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India's Science, Technology and Innovation Policy: Choices for Course Correction with Lessons Learned from China

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JOURNAL OF SCIENCE, TECHNOLOGY, AND INNOVATION POLICY AND MANAGEMENT (STIPM JOURNAL), Volume 03, Number 01, July 2018

FOREWORD by EDITOR-in-CHIEF

We are glad to announce that the journal of *Science, Technology, & Innovation Policy and Management* (STIPM Journal) Vol 3, No. 1, July, 2018 is ready for public reading and views. The journal itself focus on STI policy and management.

The aim of this issue is to combine the various perspectives of R&D management and STI policy. Original papers as well as case studies-based research are presented to the readers.

STIPM Journal is an online research journal managed by the Center for Science and Technology Development Studies, Indonesian Institute of Sciences (PAPPIPTEK-LIPI). This journal is a blind peer reviewed journal, which provides free access to research thoughts, innovation, and original discoveries that are needed mostly by the research scholars. In this edition, the STIPM Journal contains six articles dealing with science, technology and innovation policy and management written by scholars from Japan, Thailand, India and Indonesia.

The first article, entitled *India's science, technology and innovation policy: Choices for course corection with lessons learned from China* by **G.D. Sandhya.** In this paper, an attempt has been made to look at how comprehensive India's STI policies with regard to policy components; a roadmap; and strategies for execution and boldness in terms of identifying and recognising the failures and recommend major structural changes. What is intended is to understand the relationship between the domain of S&T policy and expected outcomes; the mismatch between the policy expectations and outcomes. An attempt is being made to identify possibility for correction by taking lessons from other economies, such as China.

Second article were written by **Wati Hermawati, et al.,** entitled *Outcome and impact based evaluation of research program implementation: A case of Indonesian public research institute.* This article relates to outcome and impact based evaluation (OIBE) of a research program implementation at an Indonesian public research institute (PRI) 'A'. The major funding for PRIs in Indonesia comes from government. It is very essential, therefore, for various parties including policy makers to be informed about meaningful and relevant evaluation of the outcome and impact of such PRI to the welfare of the people, to technology development and innovation, and to the policy improvements in significant ways.

Hidenori Shigeno, et al., presents the third article, *Internal innovation capability and ICT use in the innovation process from the view of connectivity in Japanese SMEs.* This article discusses how internal innovation capability such as the technological level and R&D (Research and Development) contributes to the innovation and how it is promoted by ICT use. Using the survey data of about 650 SMEs (Small Medium Enterprise) from all over Japan, this study constructs two models with ICT or without ICT and focuses on how SEMs (Structural Equation Modeling) obtain information from external linkages and the role of ICT in the innovation process

The effect of team diversity in cross-functional teams for enhancing research commercialization: An experience of Thai public research institute is an article presented by **Warangkana Punyakornwong**. This article discusses the effect of team diversity and institutional factors in terms of top management support and incentive system on the number of license agreements in the context of the National Science and Technology Development Agency (NSTDA) in Thailand.

The fifth article entitled *A contextual scientometric analysis of Indonesian biomedicine: Mapping the potential of basic research downstreaming* is presented by **Ria Hardiyati, et al**. The article discusses how to obtain a rich contextual overview of the development of biomedicine research in Indonesia, for example in the context of the down-streaming potential of research publications. The results of text data processing using a computational model and bibliometric analysis will provide a richer contextual picture as a proxy to reveal the potential for down-streaming of basic research.

Final article was compiled by **Kristiana, et al.,** with the title *The value chain analysis to support industrial cluster development of oil palm-cattle integration in Pelalawan Regency, Indonesia.* This article discusses the value chain of oil palm-cattle integration proggram and to formulate reinforcement programs to develop cluster of oil palm-cattle integration with industrial cluster approaches. Among the five products from the oil palm-cattle integration program, the liquid organic fertilizer and solid manure are more profitable than the primary product of husbandry: the beef. Nonetheless, both products are highly dependent on the beef cattle existence. In other words, if the business of manure and liquid organic fertilizer are not profitable, the business of beef cattle will also fail.

In addition to all articles that presented in this volume, we also would like to thank the authors, editors, and reviewers who have worked very hard in this edition. We hope that all articles featured in this edition will be useful for the reader.

Jakarta, 16 July 2018

Editor-in-Chief

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India's Science, Technology and Innovation Policy: Choices for Course Correction with Lessons Learned from China

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ABSTRACT

A large number of developed and emerging economies have introduced S&T reforms; and some of them, such as Japan, South Korea and later China, have used them for gaining competitive advantage in science, technology and innovation through well crafted S&T policies and appropriate strategies. So far, India has pronounced four major S&T policies, beginning with the Science Policy Resolution (SPR) in 1958, Technology Policy in 1983, S&T Policy in 2003 and Science Technology and Innovation Policy in 2013. In a period of six decades, India has created a huge S&T infrastructure and made impressive achievements in space, defence and atomic energy, yet the feat is not as impressive in the industrial sector. In innovation competitiveness, R&D and human resource, the indices related to global manufacturing, competition, innovation and knowledge, India has not performed well in comparison to other BRICS countries. In this paper, an attempt has been made to look at how comprehensive India's STI policies with regard to policy components; a roadmap; strategies for execution and boldness in terms of identifying and recognising the failures and recommend major structural changes. What is intended is to understand the relationship between the domain of S&T policy and expected outcomes; the mismatch between the policy expectations and outcomes. An attempt is being made to identify possibility for correction by taking lessons from other economies, such as China.

