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An Assessment of India's Innovation Policies

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Abstract: This paper presents a detailed overview of the innovation policy framework in India in order to assess its role in innovations and enterprise development in the Indian industry. Over the decades, India's innovation strategies have been guided by the S&T policy statements, while industrial policy resolutions/statements have given direction to the development of manufacturing enterprises. These twin processes have tried to ensure that India is able to develop a sufficiently robust manufacturing base and at the same time build a sound S&T infrastructure and create a high-skilled manpower base. We distinguish between eras of closed and liberalised economy in India and account for recent policy overtures. We closely examine the Indian scenario with respect to technological capability of its industry and draw suggestive international comparisons. We devote substantial attention to the emerging issue of innovations in the SME sector in India and discuss in detail technological interventions in two traditional industry clusters in India. Finally, we highlight the existing bottlenecks in India's national innovation system. In this paper we note that the existing policy paradigm does not draw upon immediate innovation challenges that may be specific to India, particularly when developmental priorities are overwhelming. We suggest that while, economic policies should ensure sustained demand for innovations, innovation policies in India at this juncture should cater to two definite goals. First, streamline availability of broad-based skills to seize opportunities of specialization, industrial development and knowledge economy. And, second, achieve frontier R&D focused on pro-poor innovations, niche knowledge and green technologies.

Key words: Innovation Policy, India, Enterprise Development, Technological Competitiveness, Clusters

1 . Introduction

Technological change embedded in improvements in products, processes and inputs is largely determined by research and development (R&D) led innovation paradigms. Cohen and Levinthal (1989) suggest

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that R&D not only generates new information, but also enhances firm's ability to assimilate and exploit existing information. In essence, R&D efforts and knowledge creation drive technological change. However, knowledge has public good characters, i.e. knowledge has attributes like non-rivalry in consumption and non-excludability upon supply. This results in a free rider problem and drastically reduces private incentive to create knowledge – a classic case of market failure. Therefore, if knowledge creation is left to market forces it would lead to socially sub-optimum levels of knowledge. We understand that private incentives for knowledge creation is even lower under developing country conditions with small markets for technology led products, poor capital markets backing innovation investments and limited informational resources. Stiglitz (1989) argues that developing countries also lack 'non-market' institutions that ameliorate market failures to some extent in developed countries. While imperfect competition allows economic organisation around rent-seeking to promote proprietary knowledge creation (large corporations and intellectual property rights) in developed countries, it necessarily has adverse implications for developing countries that depend on 'imported' knowledge.

Historically, early industrialised countries registered a lead primarily due to technology led productivity growth over the last two centuries. Contribution of technology went much beyond contributions of physical factors like labour and capital in propelling growth in these countries. However, when it comes to developing countries, productivity growth in the strict neoclassical sense (discreet shifts of the frontier) may not apply. Technological change in the latter context would imply technological learning, improvements in the cognitive abilities of the workforce and firm level adoption and adaptation of technologies leading to productivity gains. Immediate effects in terms of technical change may be in the form of minor innovations that are historically as important a source of productivity improvement as major jumps in the frontier (Lall, 1986). Overall, technological progress in developing countries is confronted with aggravated market failure in knowledge creation, poor institutions, initial disadvantages due to foreign sources of knowledge, proprietary pricing of knowledge and unavoidable pitfalls in the process of technological learning.

India's has undoubtedly attained the status of an emerging economy in the recent decades and continues to have a unique position among developing countries for its elaborate infrastructure of scientific research. However, as the 12th Five Year Plan document rightly points out, since 1985 other emerging Asian economies invested heavily in R&D, significantly blunting India's edge in the S&T sector. The government currently accounts for nearly 70 per cent of total R&D expenditure in India. According to India S&T Report (NISTADS, 2008), six industries (pharmaceuticals, automotive, electrical, electronics, chemicals and defence) account for about two-thirds of the total industrial R&D. The pharmaceutical industry alone accounts for about 20 per cent of the total R&D expenditures. India's economic emergence has largely been attributed to technological learning (in the industry), science and technology (in strategic sectors) and human resources (in modern knowledge intensive industries). But, sluggish industrial growth, low technological value addition across manufacturing sectors, poor performance in terms of competitiveness indicators, and alleged failure to provide technology based solutions to overcome India's formidable developmental concerns often challenge such notions of technological capability. More seriously, India's technological capability has been questioned on grounds of limited innovativeness. There is growing discomfort and desperation around slow corrective actions, deficient innovation paradigms and laggard transformational changes, despite all old and new S&T policy initiatives.

Policy and institutions in India are primarily focused on economic growth and ability of firms to generate generic innovations that are not always aligned with priorities of national well-being.[1] We observe that neglectful innovation paradigms with poor understanding of national welfare and key societal needs of immediate significance might cause irreversible damage.[2] Clearly, disservice done is forthright conspicuous when science remains out of reach for a significantly large number of people and when it falls short of providing innovative solutions to existing and eventual societal needs. This defines the scope of public policy in this area and reiterates the need for continued intervention by the state to ensure fulfilment of such objectives. Against this backdrop, in this discussion paper we intend to take a critical look at India's overall innovation policy framework and try to understand policy levers that facilitate technology generation in the industry. We would extend our analysis further into the domain of innovation and enterprise development in India as a case and contribute to the understanding of developing country perspectives in this regard. Finally, we intend to look at recent initiatives in India towards innovation and enterprise development in traditional industry clusters where interventions for technological upgradation by government agencies and public funded R&D institutions have been successful. We shall present detailed case studies of such initiatives to understand the nuances of innovation paradigms that potentially link modern systems of innovations to traditional industry clusters common in developing countries.

We have the following sections in this paper. After the introductory Section 1, in Section 2 we discuss the scope of technology policy. In Section 3 we introduce the national innovation system approach. In this Section, we highlight technological capabilities of East Asian nations and that of Japan. In Section 4, we present an extensive and elaborate overview of innovation policies and enterprise development in India. Against the policy framework described in Section 4, in Section 5 we closely examine the Indian scenario with respect to technological capability of its industry and draw suggestive international comparisons. Section 6 explores the existing bottlenecks in India's and national innovation system and discusses the new initiatives undertaken by the government in that direction. Section 7 presents case studies of technological interventions in two traditional industry clusters in India. Section 8presents our concluding remarks.

2. Scope of Technology Policy

Traditionally, R&D policies have been one of the most prominent public policy instruments and their scope has so far been defined around government's role in promoting R&D. In developing countries and in some of the newly industrialised nations, governments have also been sincere about adopting policies that ensure technology acquisition, adaptation and catch-up. The core economic logic guiding policy starts with market failure in knowledge creation necessitating government funding of R&D in the first place and typically ends in arguments around competitiveness in so far as the firm level technological capabilities are concerned. More recently, public policy in this area has been directed towards linking various agents who individually or jointly share responsibilities of identifying and conceiving technological problems and engage in developing technological solutions.

Governments' funding of S&T infrastructure and basic research is based on the fact that knowledge creation is vulnerable to market failure due to public good characteristics of knowledge outcomes. Knowledge has attributes like non-rivalry in consumption and non-excludability upon supply which leads to free rider problems and reduces private incentives for create knowledge. Hence, there would be socially sub-optimum supply of knowledge if knowledge creation is left to market forces. This calls for government intervention in knowledge creation.

However, technology policies are meant to address more complex technical sources of market failure.[3] Technology embodies applicable knowledge that arises out of scientific research. Naturally beyond public good characters of underlying knowledge, technologies generate production externalities. Markets provide inadequate incentives for technological innovations given that there are externalities of knowledge production, and efficient pricing reflecting full benefits associated with the use of innovation outcomes may not be possible. Even as government patronage of basic research is considered a ‘subsidy’ to ensure socially optimal levels of basic research in the presence of externalities, this may not straightaway solve similar problems at advanced stages of technology development (which is mostly undertaken by the industry). There is however a caveat! In suggesting public good characters of knowledge and free-riding one readily accepts that knowledge spillovers and learning are costless. But firm level learning and assimilation of knowledge turns out to be costly and at the same time R&D driven. Therefore, private/industry incentive to invest in R&D could be significantly motivated by long term goals of learning and may not be restricted to possible opportunities of commercial exploitation of innovation outcomes. Hence, policies affecting firm level technological learning are of great importance in developing countries.

