer and co-operative partnerships. Identification of new skill requirements not only towards its supplying the skill sets but also towards appropriate faculties to create the skill sets has been duly recognized in China and Korea.

A factor that provided fillip to nanotechnology in China has been development of capital intensive equipments required for nanotechnology research. Both the countries targeted enhancement of the capacities of their ICT industry and advanced manufacturing industries.

Creating new organizations for meeting the challenges of emerging technologies in research, academia and industry has been another very important factor in case of both China and Korea. The process has included both demolishing the old structures and creating new ones. Identification of new skill requirements not only towards its supplying the skill sets but also towards appropriate faculties to create the skill sets has been duly recognized in China and Korea.

India needs to strengthen the organization and management of R&D. 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 is not the mainstay of policies in general. For instance, China has challenged the dominance of advanced OECD countries by emerging as a leading country in nanotechnology and Korea has been ranked among the top 4 countries in nanotechnology. The nanotechnology case is illustrative of an innovation plan in case of both China and Korea. 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 through creation and 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.

Although, nanotechnology is gradually emerging as a priority area with lot of attention being given to it by the Government of India from 2001 onwards in a mission mode, yet a lot more can be done to enhance the capacities and capabilities. The factors that can enhance the progress of nanotechnology in India include the creation of specialised human resource faculty/capacity for imparting teaching and training in the domain of nanotechnology; the development of indigenous instruments for nanotechnology research; the synchronisation of nanotechnology development with the country's needs and goals; the intensification of collaboration of a strategic nature by creating key centres; the development of short, medium, and long term plans for creating innovative capacity in nanotechnology; the creation of a risk analysis, assessment, and management centres; introducing anticipatory and adaptive governance; creating mechanisms for development of linkages among different stakeholders; establishment of a department of nanotechnology to help in coordinated action, development of a road-map, and in synergising policies and programmes; creation of bridging institutions; translation of "blue sky research" to innovation; creation of science parks, high industrial zones, university-industry joint research centres to encourage joint technology development, technology transfer and other cooperative partnership, and so on and so forth.

What China has been able to achieve is not merely through increased R&D but through creating conditions that encourage learning and leveraging. The focus on manufacturing similar to that of Korea explains the growth dynamism in China.

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. Given the resource crunch India faces and the demographic edge that India has; it becomes imperative to use national resources judiciously to leverage internal strengths.

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;

- Strengthening the strategic focus and target-centric approach in the industrial sector

- Optimal investments and timely implementation
- Strengthening links amongst R&D, innovation, and production systems. The focussed and targeted R&D for innovation paradigm and regional research
- Commensurate structural and functional changes in the organizations involved in S&T and innovation including the infrastructure for innovation.
- Streamlining organization and management of R&D in the emerging technologies like biotechnology, nanotechnology requiring strong R&D and production synchronization.
- Increased participation of local governments in terms of the formulating regional schemes and mobilization of resources.
- Vigorous measures related to human resource generation and augmentation
- Development of efficient geographical clusters
- Creating safeguards for incremental innovation.