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I. INTRODUCTION

Science and Technology (S&T) policies cover the entire gamut of government initiatives, which are taken for the creation, funding, support and mobilization of scientific and technological resources[1]. As countries pass through various stages of economic growth, from various factors to innovation driven growth, they need to chart out changes in the S&T policies for seeking desired growth stage. Such initiatives reflect governments' vision and commitments about using S&T for development. S&T reforms have been introduced by a large number of developed and emerging economies and some of them, such as Japan, South Korea and later China, have used reforms for not only gaining competitive advantage in science, technology and innovation (STI), but also using it for the economic development.

India began to recognize the role of Science and Technology (S&T) towards socio-economic transformation, way back in 1958 through its first Science Policy Resolution (SPR) which gives topmost priority to technology. The SPR aimed to "foster, promote and sustain, by all appropriate means the cultivation of science and scientific research in all its aspects: pure, applied and education". The policy laid emphasis on adequate supply of research scientists of highest quality; training of scientific and technical personnel required for science and education, agriculture, industry and defence. The policy also underlined the need for encouraging creative talent, individual initiatives for acquisition and dissemination of knowledge. The SPR was a cornerstone in creating conditions for directing India on a path of science-based industrialization. The first two decades after the enunciation of SPR, India witnessed the creation of a huge infrastructure in science and education. India witnessed a change in its science policy over a sixty year period in terms of regime of issues under the infrastructure phase (1947–1960), assessment and reorientation phase (1970–1980) and accountability phase (1980 and beyond) (Sandhya & Jain, 2003). The initial period, from the forties to the sixties, witnessed the creation of a large infrastructure of S&T institutions in atomic energy, agriculture, defence, space, medical, and industrial research. The experience of India in non-market sectors such as defence, space and atomic energy turned out to be more successful in comparison to the sectors where firms had to face market dynamics.

In the next Assessment and Reorientation Phase beginning in the 1970's, it was recognised that there has been an overlap between the science, economic and industrial policies, and thus, socio-economic justifications and subsequent changes in the policies were required. Though the SPR gave utmost priority to technology, a clearly enunciated technology policy came only in 1983, which gave emphasis on technological competence and self-reliance. This policy statement also reinforced the importance of technological self-reliance for tangible improvement in the conditions of the population's weakest sections.

Another policy on S&T was adopted in 2003 through the Science and Technology policy of 2003. This policy emphasized on the need for high R&D investments and integration of socio-economic sectors with national R&D system for solving national problems. Globalization brought in a new impetus by bringing in the concept of marketing of R&D in the 1990s.

The next policy on S&T as Science, Technology and Innovation Policy (STIP) was unveiled in January 2013, with innovation as the additional focus. This policy acknowledged the lack of importance given to innovation in the earlier decades and marked the beginning of innovation led development in the policy discourse. This policy pronouncement was preceded by the declaration of 2010–2020 as the `Decade of Innovation'. The STIP 2013 has envisaged a focus on prioritizing critical R&D areas such as agriculture, telecommunications, energy, water management, health and drug discovery, environment, etc. It has also talked about STI driven entrepreneurship with viable and highly scalable models.

Some of the key points of STIP 2013 revolved around are enhancing skill base of S&T manpower, establishing world class infrastructure for R&D for gaining global leadership, positioning India among the top five global scientific powers by 2020, creating an environment for enhanced private sector participation in R&D, enabling conversion of R&D outputs into commercial applications, and creation of a robust national innovation system.

It is seen that STI policies in India have focussed on issues which are considered important by STI dominated countries. All the policies have laid emphasis on core STI issues, yet the outcomes do not seem to be complying with the stated objectives. The STI Policy 2013 has been criticized on account of conflicting goals and policies (Abrol, 2013, Krishna, 2013).

In this paper, an attempt has been made to look at India's STI policies with regard to policy components; a roadmap and strategies for execution and boldness in terms of identifying and recognising the failures and recommend major structural changes. It is intended to look at the relationship between the domain of S&T policy and intended outcomes; the mismatch between the policy expectations and outcomes. An attempt is being made to identify possibility for correction by taking lessons from other economies, such as China. So far, India has pronounced four major S&T policies beginning with the Science Policy Resolution (SPR) in 1958, Technology Policy in 1983; S&T Policy in 2003 and Science Technology and Innovation Policy in 2013. The overall developments in the field of S&T in India show that the country has done exceedingly well in S&T in the spheres of space, nuclear and defence related innovation.

However, developments in industrial sphere where S&T can play a major role in enhancing industrial competitiveness generates outcomes that are not commensurately impressive. The indices related to innovation, R&D and human resource, global manufacturing, competition and knowledge, show that India is lagging behind China, its rival in economy (Mrinalini, Sandhya, & Tyagi, 2014). The paper, therefore, essentially delineates the S&T policy discourse in India with regard to the industrial sector where India has not done so well in terms of manufacturing and innovation.

The first section discusses importance of STI policies followed by an overview of India's STI policies in section 2. An elaboration on the challenges for the STI policies in India covering the most fundamental issues confronting Indian science is done in section 3. Chinese roadmap of STI policies is presented in section 4. India's STI policies are discussed by drawing lessons from the Chinese STI policies in section 5. The conclusions are drawn in section 6.

II. THE MODEL OF STI POLICIES

S&T has played a significant role in the development of developed and emerging economies with governments taking a proactive role in targeting development through sustained S&T support. STI policies can enhance the efficacy of application of science to innovation for achieving socio-economic objectives by creating conducive situations. The role of policies is to create conditions for enhancing linkages amongst the innovation actors and limiting the barriers in strengthening the national innovation system. The STI policies are important, as countries are under pressure to confront both the national challenges as well as global challenges. It has been seen that countries that have succeeded in STI have meticulously worked on developing and implementing sound STI policies through strategic planning and management.