It is also known that inputs required for knowledge production often come as indivisible units like laboratories, industrial plants and pool of knowledge workers entailing prohibitively large fixed costs for a private investor. Moreover, with sunken costs of large magnitudes borne by the original creator, the relative costs of producing marginal units of knowledge at a so-called production unit may be small. Hence any form of marginal cost pricing would be untenable in the face of lower revenue and inability to recuperate initial fixed costs. And finally, investing in research, knowledge creation and technology generation might be looked upon as a risky business proposition given inherent uncertainties.[4] Risk-funding form established financial institutions, venture capital funds, and generous funding from non-commercial sources try to address this issue.

The Schumpeterian hypothesis that large firms with significant market power are more likely to innovate has been inconclusively testified.[5] However, when chances of imitation are limited competition provides the best incentives for innovation and technology generation.[6] Intellectual Property Rights (IPR) on knowledge outcomes, i.e. patents, arguably generate incentives for investment in knowledge creation by enhancing chances of appropriability of innovation outcomes.[7] However, IPRs by their very principle encourage monopoly on knowledge outcomes and can bring down overall incentives for innovation.[8] This captures the dilemma of competition and anti-trust policies that are meant to strike a balance between these two kinds of incentives.

We also note that the concept of technology policy is being replaced with that of innovation policy. This may be because of the following reasons. First of all, while technology policy is based on mitigating market failures in knowledge it inadequately focuses on the direction of technical change. Rosenberg (1969) points out that the choice of the direction in which a firm actually goes in exploring for new techniques might not be solely dictated by economic incentives of technical change captured in cost saving choice of technologies. Secondly, it is now widely recognised that variables such as firm size, market power, and potential for innovation are endogenous variables within systems in which the most important factors determining overall economic outcomes are technology, institutions, demand, strategic considerations, and randomness.[9] Thirdly, the formal R&D is only one form of technological effort: production engineering, quality control, trouble-shooting and even shop-floor experience are all possible sources of technical change.[10] Technological capability and export performance of developing country firms are largely determined by minor innovations achieved through production engineering and reverse engineering. Fourthly, behavioural (evolutionary) approach to technological change emphasises on channels of knowledge spillovers, importance of R&D efforts in initiating technological learning and the diversity in the process of discovery of technological opportunities. Fifthly, it has been observed that prospect of innovation is seriously curtailed in the absence of an innovation system that connects various actors like government, private businesses and R&D institutions. This led to the innovation system approach which we discuss in detail in the folowing section III. Finally, more recent innovation paradigms have recognised innovation prospects outside formal R&D facilities – in frugal and need-based innovations and community based learning.

3. Understanding the National Innovation System (NIS)

3.1 The NIS Approach[11]

The National Innovation System approach that was first floated in the 1980s has influenced academic thinking in the area of innovation studies in the following decades (Freeman 1987, Lundvall 1992, Nelson 1993, Patel and Pavitt 1994, and Metcalfe 1995). This approach goes beyond market failures to address bottlenecks in terms of systemic failures arising out of complexity in the forms of interaction between diverse players involved in the process of innovation. The innovation system is defined as ".. that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies" (Metcalfe 1995). The problem of market failure, necessity of enriching the knowledge base and the ultimate goal of ensuring that society benefits from innovations calls for a set of institution and policies for the generation and dissemination of technology. Such institutions define an innovation system involving both the public and the private sectors.

OECD (1997) identifies four kinds of information and knowledge exchange that form the bedrock of an innovation system.

1. interactions among enterprises, primarily joint research activities and other technical collaborations;

2. interactions among enterprises, universities and public research institutes, including joint research, co-patenting, co-publications and more informal linkages;
3. diffusion of knowledge and technology to enterprises, including adoption rates of new technologies by the industry and diffusion through machinery and equipment; and
4. personnel mobility, focusing on the movement of technical personnel within and between the public and private sectors.

Evidence suggests that attempts to integrate these processes with firm performance result in high levels of technical collaboration, technology diffusion and personnel mobility that contribute to improved innovative capacity of enterprises in terms of products, patents and productivity.

Experience of most countries, including OECD members, shows that public sector entities engage in both basic and applied research. These entities make significant contribution in basic research since the problem of market failure is more pronounced in case of basic research. Although defence and space programmes are funded almost wholly by governments, they have significant spillover effects for other areas like airplane, computers, modern semiconductors, etc., that are primarily promoted by the private sector. Further, technologies developed by universities and research institutes may be licensed to the industry for commercial application. On several instances, technologies have been developed jointly by the university and the industry through collaborative research. The interface between the industry and universities (and also public funded research institutes) enables the latter to identify technologies that have commercial value.[12]

The innovation system approach establishes a close relation between academic research and industrial growth. In the United States (US), university science and engineering and the science based industries grew up together. Chemistry took hold as an academic field at about the same time that chemists began to play an important role in the industry. The rise of university research and teaching in the field of electricity occurred as the electrical equipment industry began to flourish in the US. On both cases, academic research provided the industry with new knowledge about process and products and also with technical people. However, this situation is dynamic and not static. Academic research in chemistry and engineering over the years became less important as a source of knowledge for the industry. These were replaced by biology related fields and computer sciences where academic research undertaken at the universities provided new ideas to the industry.

The private sector plays a central role in the innovation system. It has its own mechanism of identifying prospective technologies that need to be developed, invests to develop those technologies and adopts market strategies for their commercialisation. Importantly, these processes are not done in isolation. They involve interaction with other firms, with the public sector institutions and also with the market. In such a framework, market provides the necessary information that leads to new concepts. Interestingly, in the case of Japan, the system approach promoted by the erstwhile Ministry of International Trade and Industry (MITI) enabled creative reverse engineering by implementing measures to facilitate effective dialogue between the firm responsible for assembling and marketing a final product and numerous suppliers of intermediate inputs like components, castings, materials, sub-assemblies, etc.

Finally, human capital arguably forms the main pillar of an innovation system. Scientists and engineers are the ones who implement new concepts and strive towards new technologies. Needless to mention, education system ensures a functioning innovation system by providing quality human capital. Therefore, an innovation system is supported by the overall education system as well. Japanese system of industrial training is an example of bringing education and training close to the innovation system. Industrial training was implemented to enhance prospects of product and process innovations. The aim was to acquaint workers with the problems that are likely to arise and give them thorough understanding of firm operations.

3.2 Technological Capability of Nations: Japan and East Asia

Early industrialisation created technological leaders in the west. The large constituency of developing countries elsewhere only had the option of maturing through technological learning.[13] Technological learning has been concerted, broad-based and effective across sectors not only for the Newly Industrialised Countries (NICs) in East Asia, but also for Japan in the initial phases. When Japan was in the process of catching up with the advanced west, it made deliberate attempts to forge such synergies very much in the spirit of what we call innovation systems today. MITI orchestrated the innovation system.[14] However, the most noticeable feature in the Japanese innovation system was its strength in technological forecasting. According to Freeman (1987) Japan was not amongst the original contributors to radical innovations. However, the Japanese technological forecasting system achieved expertise in forecasting the elements of emerging ICT paradigm earlier than elsewhere and this enabled Japanese firms to exploit the potential of the new paradigm in such areas as robotics, computer numerically controlled (CNC) machine tools and flexible manufacturing systems (FMS) more rapidly than anyone else (Freeman 1987). In the Korean case we observe that the government was instrumental in promoting several models of public-private partnership where adequate emphasis was laid on linking the technological demand of the private sector with the R&D activities of the public sector.

We note that technological learning differed in a fundamental way between East Asia and South East Asia. While in the case of East Asia it was driven by original equipment manufacture for foreign companies located abroad, in South-East Asia the process was primarily driven by transnational corporations. Nevertheless, despite structural problems, both approaches contributed significantly to industrial innovation and national economic growth (Hobday 2000). Thereafter, East Asia developed along unique technological and learning trajectories dictated by international production networks.[15]

Finally, innovation system adopted in some of these countries and primarily in Japan, has been target oriented with significant commitment towards using science and technology for improving quality of life for its citizens. Such commitments have been religiously followed and renewed. The case in point is Japan's latest S&T Basic Plan which sets targets along four areas: reconstruction and revival from the great Japan earthquake; promoting green innovations; promoting life innovations; and reforming the innovation system towards promoting science, technology and innovation.