Vannever Bush, who directed US government research during the Second World War was credited for initiating a policy discourse on S&T more than six decades ago (Bush, 1945). He has been considered as the main founder of S&T and R&D policies of the United States. While Bush advocated targeted R&D through public funding to facilitate target production during the war and post-war. He recommended a course correction by laying emphasis on basic research. In his revolutionary report, "Science: The Endless Frontier", Bush laid down the foundation for government support to science, particularly the basic research in promoting the flow of knowledge and development of scientific talent and held government responsible as a critical agent in the entire process. He argued that only a robust foundation of research will facilitate technological and industrial development.

The argument favouring public support for research was further re-emphasized by Arrow, who in his seminal work on invention in 1962 argued that without government support, the rate of inventive activity will be low (Arrow, 1962). He argued that a firm will under-invest, particularly in basic research because of risk and appropriability. Governments have a distinct role in creating conditions to provide directions and support as R&D cannot be left to market forces alone.

Henriques and Laredo noted that much of the inspiration for a science policy for the OECD was provided by the Bush report (Henriques & Laredo, 2013). The historic report basically established the notion of government support for scientific research in the policy discourse (Pielker, 2010). The most important rationale for a government to promote R&D is that private sector is overtly guided by profit concerns and therefore may not be inclined to undertake R&D.

Globalization has expanded the domain of STI policies all the more because R&D has become more internationalised. R&D spending has increased multi-fold, not only by the developed but also by the emerging economies. Henriques and Laredo have delineated the OECD model for policy making in science based on 17 evaluations carried out for the member countries (Henriques & Laredo, 2013). The model comprises of seven functions on which an effective policy is built, which is able to accommodate the transition from science policy to S&T policies with a progressive swing to innovation. The model recognizes the need for a science policy to be very critical as it is not possible for any country to focus on everything; necessity of formulation and implementation of science policy with separate bodies and importance of central authority to be in control of co-ordination. Some of the functions of this model are advice from the experts, development of plans, prioritization of areas, involvement of stakeholders with a long-term orientation, allocation of resources including core and competitive funding and administration. The model pushes for the need of having national programmes reflecting national prioritization and in essence underlining the shift from science to technology. Most developed and emerging economies have consistently worked on setting priorities for STI, which have provided the basis on which they have evolved their STI policies.

Based on case studies initially from a large sample of fifteen countries, and deeper analysis of six country samples from Europe, Korea and New Zealand, Gassler observed that priority setting to be an important guiding principle behind STI policies based on foresight exercises (Gassler et al., 2004). Initially, Japan and then Korea followed the model and climbed the ladders of development based on S&T. The process followed by these countries basically entailed picking up economic activities with growth potential and providing all types of physical and financial resources to the enterprise with the focus on industry/technology (Nath, 2008). Later, China made a transition to development-based STI following similar process, though the country faced STI problems similar to that of India in early 1980s, (Sandhya, et al., 2012).

III. ORGANIZATION OF SCIENTIFIC RESEARCH FOR INDUSTRIAL DEVELOPMENT IN INDIA

STI policies encompass all the government initiatives which address S&T infrastructure, strengthening of S&T capacities, strengthening the STI actors such as universities and research institutions, and other institutions supporting innovation. Major economies across the globe have based their developmental agenda by orienting S&T policies with economic and industrial policies; prioritizing the key sectors and organizing S&T and innovation resources; strategizing the policy initiatives followed by time bound execution and evaluation. It is important to look at some of the most fundamental issues confronting Indian S&T including organization of both R&D as well as innovation and creation and sustenance of innovation ecosystem.

A. Government initiatives for the creation of S&T infrastructure.

India has built up a substantial S&T infrastructure in the last seven decades. The initial phase of S&T in India led to creation of S&T infrastructure through research councils for agriculture, medical, industrial, and social science research; departments for nuclear, space, electronics, ocean, environment and defence; promotional agencies such as Department of Science and Technology (DST); institutions under ministries; state-run S&T outfits, etc. India did very well in S&T in the spheres of space, nuclear and defence related innovation. However, the industrial sphere where S&T could have displayed a major role in enhancing industrial competitiveness did not display commensurate achievements.

At present, there are a total of 5,710 R&D units in the country, with 606 R&D institutes under the Centre and 1,066 under the State, followed by 538 units in the higher education sector including universities and institutes of national importance (DST, 2015). There are 3,324 industrial units with R&D in the private sector and 176 in the public sector. The size is comparable to several developed countries. However, if we look at whether the infrastructure has been appropriated to the fullest advantage, the indices related to the innovation capabilities and capacities of India in relation to other Brazil, Russia, India, China, South Africa (BRICS) countries show mixed results. India—in comparison to BRICS, particularly China on innovation competitiveness, manufacturing competitiveness, knowledge competitiveness, etc.—shows weaknesses in manufacturing and innovation competitiveness. For instance, as per the Global Competitive Index, which determines the productivity based on institutions, policies and factors in a country, India was ranked at 56th in 2003 against China at 44th in the same year. India slipped to 71th in 2014 and China improved its standing by ranked at 28th in the same year. India, however climbed by 16 places in 2015, which is attributed to improved monetary and fiscal policies.

China's position is stronger because it has made progress in some of the more enabling areas of competitiveness, such as higher education, innovation and business sophistication leading to strengthening of innovation ecosystem (WEF, 2015). Global Innovation Index (GII), which is a measure of the suitability of conditions in an economy to sustain innovation, ranked China at 29th and India at 76th place in 2014. The Competitive Industrial Performance Rank, which looks at the competitiveness of manufacturing industry in the global scenario ranked China at 7th and India at 42nd place in 2014. Based on parameters related to Knowledge Economy Index, which reflects the suitability of the environment for using knowledge for economic development, through economic incentives and institutional regime, education, innovation and Information and Communication Technology (ICT), China's was ranked at 54th in 2014 against 76th in case of India. Although India has progressed fairly and improved its global position yet in comparison with other countries including BRICS countries there are issues related to weaknesses in manufacturing and innovation.