4. Innovation Policies and Enterprise Development in India

After India's independence from colonial rule in 1947, nation builders and policy makers saw merit not only in large-scale industrialisation promoted by the state but also in parallel development of S&T infrastructure under state patronage. Not much was expected from the private sector at that juncture in either of the areas given paucity of resource in terms of capital, entrepreneurial and intellectual base.[16] While separately industrial policy resolutions and S&T policy statements were formulated to guide industrial development and S&T endeavours in the country, overall direction and resource allocation came from the Five Year Plans. The topmost priority underlying all policy measures was to demonstrate India's ability to produce manufactured commodities across sectors to meet immediate needs, build a robust S&T infrastructure and create a high-skilled manpower base. While, the entire model of industrial planning gave only secondary credence to laws of comparative advantage, S&T policies stressed exclusively on cultivation of science and scientific research in all its aspects – pure, applied, and educational. S&T policies explicitly addressing innovation concerns linked to enterprise development in the private sector have not been in focus in India, until in the recent decades. In this section, we discuss the policy framework that constitute India's five year plans and S&T policy making to ascertain the link between innovation policy making and enterprise development in India.

We choose to distinguish between the following time periods: 1) pre-1980s, when India achieved significant technological learning in the industry (both public and private) while scientific research was undertaken solely by public funded institutions; 2) the decade of 1980s itself when there was a perceived urgency for technological self-reliance although with continued focus on the public sector; 3) post economic liberalisation (1990 and thereafter) which meant primacy of private sector efforts however, with very elusive links with S&T policies; and 4) the decade of 2000s and beyond when innovation policies towards enterprise development gained more importance over standalone S&T policies.

4.1 Pre-1980s: The Era of Central Planning

The Scientific Policy Resolution of 1958 captured the vision and aspirations of a newly independent state and clearly highlighted the importance of intense cultivation of science on a large scale, and its application to meet the country's requirements. Science and technology, it was stated, can make up for deficiencies in raw materials by providing substitutes, or, indeed, by providing skills which can be exported in return for raw materials.[17] The government accordingly sought to foster, promote, and sustain scientific research in general, to secure for the people of the country all benefits that can accrue from the acquisition and application of scientific knowledge. The ultimate goal was to ensure adequate supply, within the country, of research scientists of the highest quality and to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge (see Box 1 for details).

Box 1: Aims of Scientific Policy

To foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects - pure, applied, and educational;

To ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognise their work as an important component of the strength of the nation;

To encourage, and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry, and defence;

To ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;

To encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom;

To secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

Source: Scientific Policy Resolution 1958, paragraph 7.

Review of India's Five Year Plans shows that innovation infrastructure and milieu had been built up in phases. The First Five Year Plan (1951-56) took up the task of building national laboratories and research institutions primarily under the Council for Scientific and Industrial Research (CSIR). The Second Plan (1956-61) promoted more broad-based scientific research and therefore research facilities were extended to universities and other research centres. The period under these two Plans witnessed establishment of new technological universities (the Indian Institute of Technology – the IITs) for higher education and research in engineering. Infrastructure at existing institutions of high repute like the Indian Institute of Science was simultaneously expanded. Interestingly, in both these Plans and in some others that would follow detailed proposals were drawn up to prioritise public investment in S&T and education. Each of these Plans documented comprehensive account of outcomes of all initiatives by various scientific departments of the government as is expected under a strict regime of centralised planning.

Under S&T, the Third Plan (1961-66) specifically focused on promoting research *per se*, both basic and applied (through the network of S&T institutions and institutions of higher learning). This Plan laid special emphasis on agriculture, atomic energy and engineering research and for the first time sought to streamline commercial application of research outputs. It also, for the first time, laid adequate emphasis on quality control, standardisation and productivity in the industry. Although, the Fourth Plan (1969-74) reiterated and promoted commitments laid out in the earlier Plans, the Fifth Five Year Plan (1974-79) took a sectoral approach, which was somewhat a departure from earlier Plan approaches. This was done to effectively follow up on Plan priorities and ensure interaction between research agencies and facilitate technology transfer.

In the intervening period, India took course to institutional changes in the IPR regime (Indian Patent Act of 1970) by allowing for no more than process patenting in areas of pharmaceuticals and agro-chemicals and shortening of life of patents for pharmaceuticals. Such institutional change paved the way for vigorous technological learning and process revolution in the Indian pharmaceutical industry (mostly private sector enterprises). This went a long way in facilitating a large pharmaceutical industry in India specialising in production of cheap generic drugs. Although, India switched to TRIPS compatible product patent regime in 2005, Indian pharmaceutical industry continues to rely extensively on generic production of off patent drugs.

4.2 The 1980s: The Era of Piecemeal Economic Reforms

By the time the second Science and Technology Policy was introduced in 1983 almost three decades after the first one, realities had greatly changed. Despite significant achievements in acquiring technological capabilities across scientific fields, visible impact of S&T on national competitiveness had perceivably faltered. Poverty remained a national burden. Against this backdrop, a detailed Technology Policy Statement was adopted in 1983 that placed technological self-reliance at the heart of indigenous technological paradigm. In fact, this policy underscored the need for contextualising choice of technology according to economic and social priorities. This was elaborated in terms of a noble resolve to achieve swift and tangible improvement among the weakest sections of the population and speedy development of backward regions. There were other areas of emphasis including technology forecast, employment, mass production, utilisation of traditional skills and environmental sustainability. Nevertheless, economic considerations of self-reliance through indigenous technology development within the framework of an interventionist, protectionist and inward looking policy regime remained the cornerstone.

The decade of 1980s coincided with the Sixth (1980-85) and the Seventh (1985-90) Five Year Plans that largely followed the paradigm of 'self-reliance' as stated in the 1983 Technology Policy Statement. Technological self-reliance also meant scouting of technological opportunities and sourcing of technologies from abroad. This was proposed to be implemented through a comprehensive process of technology assessment, development, acquisition, absorption, utilisation and diffusion. Although, industry was encouraged to undertake capability building and reverse engineering, import substitution was implemented with rigor. Technology import and FDI were heavily restricted with a very narrow window for clearances subject to determination of appropriateness, suitability and unavailability. On the other hand, for the first time, it was proposed that the government should offer appropriate fiscal incentives to promote indigenous technology development apart from direct public funding of R&D. Fiscal incentives to undertake R&D activities in the form of tax breaks and exemptions fall under Industrial R&D Promotion Programme (IRDPP) overseen by the Department of Scientific and Industrial Research (DSIR) under the Ministry of Science and Technology. Not surprisingly, till the early 1990s which marks the era of reforms and liberalisation of economic policies in India, these incentives were primarily restricted to promoting technology generation in public sector laboratories and institutions. In the Box 2 we present the existing provisions under fiscal incentives in terms of tax reliefs and custom duty exemptions. Income tax relief on R&D expenditure is allowed for Scientific and Industrial Research Organisations (SIROs) in the areas of medical, agriculture, natural and applied sciences as well as social sciences recognised by the DSIR. [18]

The number of in-house R&D units (SIROs) recognised by DSIR increased steadily from about 100 in 1973 to over 700 in 1980, over 1100 in 1990 and thereafter hovering between 1200 and 1250. In 2010 the number was around 1350 and by the end of 2011 the number rose to 1618. Of these, nearly 1480 are in the private sector and the rest in public/joint sector.[19] The in-house R&D units in the industry are expected to undertake R&D activities according to their business requirements such as development of new technologies, design and engineering, process/product/design improvements, developing new methods of analyzing and testing, research for increased efficiency in use of resources such as capital equipment, materials and energy, pollution control, effluent treatment and recycling of waste products. These activities are distinct from routine production and quality control and involve dedicated staff and management.

Box 2: A Short Description of Fiscal Incentives for R&D in India

The present structure of Tax Breaks may be listed as:[20]

1. Super deductions: Weighted income tax deduction of 200 per cent till 31.03.2017 for all expenditure incurred on scientific research (excluding expenditure on land and buildings).[21] This is extended to sponsored research programmes undertaken by the industry in collaboration with national laboratories, universities and institutes.
2. Tax holiday: Companies in the commercial R&D sector, approved by the DSIR before 31 March 2007 are eligible for 10 years of tax holiday.
3. Write-offs: Industrial units also enjoy 100 per cent write-off on all revenue and capital expenditure towards R&D.
4. Depreciation allowance: Accelerated depreciation allowance is allowed on plant and machinery set up using indigenous technology.

The second form of fiscal incentive refers to exemptions on custom duty for technology import. Encouraging technology imports through such mechanisms is considered crucial for capacity building and in-house R&D and conforms to norms of free trade. Accordingly, SIROs in the area of medical, agriculture, natural and applied sciences and social sciences recognised by the DSIR that are eligible for tax concessions are also eligible for custom and excise duty exemption. Further, excise duty waiver applies to production of indigenous technology based goods.[22] The pharmaceutical and biotechnology sectors enjoy special privileges in this regard. These sectors are eligible for duty free import of specific items (comprising analytical and specialty equipment) and pharmaceutical reference standards required for R&D.

Source: Authors' compilation.

4.3 Post-1991: The Era of Economic Liberalisation

We note that, since the Eighth Five Year Plan (1992-97) onwards policy making in the S&T sector has been linked to the overall economic policy framework of international integration with policy changes favouring industrial R&D, identification of technology needs and technology development.[23] During the later Plans (Ninth, Tenth and Eleventh Plan periods between 1997 and 2012) greater emphasis was laid on promotion of basic research, interface between public institutions and private industry, priority sectors, social needs, international collaborations and strengthening of human capital.

Over this period there are several instances where the scientific departments like the DST and the DSIR have been proactive in collaborating with the industry on public-private partnerships in an effort to incentivise the private industry towards R&D through shared costs and rewards. Such PPPs are common for projects with significant basic research component characterised by high investment, high risk and uncertainty. PPP in risky projects also reduces moral hazard problems given joint involvement and shared rewards.[24] The DST launched the Drugs and Pharmaceuticals Research Programme (DPRP) in 1994 that supports setting up of facilities for research including industry-institute joint research projects (on equal sharing basis) in all systems of medicines. Although research undertaken by the industry has to be fully funded by them, research projects initiated at the institutes has to be jointly funded by the government and the industry. Further, government bears all capital expenditure and takes up a major share of all recurring expenditures. There are also provisions for soft loans of up to 70 per cent of the project cost at the industry end and grant-in-aid for clinical trials in therapeutics meant for neglected diseases. The New Millennium Indian Technology Leadership Initiative (NMITLI) was promoted by the CSIR (under DSIR) in the year 2000 and is regarded as the largest public-private-partnership for R&D in India. The innovative feature of this programme is that it provides financial support to all players. The financial support is in the form of grant-in-aid to the institutional partner in the public sector and as soft loan for the partner industry with manufacturing base in India.

The Technology Development Board (TDB) established in 1996 after the adoption of Technology Development Board Act, 1995 assists firms that develop and commercialise indigenous technology or adapt imported technology for wider domestic applications. Assistance is implemented by way of soft loan or contribution towards equity capital. TDB has recently joined hands with two major private equity investors to invest in equities of start-up companies. There are some instances where the government and the private players have engaged in more target oriented projects by collaborating through consortiums. The Collaborative Automotive Research (CAR) by Technology Information, Forecasting, and Assessment Council (TIFAC-DST) is an example. The programme has been successful in bringing together different stakeholders and nucleating several R&D projects in a consortia mode.[25]

4.4 2000 and Beyond

After 1983, the later S&T Policy Statements have been adopted only in the last decade and exactly within a span of ten years – one in 2003 and the latest being in 2013. Obviously, these policy frameworks have been adopted in scenarios when India's emergence as a fast-growing and large economy based on contributions from some of the knowledge intensive sectors had been confirmed. The 2003 policy emphasised on the need to ensure synergy between scientific research and industry, provide platforms for translation of industrially relevant knowledge outcomes and it was expected that industry would be more engaged in R&D activities. While Science and Technology Policy 2003 intended to bring in a second wave of strengthening of science similar in spirit to the Scientific Policy Resolution of 1958, the very recent Science, Technology and Innovation (STI) Policy 2013 mulls over significant paradigmatic shifts to achieve innovations at all levels. The Eleventh Plan had also highlighted the urgency to put in place institutional mechanisms that may support an innovation ecosystem linking the public and the private and leverage innovation prospects in the SMEs.

The sector contributes nearly 45 per cent of all manufacturing output in India and makes up for 40 per cent of related exports. Accordingly, government support for innovations towards enterprise development is being implemented through multiple channels: a) risk-funding, entrepreneurship development and incubation; b) cluster based approach for SMEs; c) information and management support; and d) Informal and open source innovations.

4.4.1 Risk-funding, entrepreneurship development and incubation

We understand that fiscal incentives towards innovations and enterprise development might take the form of risk-funding for early stage projects for technology generation. This is crucial for bridging gaps in innovation life cycle, particularly when a nascent technological idea is being developed as a proof-of-concept that is expected to demonstrate its commercial and technological feasibility. This involves risk-taking and government assistance is called for to encourage private players.

A number of programmes were initiated by the different scientific departments of the Government of India to support the small enterprises:

1. The Small Business Innovation Research Initiative (SBIRI) launched by the Department of Biotechnology (DBT) in 2005 supports early stage, pre-proof-of-concept research in biotechnology by the industry, and late stage development and commercialisation of new indigenous technologies particularly those linked to societal needs in healthcare, food and nutrition, agriculture and other sectors.[26]
2. Technopreneur Promotion Programme – TePP (promoted by DSIR)[27] supports individual innovators. The programme entails development of an original idea/invention/know-how into working prototype/process and promotes novel delivery models to take S&T innovations to rural India.

3. The TIFAC-SIDBI[28] Revolving Fund for Technology Innovation Programme (SRIJAN) was launched by TIFAC in 2010, as a joint TIFAC-SIDBI Technology Innovation initiative. Under the scheme, TIFAC set up a revolving corpus with Small Industries Development Bank of India (SIDBI) to fund industries particularly the Micro Small and Medium Enterprises (MSME) for scaling up and commercialisation of novel products and processes. This policy is expected to encourage and promote innovation capabilities in emerging technology areas and usher new business opportunities.
4. Under Technology Development and Demonstration Programme (TDDP) the DSIR provides partial financial support towards prototype development, cost of pilot plant, cost of equipment, test and evaluation of products, user trials, etc.

Closely linked to risk-funding for technology generation is government policy for technology led entrepreneurship development. Technology Business Incubator (TBI) is a programme of the National Science & Technology Entrepreneurship Development Board (NSTEDB) under the DST for fostering innovative and knowledge based start-ups (including university start-ups). This programme provides specialised support services like early stage financing and networking among stakeholders. The TBI programme provides seed fund to incubators. The basic idea of providing seed fund is to equip a TBI with much needed early stage financial assistance for ideas/ technologies under incubation. This would enable some of these innovative ideas/technologies to graduate to an appropriate level and qualify for regular commercial borrowing and venture capital. Interestingly, the NSTEDB had launched the Science and Technology Entrepreneurship Development (STED) project much earlier to support innovative activities in small sized firms in industrially backward regions.

The government assistance for stages involving marketing of new technology based products is also implemented in some cases. The Technology Refinement and Marketing Programme (TREMAP) is one such programme. In 2009, TIFAC (DST) initiated Technology Refinement and Marketing Programme (TREMAP), to facilitate commercialisation and marketing of technologies through a network of Technology Commercialisation Facilitators (TCFs) and create an enabling ecosystem for such activities.