B. Government support to R&D

While a huge infrastructure of S&T institutions has been laid out, what are the R&D resources provided to them? India's R&D expenditure as percentage of GDP has remained stuck between 0.75 in 1990 to 0.88 in 2012[2]. The gross expenditure on R&D has trebled from Rs 24,000 crores to around 72,000 crores but the R&D : GDP ratio has remained at around 0.88%. If this is compared with some other BRICS countries, the ratio for Brazil, Russia and China is 1.17%, 1.25% and 1.7%—now it is more than 2%—respectively. Although funding R&D by the government alone cannot be a deciding factor in fostering innovation, the underlying trends from other countries and their relative ascendency not only in science but also innovation raises important questions. The STIP 2013 has targeted to increase Gross Expenditure in Research and Development to 2% of the GDP, and that 2% has eluded India for a long time now.

The policy concern is about higher participation by the private sector. The share of private sector in R&D in India is low compared to the government. The major source of R&D financing is still the public sector. The STIP 2013 has targeted the share of private sector to go up to 50% in the next five years. How does one increase the number of firms doing R&D? The policy also targeted higher share of high technology products exports from India through greater technology inputs from R&D. Participation of enterprises in R&D and innovation. Gross expenditure on R&D mainly by government sector comprises of central government 54.4%, state government 7.3%, higher education 4%, public sector industries 5.3% with private sector contribution at around 28.9%. The private sector's R&D expenditure has been significant in few sectors such as pharmaceuticals at 27.7%; transportation at 14%; information technology at 13.6 %, followed by defence.

The S&T efforts until 1980's have enabled India to attain self-reliance in industrial production but pressures resulting from liberalization and globalization have not encouraged technological innovation in several industries. For instance, globalization demands enhancement and continuous upgrading of R&D and technological competitiveness of both R&D institutions and industry and a hand-holding support to small and medium enterprises. Though there is a huge and well developed S&T infrastructure, its usage for enhancing industrial competitiveness has not been very encouraging.

C. Innovation ecosystem in India

While investments in R&D are a crucial factor in developing S&T capabilities, innovation is dependent on a well supported innovation ecosystem, which is created and strengthened by the dynamic interaction of production system and technological and non-technological support system. Innovation is an interactive process that requires intensive communication and dealings among several actors such as universities, research institutes, educational institutions, suppliers, customers, financial institutions, etc. It requires an ecosystem that is nurtured by an active involvement of various agencies for technology generation: mainly research organizations; technology diffusion/marketing for marketing technologies; technology consultancy organizations; tools, equipments and prototype development organizations; organizations providing common facilities/testing centres for testing, standards, calibration, etc.; raw material, machine and equipment suppliers particularly for SMEs; finance and refinance; infrastructure development organizations for developing basic infrastructure facilities; and organizations for imparting training and skill development and entrepreneurship development programmes. In India, the support for innovation is provided by these organizations (Nath, Mrinalini, & Sandhya, 2014).

Therefore, when STIP 2013 underlines the importance of innovation ecosystem, an important point that should be seriously pondered is that, has due attention been paid in India to all the innovation actors? As the study on the status of innovation in India based on a sample of 9,001 firms drawn from a population of 20,8415 micro, small and medium sized firms from all over India, for 2009–2010 from the Annual Survey of Industries (ASI) database noted that there is a disconnection between the production system and innovation support system (Nath et al., 2014). There is a domination of technology generation organizations, yet access to information/knowledge was found to be a major factor inhibiting innovation. Similarly, when one looks at the numbers of organizations for supporting and promoting innovation, the numbers are inadequate.

The study also noted that at the local level, there is an absolute dearth of organizations, supporting technology generation, technology diffusion, consultancy, tools, equipment, prototypes, common facilities for testing, etc.

D. Responsiveness of S&T infrastructure to industrial R&D needs

The STIP 2013 has also laid emphasis on sectoral prioritization and manufacturing. There are 36 millions of Micro Small and Medium Enterprises (MSME), which contribute about 8% to GDP and provide employment to over 80 million people. The sector contributes to about 45% of total manufacturing output and 40% of exports from the country[3]. There has been a decline in the share of MSMEs towards manufacturing and exports largely because of China's emergence as a major player in the manufacturing. India is losing out to rival economies even in areas where it could have been a major player. MSMEs are facing tough cost and technological competition which can only be countered with competitive manufacturing by producing superior products with better technologies. It is well known that this sector lacks the technological capabilities to introduce superior products with cost competitiveness. In order to revive this sector for competitive manufacturing, therefore, there is a need to enhance both technological and non-technological support to them which is not difficult given the infrastructure which is present in the country.

There are 350 small scale industry clusters and 2,000 rural and artisan based clusters, which contribute 60% of the manufactured exports[4]. These are in large number of product categories including textiles, chemicals and pharmaceuticals, food, leather, auto components, engineering products, etc., and have medium to high technology upgrading potential. As mentioned already, there is a huge S&T infrastructure which is comparable to several developed countries, but the crucial question is how such a system with a large number of learning and knowledge generating institutions can be made responsive to the needs of MSMEs which are so crucial for the economy?

To boost manufacturing, the government has announced a programme, "Make in India". The programme was announced on September 25, 2014 and includes new initiatives to facilitate investment, foster innovation, protect intellectual property and build best-in-class manufacturing infrastructure[5]. The new processes target to ease out the procedures, reducing the complexities and enhancing speed and transparency in doing business besides strengthening the infrastructure including creation of clusters. There is a focus on sectors such as automobiles, automotive components, aviation, pharmaceuticals, chemicals, biotechnology, construction, defence, information technology, railways, renewable energy, etc. To support Make in India initiative, there is need to strengthen the manufacturing in the MSME sector. A major issue, therefore, is if that is possible to support and sustain manufacturing without strengthening the institutions related to science, technology and innovation (Sandhya & Mrinalini, 2016).