4.2.2 Cluster Based Approach for SMEs

The National Innovation Council (NInC), a first of its kind effort, which is still serving its term, has aimed at facilitating and nurturing innovation ecosystems in industry clusters including those in the traditional sectors. The primary objective is to establish such mechanisms like Cluster Innovation Centres (CICs) which would provide a platform for exchange of knowledge and learning among workers, entrepreneurs, exporters, public funded S&T institutions, government agencies, etc. An established mechanism of this nature would significantly augment prospects of technology adoption and ensure speedy diffusion. However, this project by NInC is still in its pilot phase.

The Ministry of Micro, Small and Medium Enterprises has also adopted cluster development approach as its key strategy for enhancing the productivity, competitiveness and capacity of Micro and Small Enterprises (MSEs). Clustering of units enables agencies including banks to provide services at lower physical and transaction costs. This in turn ensures improved availability of these services for enterprises in this sector. The flagship scheme is the Micro & Small Enterprises – Cluster Development Programme (MSE-CDP) which was launched in October 2007. The objective of the scheme was to support growth and sustainability of MSEs by addressing common issues such as improvement of technology, skills and quality, market access, access to capital, etc. and to set up common facility centres (for testing, training centre, raw material depot, effluent treatment, complementing production processes, etc). The scope of the scheme includes diagnostic studies, technology acquisition, facilitating the transfer of technology from producer to end user and R&D. Financial instruments under this scheme involves substantial support in the form of grant-in-aid and soft-loans. Other schemes include Credit Link Capital Subsidy Scheme for Technology Upgradation that provides capital subsidy up to a certain level on institutional finance availed by individual units for acquiring new technologies.

The government support is also provided for entrepreneurial and managerial development in the SME sector with thrust on capacity building for tooling, training, intellectual property protection and technology upgradation and quality certification.[29] These supports are based on the premise of helping firms in this sector to gain competitive edge in the face of market competition not only from global companies but also from established domestic businesses.

4.4.3 Information and Management Support

The industry and individual entrepreneur/innovators are also expected to benefit from some of the other schemes and programmes promoted by the government. The scope and mandate of such programmes cover diverse areas of capacity building, information support, marketing support, managerial and consultancy support, and technology based entrepreneurship development among women.

The International Technology Transfer Programme (ITTP) supports transfer of technologies, projects and services from India with a view to enhance the reach of Indian industry beyond the national boundaries. At the same time it also promotes transfer of technologies from other countries to India to enhance the technology export capability of the Indian industry. The very recent (March 2013) Patent Acquisition and Collaborative Research and Technology

Development (PACE) programme seeks to support Indian firms to acquire patented technology at an early stage from within the country or overseas on an exclusive or non-exclusive basis, add value to the acquired technology (either independently or in collaboration with a public funded research institutions in India or abroad) and develop "Made in India" products of international standards in the category of socially relevant products meant for public consumption.

The Technology Management Programme (TMP) of the DSIR works in close association with the industry, industry associations, research organisations, academic institutes, state level agencies and government organisations, consultancy organisations and other government departments towards enhancing technology management capability of a wide spectrum of institutions. Similarly, the Consultancy Promotion Programme (CPP) under DSIR; with the Consultancy Development Centre as its nodal agency aims to strengthen and promote consultancy services in various areas including acquisition/import of technologies – requiring technological and managerial competence to evaluate those technologies and adapt them as per local conditions. This also covers consultancy services for export of technologies and setting up of joint ventures abroad.

The Technology Information Facilitation Programme (TIF) is one of the components of Technology Promotion, Development and Utilisation (TPDU) Programme of the DSIR. The broad objective of the programme is to create endogenous capabilities for the development and utilisation of digital information resources, provide inputs to S&T research and promote industrial development. The Technology Development and Utilisation Programme for Women (TDUPW) is aimed at promoting adoption of new technologies by women and technological upgradation of tiny, small and medium enterprises run by women entrepreneurs.

4.4.4 Informal and Open Source Innovations

Innovators in the informal sector usually lack adequate financial resources. This possibly promotes frugal innovations, those that often fill technological gaps between need and supply. Moreover with the given resource constraints, on most occasions such innovators are unable to scale up production and/or market their innovation. Commercial loans are not available for want of a guarantor or collateral. Although, in some cases ideas are developed into prototypes, those cannot be further pursued for commercial production. The National Innovation Foundation (NIF) under the DST created a dedicated risk fund for such innovators – the Micro Venture and Innovation Fund (MVIF) with the support of SIDBI in October 2003.[30] Under the scheme, support from the MVIF is made available for technology commercialisation subject to assessment of business prospects of innovators and entrepreneurs who are associated with NIF.

Finally, the Open Source Drug Discovery (OSDD) is a CSIR-led consortium with global partnership that aims at providing affordable healthcare to the developing world through a platform of global collaboration to solve complex problems associated with discovering novel therapies for neglected tropical diseases like malaria, tuberculosis, leshmaniasis, etc. The OSDD is a translational platform for drug discovery, bringing together scientists, contract research organisations, doctors, hospitals and other agents who are committed to introduce affordable therapeutics.

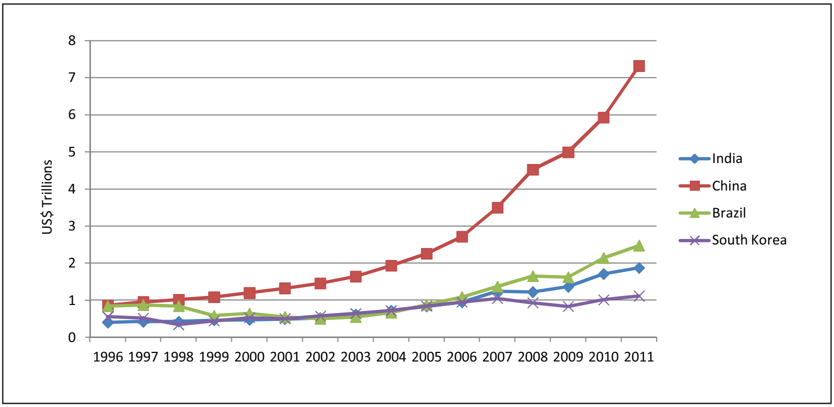
5. Technological Capability and Industrial Competitiveness: International Comparison and the Indian Scenario

5.1 International Comparison

India enjoys emerging economy status characterised by rapid income growth and technological development with mature institutions and policy environment that tend to be oriented towards long-term economic development.[31] We compare select parameters like GDP growth, R&D intensity, resident patent filing and technology exports for countries like China, Brazil and South Korea with that of India to motivate our assessment of technological capability and competitiveness of the Indian industry. We note that such comparison of broad parameters may not comprehensively reflect industrialisation, technology generation and learning trajectories in these countries, yet would go some way in placing India in context. Moreover, the choice of comparable countries is not altogether random. While China exudes exuberance of income growth and technology lead industrialisation spectacular among developing countries we feel it may be appropriate to compare India with a Newly Industrialised Country of East Asia namely South Korea and an emerging economy peer, i.e. Brazil. All the four countries are fast growing open economies. While, South Korea has been an early member of the NIC-East Asia Club, by all estimates, China lies much ahead of the others in terms of FDI and trade.

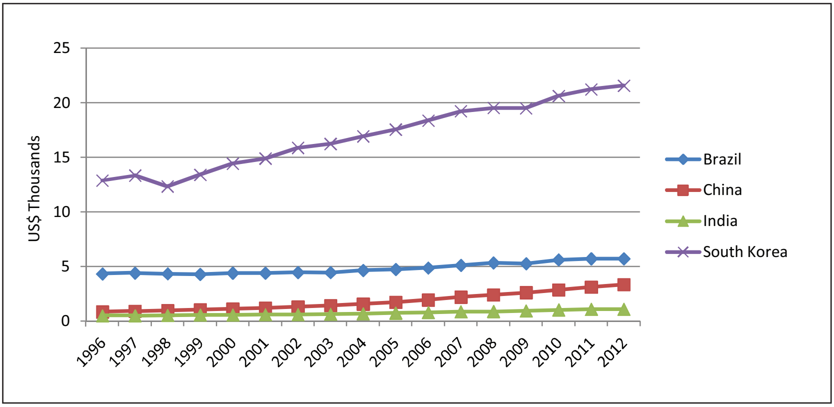
The Figures (1, 2, 3, 4 and 5) present time series of GDP, per capita real GDP, R&D intensity at the macro level, patent application by residents and value of high technology exports for India, China, Brazil and South Korea for a period between 1996 and 2011. Although we do not have information for some countries for specific years, data series are continuous between series endpoints. India presently stands to be a near 2 trillion dollar economy ahead of South Korea. Brazil has a larger economy than India in nominal GDP, however, modest to the extent that it is less than half the size of China (see Figure 1). For developing countries, size of the economy per se may not indicate the level and stage of development. Therefore, we take into account per capita real GDP for these countries as well (see Figure 2). We find that India has the minimum per capita real GDP behind China and Brazil. South Korea, as one of the Newly Industrialised Countries of Asia, of course, has a much higher per capita real GDP than the remaining three.