E. India on a human resource parameter

Human resource is another area where India has created pockets of excellence, but India faces challenges in maintaining quality, quantity, equity and governance while lacks a coherent long-term policy for the higher education and a vision of development (Tilak, 2012, 2013). Tilak puts the blame on the absence of policy making and planning in the higher education, the absence of which leads to interpreting the government perspectives through the budget speeches, five year and annual plans, budget speeches and statements made by ministers on various occasions or schemes announced by the government. The number of universities in India grew from 184 in 1990–91 to 409 in 2008–2009[6].

There are problems of requisite institutions, lack of autonomy in hiring staff, curriculum development, faculties, governance, intersecting disciplines, or inadequacy of the system to inculcate creativity. The National Knowledge Commission (NKC) was set up to prepare a roadmap of knowledge creation in 2006. This recognized the factors that ail higher education in India, ranging from inadequate infrastructure, unchanged curricula, learning and creativity bottlenecks, barriers in developing knowledge at the intersection of disciplines, segregation of research and teaching, etc. Therefore, though the NKC has recommended several action points with regard to expansion, regulation, increased spending, establishment of national universities, etc., the actual implementation through workable policy instruments for realizing the aforementioned objectives may still require a lot of effort. The reforms have also indicated a need to bring back research to universities and strengthening undergraduate education.

Is there any roadmap which can provide a common platform which can translate the R&D and technological needs of the industry and bring together the entire S&T and innovation infrastructure? The articulation of Chinese Government's STI policy through a roadmap involving all the stakeholders will be delineated in the following section.

IV. STI POLICIES IN CHINA

China is emerging as a more visible force in science, technology and innovation. It may not be lauded for breakthrough research, but it has moved very fast in developing distinct innovation capabilities in many sectors and also occupying the frontiers of knowledge in some fields (Preeg, 2008; Bound, Saunders, Wilsdon, & Adams, 2013). Through consistent and sustained initiatives, China has not only narrowed down but even closed the scientific gap with the developed countries (Sandhya, et.al, 2012). While acknowledging the weaknesses in the Chinese innovation system, studies have linked the growth and momentum in China to pragmatic policies and policy learning (Gu & Lundval, 2006; Huang and Soete, 2008 and Sandhya, et al., 2012). Studies have pointed at an active role of Chinese Government in financing and directing R&D also subjecting its institutions and organizations to massive restructuring and transformation including its S&T system (Jefferson, 2005; Lu & Lazonick, 2001 and Sandhya, et al., 2012).

A. Science Policy making in China

Chinese model of development treated STI as a complement to economic transformation operationalised through a number of policy structures which enabled the government to define an S&T policy. The Chinese policy formulation is essentially based on the OECD model that was adopted by Japan and later Korea according to which China developed its plans and evolved its national priorities based on experts' advice through extensive deliberations with a long-term orientation. The process can be summarised as follows.

1) As a follow-up of the opening of the economy, Chinese Government targeted to catch up with the world through an S&T policy which laid emphasis on initiatives related to R&D, technology and innovation. China embarked on a series of policies and programmes to enhance its S&T capacity and innovation to enable China catch up with the world in selected priority sectors and technologies. China 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.

   In targeting the catch-up with developed countries, China enhanced its R&D spending in terms of percentage of GDP from 0.6 in 1995 to 1.83 in 2011 and 2.08 in 2013[7] Globally, China ranks second in terms of absolute R&D spending. Prior to 2000, Chinese investments in R&D were at par with India but increased by 161% by 2011. China's increase has been more than 20% each year. The share of private sector in R&D has consistently grown over the years and it accounts for 76.6% of total R&D expenditure followed by government affiliated research system at 155 and higher education sector at 7.2%.

   Government support for R&D has grown at a high rate, but the role has been in terms of guiding and steering the private sector to get in to R&D and innovation. Amongst the industrial sector, seven sectors account for 61.3% of total R&D which is due to governments' commitment to focus on the sectors prioritized by the government. This is in line with the OECD model of S&T policy which insists on the need for national programmes to address national priorities and thus entail transition from science to development of technology (Henriques & Laredo, 2013).

2) Chinese S&T policy has been laid down through national programmes which is a reflection of the core priorities of the government. China announced a series of national programmes to enhance its capacity and capabilities in S&T. The major policy decisions which defined China's overall direction for orienting S&T and laid a framework included, The 1985 Decision on the Reform of Science and Technology Management System; The May 1995 Decision of Accelerating Scientific and Technological Progress, and The Medium and Long-Term S&T Development plan in 2006. Both the 1985 and 1995 decisions of the Chinese Communist Party were discussed over major conferences and the Medium & Long Term Programme of 2006 took three years and a series of discussions to finalize the action points.

China pronounced a series of programmes along the entire chain of innovation from basic research to innovation. The main impetus to basic research was first provided by setting up the National Natural Science Foundation (NSFC) in 1986, followed by the Climbing Programme in 1991 and the 973 Programme in 1997 Applied research and high Technology were promoted by the Key Technologies R&D Programme in 1982, Advanced Technologies Programme, and the 863 programme in 1986. The major programmes for supporting Innovation included the Torch Programme in 1988, the National New Products Programme in 1988, the Innov-fund for small and medium enterprises in 1989, the Spark Programme in 1986 and the Knowledge Innovation Programme in 1998.

These programmes, with lot of prioritization and strategization, received massive funding. The programmes have been given continuous support through five year plans and continuity is maintained along with incremental changes. The programmes have not only maintained continuity, but also have been mandated to be output oriented with close monitoring and evaluation.

3) Human resource policies in China have received unabated attention by the policy makers for generating and augmenting human resource since 1980s under a long-term vision. This has been done again by implementing a number of programmes and policies. Some of the reforms to revamp the higher education system in the mid-1980s included university modernization, changes in curricula, autonomy in administration, and the participation of regional goverenents, etc. (Sandhya, et al., 2012). Two major initiatives to revamp higher education system in China included the Project 211 and Project 985. The Project 211 was launched in 1996, aimed to strengthen about 100 higher educational institutions and key disciplinary areas as a national priority for the 21st century. The Project 985 targeted founding of world-class universities in China and was launched in 1998 with a mandate of targeting ten universities with special three year monetary grants. These two university modernization programmes were supplemented with other programmes to attract the best manpower from within China and abroad. Some of these were One Hundred Talents, the Cheung Kong Scholar Programme, National Science Fund programme, Chunhui Programme, Yangtze Scholar's and Hundred, Thousand, and Ten Thousand Talents Programme.

These initiatives led to changes on not only the focus of the Chinese universities from education to research, but also research to commercialization in the period followed. Universities have become significant contributors in knowledge generation, diffusion, innovation and an important carrier of technology commercialization. China has encouraged its universities to set up of their own enterprises to counter the problems of technology markets. The practice of university-affiliated enterprises is a unique feature of the Chinese innovation system. The concept of enterprises in China has redefined the role of universities from being training centres to profit generators. University Science Parks have been created in China to incubate spin-offs created by university professors and students. The practice of spin-offs from universities in China has been an important factor in off setting the problems of technology markets (Kroll & Liefner, 2008). These have exhibited a great deal of dynamism in fostering linkages amongst Government Research Institutes (GRIs), universities, and the industry. Some of the most visible impact of these measures pertains to publication outputs, prominence of Chinese universities in select fields, enhanced global ranking of Chinese universities, etc.

4) One of the major challenges China faced in the 1980s was weak research infrastructure, which suffered from poor linkages with the industry, low productivity, and poor utilization of research to commercialization issues. The consequent reforms in China on this front targeted research infrastructure, funding in core areas, S&T talent, strengthening commercialization (Sandhya, et al., 2012).

The ensuing major policy initiatives targeted funding reforms; restructuring of GRIs; consolidation of linkages among research, academia, and industry; commercialization by the creation of `Technology Markets, creation of S&T parks, etc. The first step taken in revamping the governance of government research institutions was to discourage the government from providing unconditional funding. The funding of GRIs shifted from fixed annual allocation to a multiple allocation system to encourage links with industry, competition, and more industry relevant research. This was done to encourage research institutes to face the market and enhance their connectivity with the industry to reverse the damage done by the earlier system.

To facilitate this, The State Council of China disengaged the R&D institutes connected with economic development and got them engaged in manufacturing. In 1998, the State Council abolished 10 ministries (including the Ministry of Machine Building, the Ministry of Metallurgy Industry, the Ministry of Coal, etc) in order to increase the power of the market in resource allocation. By 1999, the first batch of 242 research-institutes that were affiliated to the aforementioned ten ministries was converted into enterprises. These enterprises were supported through financial incentives such loans, subsidies, personnel, and tax incentives, operational funding, etc. In 2000, another round of 134 R&D institutes under the Ministry of Urban Construction was converted into enterprises.

The Chinese Academy of Sciences (CAS) is China's highest academic institute and comprehensive research centre in natural sciences. It is the highest advisory body in China on issues of science and technology, plays an advisory role in the formulation of national S&T strategies and national S&T development programmes, and conducts research on major S&T issues. Restructuring within the basic research institutions in CAS was conducted to strengthen basic research capabilities. By 2008, the academy had brought down 122 research institutions in to 91 from 1985 to 2008.

The problems of a lack of drive from the industry to exploit the research results from institutions and enhance the commercialization of research was countered through several government initiatives such as research institution owned enterprises, creating spin-offs and support measures. The CAS helped in the commercialization of its own research results by launching its affiliated enterprises, and setting up spin-offs. Support for commercialization in the high-tech area was garnered through the Technology Innovation Fund (Innov-fund) in 1999, for supporting high tech SMEs/spin offs through additional loans.

The State Council launched the Torch Programme to facilitate commercialization of research results, since the Chinese system of innovation suffered from poor translation of research into applications. The programme targeted commercialization of research results from universities, GRIs, and high tech industries. The programme was launched in 1988 and was expected to connect to the 863 programme which created research outputs in high tech areas such as information technology, biotechnology, new materials, new energy, etc.

Provinces, municipalities, and autonomous regions were also asked to attract high calibre researchers from abroad in accordance with their development plans. Developed regions, particularly the east coast belt and the central cities, took measures to ensure this in special projects in high tech parks, overseas Chinese pioneering parks, and campus S&T Parks[8].The Chinese Ministry of Human Resource and Social Security also established a dedicated service system to facilitate the launch of high tech businesses and S&T Parks by overseas Chinese returnees[9].

5) The Chinese innovation system has been nurtured within a dynamic ecosystem, which is marked by the creation of S&T parks, university parks, high technology development zones, technology business incubators with

necessary intermediaries support; evolving relationships amongst the innovation actors and modernization of the higher education system along with revival of the government research system (Sandhya, et al., 2012). The networking and linkages can be seen through the operation of S&T parks. For instance, one of the most successful parks such as the Zhongguancun Science Park (Z Park) in Beijing, which is hailed as Silicon Valley of China, has nurtured more than 20,000 high tech firms in several industry clusters created around academia and government research institutions with manufacturing as the mainstay. Many of the leading Chinese giants such as Lenovo, Founder, Stone, etc., have spun off from the universities and GRIs.