Figure 1: GDP at Current US$



Sources: World Bank national accounts data, and OECD National Accounts data files.

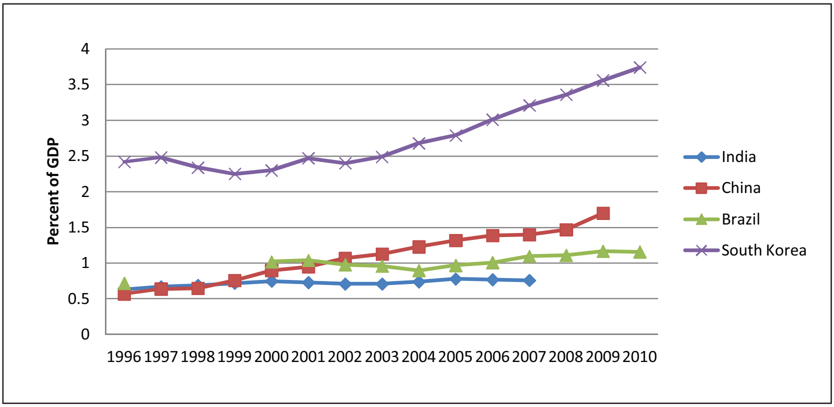
Figure 2: Per capita real GDP in US$



Sources: World Bank national accounts data, and OECD National Accounts data files.

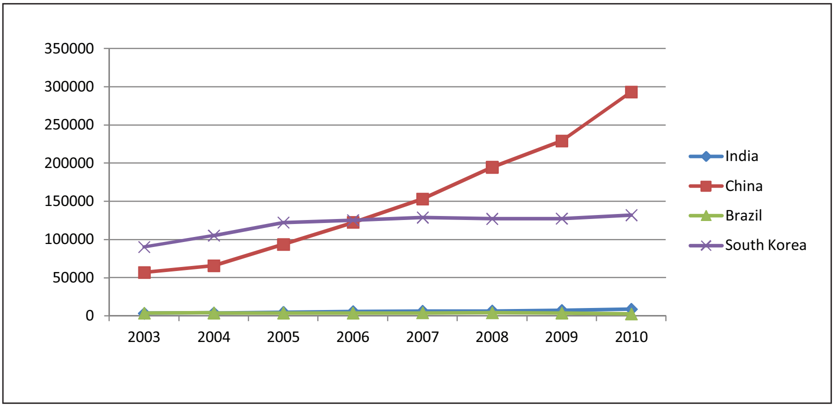
Talking of technological capability one is compelled to look at R&D expenditures at the national level. R&D expenditure in India continues to be less than 1 per cent share of GDP, lagging significantly behind the other three countries. South Korea however, tops the four with a R&D intensity of over 3.5 per cent (see Figure 3). We further note that patent applications by residents gives a measure of innovation outcomes specific to a country and effectively portray indigenous innovation potential in terms of commercially applicable knowledge. Figure 4 gives an account of the trends in patent applications by residents for Brazil, China, India and South Korea.[32]

Figure 3: R&D Intensity



Sources: United Nations Educational, Scientific, and Cultural Organisation (UNESCO) Institute for Statistics.

Figure 4: Patent Application by Residents

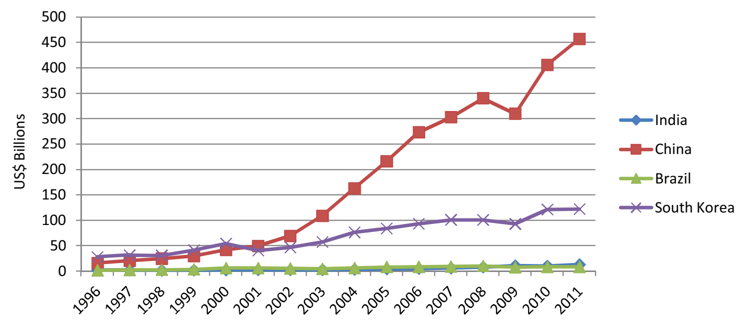


Sources: World Intellectual Property Organisation (WIPO), World Intellectual Property Indicators and www.wipo.int/econ_stat.

We observe that patent application by residents in China is stupendously high and South Korea comes a distant second. Growth in patent applications by residents in China have risen inexplicably fast since 2004. For South Korea which undertakes considerable R&D, patent application by residents has stagnated over the recent years. Although India lies slightly ahead of Brazil in terms of patent applications by residents, none is close to South Korea. We are aware that given the stark variation among these countries in terms of their population, aggregate figures on patenting needs adequate controlling for the size of the population. Reliable estimates in this regard that could better serve the purpose of such comparison, however, are presently unavailable. Nevertheless, the average size of S&T personnel may be a close indicator for comparing the labour input for S&T. According to the UNESCO estimates, between 2000 and 2005 the number of researchers in R&D per million people rose from 110 to 136 in India, from 548 to 856 in China, from 424 to 588 in Brazil and from 2357 to 3822 in South Korea (figures rounded off to nearest integer values). Again, India has the minimum average pool of R&D personnel.

In order to explore technological depth in industrial production for each of these four countries we look at the value of high technology exports. According to the data source i.e. the World Bank, the high-technology exports are products with high firm level R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery, etc. Figure 5 shows that China has surpassed 450 billion US dollars worth of high technology exports. South Korea, which has been one of the Asian tigers and had initiated equipment manufacturing and electronics industry much before China falls behind. One is again struck by the pace of Chinese progress – even a decade back South Korea was ahead of China in high-technology exports. Clearly, both Brazil and India are yet to catch up in high technology exports. Over the same period (1996-2011), China increased its share of high technology exports in total manufactured exports from 12 per cent in 1996 to 26 per cent in 2011. For South Korea this share remained more or less constant at around one fourth of the total manufactured exports. Although Brazil registered an increase on this count (from 6 per cent share to 10 per cent share), for India the share remained constant at 7 per cent at endpoints (1996 and 2011). Finally, a closer look into performance of these economies in terms of export of ICT services may be useful in ascertaining the promise that skills and technical knowledge hold for their economies. Accordingly, we find (as accessed from the World Development Indicators), the share of exports of ICT services as a percentage of total service exports in 2011 are as follows – 61.5 per cent for India, 32.8 per cent for China, 52.9 per cent for Brazil and 20.4 per cent for South Korea. The fact that India appears to be better placed with regard to ICT services confirms its leading position in this area.

Figure 5: High Technology Exports (Current US$)



Source: United Nations, Comtrade database.

5.2 The Indian Scenario

India followed an inward-looking development strategy for long (till the 1980s) and industrialisation was implemented under regimes of protection, intervention and regulation. Naturally, prospects of technological progress in the Indian industry were heavily curtailed in the absence of competition and there was practically no incentive for technological upgradation in most industries. At the same time, compulsive obsession with self-reliance countered notions of comparative advantage and halted resource based specialisation of any kind in the Indian industry. As a result, India did not only fall behind Newly Industrialised Countries (NICs) of East Asia in mass manufacturing capabilities, but has also failed to demonstrate technology-led industrialisation in the long run.