The Chinese government's support has been in terms of creating intermediary structures for supporting commercialization with a supportive policy package for enhancing dynamism in these geographical clusters. These parks have a mix of large and medium enterprises, small and medium enterprises and multinational corporations with linkages amongst academia, GRIs and industry. Local governments have participated in the infrastructure creation, governance and resource provision. Similarly in yet another park, the Shanghai S&T Park, the Shanghai S&T Commission formulates and implements policies while also acts as an administrator of service centres (technology transfer exchange centre, high-tech commercialization service centre, and high-tech enterprise incubators) that aid in innovation. It administers the high profile S&T programmes. Shanghai Technology Transfer Exchange acts as a technomart where technology transfer transactions take place. It plays a role in providing business services including feasibility studies, market research, technology transfer certifications, venture capital financing. A large number of domestic firms in these clusters similar to Z Park have emerged either as spin-offs or in the form of affiliated enterprises which are owned by universities and research institutes. Similarly, firms created by research scientists and the university professors too have been established in the park. These are supported by national programmes on R&D and human. The park has a range of firms from MNCs to small and medium enterprises and GRIs as well as universities.

B. Lesson Learned from China

China's has strengthened its position in several areas of competitiveness discernible through various indices such as Global Innovation Index, Competitive Industrial Performance Index, Manufacturing Competitiveness and Knowledge Competitiveness. As elaborated in Section II, appropriate STI policies have brought the rise in manufacturing and innovation competitiveness. The entire process of Chinese transformation suggests targeted restructuring and reorganisation along the entire innovation chain which included research institution and universities and created S&T Parks for facilitating innovation in the enterprises. The process of streamlining and its continuity of changes have not only led to a qualitative improvement in the institutions involved, but also enhanced linkages amongst the actors of innovation. For instance, China's lack of initial success in creating markets for technology was followed by a structural transformation of research institutes into enterprises and supporting commercialization of research by the inventors through the support provided by the 'Torch Programme' and `Innovation fund`. The R&D focus 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. The indigenous innovation policy supported industries in areas where indigenous research had been undertaken.

Is there anything one can learn from China? The vision, strategies and S&T policy initiatives taken by China suggest the necessity of a roadmap with appropriate changes in all the concerned institutions along the entire innovation chain. The S&T policies in China targeted catch-up and later innovation based development and subjected the concerned organizations to ruthless restructuring. The policy trajectory shows connectivity and concurrence with lot of consolidation in the last three-four decades. There is a rational analysis of policy outcomes and achievements which is done with a view to learn from failures. Success or failure is determined by programme/project outcomes rather than financial accountability.

V. INDIA'S STI POLICIES AND THE GAPS

It has been seen that countries that have witnessed S&T-based transformation have done it by orienting their economic policies with initiatives to nurture S&T-based development and innovation. As has been discussed in the section on the model of S&T policies, it is extremely crucial to have STI policies as it is not possible for any country to focus on everything. The model makes a strong case for prioritization of areas considered important by the countries and forming national programmes with a long-term vision drawn on the basis of inputs from experts. Priority setting forms an important component and countries have used foresight exercises for enabling the STI policies. It has been seen that initially, Japan and then Korea followed the model and China followed the same route. These countries made huge investments in S&T for infrastructure creation, knowledge generation, high-end skills and created strong innovation ecosystem by following a long-term roadmap.

On a global level, India's performance over a number of competitiveness parameters as discussed earlier does not reflect a robust situation. Even amongst BRICS countries, the situation is not that impressive. For instance, as noted by 'The Global Competitiveness Report 2015–2016', China's position is strong because it has made progress in some of the more sophisticated areas of competition which has led to strengthening of innovation ecosystem. These include higher education, innovation and business sophistication.

There are few issues which are critical to India and are important to consider for enabling S&T based sustainable development. One is about the organization of science and organization of industrial R&D, which is one of the components of an STI policy. The setting up of agenda along with the execution of agenda is a critical issue. The use of STI Policy is in terms of helping in identifying areas with our core strengths and then helping the industry overcome the weaknesses. Just to elaborate the point, Indian pharmaceutical industry has come a long way from mere marketing of drugs some six decades ago to production of most of the required drugs in the country based on indigenous technology. One of the most potent factors behind developing R&D and technological capabilities in the industry was the Indian Patent Act of 1970, which provided patent protection for the process rather than the product. This policy enabled the Indian pharmaceutical industry to develop process capabilities for producing large number of drugs based on indigenous technology by working on alternative processes. Today, this has become the most R&D intensive sector and industry spends 5% on R&D. Council of Scientific and Industrial Research (CSIR) has played a crucial role towards this. Some of the CSIR laboratories—Central Drug Research Institute, Indian Institute of Chemical Technology, National Chemical Laboratory, to name a few—have played a very crucial role in providing crucial inputs to the industry from 1960s till the introduction of new patent regimes by which time more than two-thirds of large pharmaceutical firms had developed significant linkages with the CSIR and academia (Sandhya &Visalakshi, 2000).

Today when the industry is confronted with global pressures of product patent, it is important to assess as to what is our level of preparedness to combat global pressures and our long-term strategy for the pharmaceutical industry. This is the second most attractive destination for attracting Foreign Direct Investment (FDI) in R&D, where the investments for R&D have come to India, to Indian contract research organizations for doing different stages of R&D (Sandhya, et.al, 2014). There are several stages in drug manufacturing which are quite complex and cost-intensive; including development of new drug molecules, clinical trials, developing IT based solutions for data management, statistical analysis, and bio-informatics. Foreign firms are outsourcing these stages to Indian contract research organizations. Is it not important to make an assessment of India's long-term gains or losses about who is benefiting more? Is there a long-term plan to synergize India's industrial core competencies in public research system institutions and industry for major break throughs? The first trigger to industry was provided by the 1970 Patents Act but there appears to be some bit of complacency or loss of purpose in terms of future direction to this industry, for there are competencies with industry, research institutions and availability of R&D, technological and manufacturing skills yet no meaningful direction to hone the strengths and capabilities are visible.