However, Indian industry has been credited for significant technological learning through reverse engineering and shop floor trouble shooting in some of the knowledge intensive sectors. It is here that one is struck by the variety of learning trajectories that may exist in the process of technological catch-up. Ray and Bhaduri (2001) claim that in the Indian case, two of its technologically dynamic industries, viz. pharmaceuticals and electronics, experienced learning paths that were different from each other. Production engineering that resemble *know how* type of technological learning was crucial for electronics. However, in pharmaceuticals reverse engineering, i.e. *know-why* type of technological learning offered significant technological edge to the industry.[33] However, failure to ignite innovative temperament as a logical second step of moving ahead beyond shop-floor technological learning, imitative R&D and trouble-shooting has only prompted some new ways of thinking and broadening of innovation perceptions in the last decade. As described above, there have been new efforts to put in place an innovation ecosystem to pre-empt wasting opportunities of broad-based innovations at all levels. Yet we argue that importance of technological innovations remain as strong as ever.

We note that Indian industry has been successful in acquiring R&D capabilities in knowledge intensive sectors like biotech, pharmaceuticals and ICT. Even here, India allegedly lacks creativity and, therefore, its proficiency in routine (and repetitive) tasks appears to be the only survival factor.[34] However, as described in Ray (2008) such repetitive tasks involve high-end skill and India has made a mark in such skill intensive protocols that drive knowledge based industries.[35] Overall, India's technological advantages include process, product and capital engineering in skill intensive industries such as auto-components, pharmaceuticals, forgings (both automotive and non-automotive sectors), power and transport machinery, some high-end electrical and electronics, medical equipment and specialty chemicals. Such advantages have emerged out of abundance of particular kinds of skills, established raw material bases concerning these industries, a mature supply base and a growing domestic demand.[36]

It has been suggested[37] that some key technologies of dual-use[38] nature may not be easily accessible, unless developed indigenously. Moreover, the National Manufacturing Policy (2011) has strongly argued in favour of a robust capital goods industry.[39] It is also expected that India would focus on some of the niche (like nanotechnology) and high-tech (like aeronautics) areas in order to move closer to the global technology frontier.[40] Under given realities of very limited research expenditure by the private sector such technology-led industrialisation targets seem implausible. Such visionary goals call for significant role of the private sector with efforts being made towards harnessing research capabilities of the public sector backed by clear policy directions from the government.

One perceives some new changes in India's innovation prospects with the advent of MNC-R&D centres. Such developments are indeed outcomes of conscious business strategy of relocation to take advantage of costs and skills. So far, ICT has been the mainstay of MNC-led R&D in India.[41] However, the impact of these R&D units on India's overall innovation performance is yet to be confirmed, since mere re-location and captive R&D may not necessarily spur innovations by domestic firms. We also note that a now matured domestic pharmaceutical industry has adopted a new business model where firms undertake contract manufacturing. However, patent yielding R&D projects are hardly outsourced to India, and most outsourcing takes place for clinical trials (Basant and Mani, 2012)

Finally, stagnant industrial sector in India (in terms of contribution to national income) and low technological value addition in industrial production pose a challenge of disproportionate magnitude. No wonder, the very recent Five Year Plan of the Government of India (Twelfth Five Year Plan 2012-2017) stresses on the urgent need to increase technological depth with focus on the level of domestic value addition in Indian industry to address national strategic requirements. We believe that the question of accelerating industrial development and enhancing technological depth therein is practically hinged on the level of innovation capabilities that India can acquire. Innovation ecosystem failing to address this is not desirable despite noble intentions.

6. Innovation Bottlenecks and New Initiatives

Foundation of a sound innovation system rests on appropriate coordination between the public and the private sector. However, university-industry interface in India has been rather ineffective despite efforts in that direction over the last couple of decades.[42] Although some of the premier universities and research institutions enjoy international repute, world rankings based on quality and impact of knowledge creation remains short of significance. The larger S&T set up including higher education suffers from chronic problems of heterogeneity both in terms of quality and infrastructure. It is commonly held that Indian industry is myopic and risk averse and is often sceptical of collaborations with academic institutions. On the other hand, academic scientists are criticised for having failed to understand the commercial and technical needs of the industry. This is also linked to India’s inability so far to nurture learning and innovation networks with participation from both the public and private sectors. Policy initiatives, however focused and well intended, have failed to forge synergies and coordination in this direction.[43]

During the previous and the present tenure of the incumbent union government one observes new efforts through commissioning of high level committees for formulating policies on a grand scale to attain comprehensive innovation goals. This breaks away from long adhered to norms of S&T Policy making solely at the behest of departments engaged in management of science and technology and higher education. Such developments suggest strong political economy considerations behind innovation policies in the present day context, given that the national constituency is sharply divided between the upwardly mobile sections of the society with high stakes in prospective innovation outcomes and the rest who await an innovation paradigm that could induce a transformation in favour of equity in access to technological solutions. Moreover, while India has been successful in churning out a high-skilled professional labour force, middle level skill base remains extremely weak and a high proportion of the workforce remains at the periphery, lacking meaningful education and skills. Fears run high that India's demographic dividend might soon be a liability if skill generation is not universal and broad-based. Much faster spread of primary and tertiary education is, therefore, invincible.

The National Knowledge Commission (2006-2009) devoted substantial attention towards identifying existing bottlenecks and chalk out a plan for an effective innovation ecosystem. To take its mandate forward the Commission focused on five key aspects of the knowledge conundrum: enhancing access to knowledge, reinvigorating institutions where knowledge is imparted, creating a world class environment for creation of knowledge, promoting applications of knowledge for sustained and inclusive growth and using knowledge for efficient delivery of public services. To our understanding, the topmost priority for NKC was to identify and recommend on deficiencies in skill generation, scientific education and knowledge creation. The other areas where the Commission came up with key recommendations pertain to information networks, intellectual property protection, innovation and entrepreneurship development. Indeed this process of finding a ‘way-out’ gained momentum with the National Knowledge Commission brainstorming on relevant issues and the existing scientific departments formulating polices and implementing schemes that strengthened the innovation ecosystem during the Eleventh Five Year Plan period.

India has attempted to incorporate some of the technical features of the innovation system approach into its policy making in the area of S&T. This is evident from the efforts made by the National Knowledge Commission (NKC) and now by the Department of Science and Technology (DST) to map the innovation landscape of India through Innovation surveys.[44] The NKC Survey (2007) came up with very interesting insights on innovation behaviour of Indian firms. It was found that ‘innovation intensity’ (i.e. the percentage of revenue derived from products/services which are less than three years old) increased over the first half of the last decade for both the large firms and the small and medium enterprises (SMEs,) with SMEs registering a greater increase in innovation intensity than large firms.[45] The DST pilot study indicates that significant innovation activity is underway at the firm level.[46]

The decade of 2010-2020 has been announced by the Government of India as the Decade of Innovations. The National Innovation Council (NInC) has been set up (which may be considered a sequel to the NKC) to help the country adopt a holistic innovation strategy to benefit all citizens and promote innovativeness at all levels. Its approach is multi-pronged and aims at creating inclusive innovation fund, industry innovation clusters, university innovation clusters, nurture innovation through education and create state and sector-specific innovation councils. The issue of inclusiveness is paramount, reflected in priorities such as connecting people and technology for innovation through rural broadband and implementing ICT interventions in policing and jurisprudence. Existing emphasis on grassroots innovations is proposed to be strengthened through new means of identification and support. The NInC has been promoting efforts towards digital information sharing platforms and knowledge networks of the most advanced kind within the country and with other countries across the globe.

7. Innovation and Enterprise Development in Clusters: An Indian Perspective

The origin of most traditional industries like textile, metal ware, pottery and handicrafts predates industrial revolution. Post-industrial revolution, factory modes of production have been pervasive in the developed world, even as some of the developing countries steadily promoted industrialisation. While the modern sector experienced innovation led productivity growth, traditional industries operated at low levels of productivity and value addition. Only select industries in the traditional sector attained some level of mechanisation, if at all. India is not an exception, rather legacy of a poor and a latecomer economy meant that most of its industries in the traditional sector continued to follow age old practices for a long time. NInC reports an estimated 5000 regional MSME clusters in India comprising of industrial units in such sectors like handloom and handicraft.