The other illustrative case of increasing participation of industry in R&D is that of auto-components industry[10]. Today, this industry ranks among top five R&D spenders along with drugs and pharmaceuticals, biotechnology, information technology and scientific instruments. Government Support to R&D will be more effective if it is thought of in terms of a long-term strategy. Though the STIP 2013 has prioritized sectors as critical R&D areas and enhancing private participation in R&D, it lacks the rigour required to undertake it in a mission mode.

The second very important role of industrial R&D could be for the MSME sector which is in dire need of R&D and technological help as the sector is facing tough cost and technological competition from China which has emerged as a major player in the manufacturing. This can only be countered with competitive manufacturing by producing superior products with better technologies. Is it difficult to strategise the revival of this sector for competitive manufacturing, given the huge infrastructure available in the country?

While there are pockets of dynamism exhibited in sectors, such as chemicals and pharmaceuticals, automotive, leather, etc., these sectors exhibit capabilities in R&D, technological development and manufacturing. The textiles sector has demonstrated substantial manufacturing capabilities. India also has a chain of industrial research institutions in the textiles sector capable of catering to requirements of the industry. However, in the absence of proper articulation of role of these institutions towards enhancing technological capabilities of the industry, their contributions remain limited.

According to the Ministry of Textiles, the textile industry contributed 14% to industrial production, 4% to GDP, 27% to country's exports earnings, and employing over 45 million people (second only to agriculture) in 2015. The role of R&D in enhancing the competitiveness of this sector thus cannot be underestimated; therefore, there is a need to strengthen it[11]. There are eight Textile Research Associations (TRAs) under the Ministry of Textiles to cater to research and the technology requirements of the Indian textile industry. Though the TRAs were created to cater to the research and technological requirements of the industry, they have witnessed a gradual depletion in human resource over the years and have become irrelevant to the needs of industry. The withdrawal of government funding and the pressures of earning have forced them to orient their activities around revenue generation.

The textile industry is represented by big technologically advanced and export oriented firms on one hand and decentralized low-tech small firms on the other. Since large firms have their own means of technology acquisition and upgrading the small decentralized sector continues to suffer from technological obsolescence, the TRAs can be of very significant value to the small decentralized sector. Even though the TRAs can provide substantial support to the decentralised sector, they have been marginalised in the liberalised scenario. The main concern of these organizations in the liberalized regime has been to earn money through routine activities, such as testing or equipment based services, and use money from sponsored projects to set up modern R&D intensive facilities, which remain underutilized. Strengthening the research skills in the TRAs has never received the required boost and they have suffered from severe human resource constraints (Nath, Mrinalini, & Sandhya, 2001).

VI. CONCLUSION

The experience of Japan, Korea and later China shows that these countries oriented their STI policies with economic policies and also picked up economic activities with growth potential for enabling S&T led industrialization (Nath, 2008; Sandhya, et al., 2012). In India, the STI policies require stronger coordination between economic and S&T policies with targeted prioritization. India cannot afford an all inclusive R&D scenario and thus needs to work judiciously in targeted areas where India has competitive advantage. India's competitive advantage is discernible in sectors where India has shown both manufacturing as well as R&D skills. India has attracted FDI in R&D in pharma/biotech, information technology and auto components sectors, which is a reflection of India's skill base in these areas.

The STI policy must focus on a long-term basic research in these niche areas. China adopted this policy by focussing on manufacturing and R&D in selected priority areas such as IT, electronics, life sciences including pharmaceuticals, medical devices and biotechnology, space, nano technology, environment, clean energy, food and agriculture. The pumping of R&D investments in selected areas helped China in enhancing its relative position globally in research in areas such as super computing, nano technology and clean energy.

As far as the Indian STI model is concerned, it had and still has the linear model assumptions that industry is sufficiently advanced to recognise the research capabilities in the public research system and is not enterprise driven. Although a number of initiatives have been taken by the Indian government to encourage indigenous R&D and innovation; strengthen the links among stakeholders in the process of innovation; and reorganize and restructure R&D institutions, yet the absence of a target-centric and firm-oriented approach coupled with the lack of major structural changes in stakeholders, the initiatives had not resulted in outcomes, as could be seen elsewhere. There are ample policies and institutional structures, but concurrence and connectivity amongst them require more corroboration. The lack of rational analysis of policy outcomes and achievements, as well as learning from failures underlines the poor outcomes.

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Endnotes

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10 The Indian auto-components industry suffered from low technological competence, poor quality products with no access to the international market in the pre mid-1980s. The R&D investments have come from the private sector in a manner where the suitable conditions were created by the government for innovation to take place. This included allowing entry of MarutiUdyag limited and other policies related to import substitution and Phased manufacturing Programme which stipulated an increase in the local content to over 90% within five years. This forced auto majors such as Maruti first and later others to increase the domestic content by subcontracting the production of auto-components to domestic firms. Producing for the auto majors by the component manufacturers necessitated development of technological competencies, quality consciousness and financial management and supply chain as an institution got institutionalized because of appropriate mix of policies. The dynamic interaction between the auto majors and their component manufactures had resulted in innovations related the organization, information exchange, skill enhancement, developing improved products as well as processes, wastage reduction, quality improvements so on and so forth (Sandhya& Mrinalini, 2002).

11 A study done by NISTADS on `Evaluation of Textiles Research Associations' with financial assistance from the Ministry of Textiles highlighted the need for their incorporation in to the larger framework of research for the industry.