Traditional industries are characterised by significant use of traditional knowledge held by particular communities and ingrained in long standing practices spanning centuries.[47] Sharing of knowledge on production techniques through informal modes of learning imposed limits to further spread of such information – leading to natural clusters around traditional industries with organic characters like concentration of skills. Prospects of technological value addition in such clusters remain more or less stalled posing a certain threat to their sustainability. The language and paraphernalia of modern systems of innovation, however, can only be partially relevant in such cases. Contemporary STI paradigms may be contextualised to ensure effective intervention in all outstanding technological needs of these industries without disrupting the delicate balance that remains at the core of their survival.

STI polices are often set keeping in mind formal sectors of knowledge creation and their influence on industrial production and productivity. However, when it comes to traditional industries known characteristics of industrial organisation may be largely absent. Hence knowledge creation and transfer in these industries may not be in conformity with conventional approaches; not even with evolving dynamics of national innovation systems that aim to build formal networks of public institutions and the private industry with the aim to streamline mutual learning and collaboration. Traditional industries are embedded in rural and poor societies with a complex socio-economic mesh where household production units are coordinated by small entrepreneurs and market interface happens mostly through outsiders and middlemen. None of them are aware of the benefits associated with innovations and are not adequately endowed to articulate technological needs. Most changes in production techniques are adopted to meet demands of new variety/design emerging from customer bases. Public-private collaboration and dialogue on innovations is difficult under such circumstances.

Such considerations call for innovation paradigms towards enterprise development that are focused on implementation strategies that go beyond policies on science, technology and innovation when it comes to traditional industries. These implementation strategies could be holistic towards inputs, value addition and commercialisation. Government's role may be conceived around creating agencies to foster and handhold industries in traditional sectors. Such agencies would not only ensure capacity building at the grass root level but also assess technological needs. Subsequently, technological solutions may be sourced from S&T institutions or achieved through switching over to new practices. Moreover, innovation may not be *de novo* when production techniques are embedded in traditional practices and could mean strengthening of existing structures to achieve greater efficiency. It is rather important that benefits of innovation in any form should be widespread. It is expected that when elements of the modern systems of innovation collaborate with traditional forms of production it should essentially promote livelihood protection and employment that, from a developing country perspective, could surpass standard benefits like increase in productivity and efficiency. Recent efforts in India, along these lines, have been considered effective. We present two case studies for illustration.[48] The first is the case study of incense stick cluster in one of the north eastern states i.e. Tripura and second is that of the brassware cluster in Moradabad, Uttar Pradesh. Both Tripura and Uttar Pradesh are among the backward states in India.

7.1 Incense Stick Cluster, Tripura

7.1.1 Profile and History[49]

The incense stick making sector of Tripura is essentially a rural cottage industry which is characterised by community level economic activity. This cluster provides full time and part time employment to rural men and women throughout the year. Incense stick making in Tripura holds potential for large scale employment and livelihood opportunities in rural areas. Over 200,000 artisans (in approx. 50,000 business units) are engaged at different stages of incense stick making in this cluster and the industry generates a turnover of over 0.44 billion US$ nationally. Interestingly, despite its rural character, the cluster benefits from a complete value chain comprising of a strong supply base of raw materials like bamboo and an effective link with the market (for finished products).

India offers a large domestic market for incense sticks. Incense sticks are burnt and offered during prayers both at homes as well as at places of worship. Incense sticks are also used as an air-refresher with de-odorising properties. Incense sticks are being increasingly used as mosquito repellents, in spas and for aroma therapy application as in traditional medicine. With product diversification and improved quality, the demand for incense sticks has increased not only in the domestic market but also in export markets. India has emerged as one the largest producer of incense sticks in the world.

The incense cluster in Tripura has developed in phases. The supply of bamboo sticks and bamboo products have been a key economic activity for the state of Tripura since the 1950s. Bamboo stick making for incense related products is as old. Tripura is the largest supplier of bamboo sticks for the domestic incense stick industry; it supplies more than 70 per cent of the requirement. Initially, these sticks were sold to incense stick makers in South India. However, over time, the same agents who participated in the bamboo sector saw potential for establishing incense stick making in the state of Tripura itself given a very orderly supply chain that was already in existence. The incense sticks sector has grown in terms of production, livelihood opportunities, quality up-gradation and in turnover. Making of rolled incense sticks (rolling incense paste on bamboo stick) had been introduced a decade ago. Initially, incense stick making was restricted only to a few pockets; however, in recent years this sector has seen tremendous growth with involvement of large number of local people. Both market demand and proactive role of the government in providing strategic inputs contributed to the expansion of this sector. After bamboo sticks, rolled incense sticks making has now become a major source of livelihood for rural household level workers in Tripura, particularly women.

7.1.2 Bamboo sector and the Role of the State Government

The Tripura Industrial Policy and the Industrial Investment Promotion Scheme 2007, announced by the Government of Tripura, identified bamboo as the principal non-timber forest produce of Tripura. The government has constituted the Tripura Bamboo Mission (TBM) to undertake the integrated development of the Bamboo sector in the state, with an objective to ensure employment generation and economic development based on available bamboo resources in the state. The focus is to develop technology-based applications of bamboo and establish viable enterprises engaged in the production of high value added bamboo based products in the state. The mission has a subsector specific focus that includes handicrafts, furniture, incense, sticks and blinds, mat as well as use of bamboo in industrial production. The project is being implemented by IL&FS Cluster Development Initiative on a PPP framework.

The TBM elaborates its strategy as:

- Build sustainable bamboo based livelihoods on a cluster based approach.
- Develop an institutional structure owned and managed by grassroots producers and their federations.
- Build enterprises based on commercially sustainable business models.
- Provide infrastructure, skill training, design support and direct market linkages.
- Mobilise private investment in the bamboo sector in areas like bamboo composites, mechanised sticks and other industrial products.
- Promote plantation in non-forest areas, private land holdings and homestead plantations.

7.1.3 Scope of Innovation

The first step in the production of incense sticks is making of bamboo sticks. These sticks are primarily handmade, with machine made sticks making up for less than 10 per cent of total value. Next comes rolling of premix on bamboo sticks. The premix used are often of cheaper variety containing only charcoal powder or low quality sandal wood powder with a mixture of 30-40 per cent of "wood gun" (*jigat*) powder. This combination of charcoal powder and *jigat*, is known as premix. This premix is made into a paste which is then rolled-on bamboo sticks using hand or machines. *Jigat* is the trade name of the bark of a tree named *Litsea Glutinosa*. The bark is extracted and cut into small pieces before being fed into a pulveriser. Similarly, charcoal collected from households or from forests is crushed in the pulveriser. *Jigat* has a special characteristic which imparts adhering property to the mix when water is added to it. We note that almost 85 per cent of the incense sticks produced in India is hand rolled. Finally, the sticks undergo perfuming and packaging. Based on quality the final products may be graded as premium grade or non-premium grade.

The TBM as well as the National Innovation Council (NInC) has undertaken detailed assessment of the technological needs of this cluster and scope of value addition and process innovation therein. TBM is also mandated to support all commercialisation efforts pertaining to the bamboo sector in Tripura. The scope of significant process innovation was felt given low levels mechanisation in the production of bamboo/incense sticks. However, the kinds of machines that are normally used elsewhere for such purposes are reportedly expensive and are not effective on the locally available bamboo. Therefore there was a perceived need to develop indigenous machines and technology to suit requirements of this particular cluster. Also adequate perfuming facilities are not available in this cluster, and local entrepreneurs have to depend on external resources.

On product innovation, interventions have been proposed at two levels.

- *First, in raw materials, specifically in the composition of jigat.* Though there is a sustainable supply of bamboo in the region, there are constraints on the availability and supply of *jigat*, a major component of the incense sticks premix. The current *jigat* requirement per annum at this cluster is 157.5 Metric Tonne (MT), out of which only 105 MT is being met through domestic supply (from within the cluster). Also the *jigat* collection from the forests is becoming difficult which is pushing up prices.

- *And, second for value addition*. The existing product range is largely restricted, in terms of quality and variety. Since almost a century now, no other innovative product has replaced the traditional products, namely raw incense sticks, scented incense sticks, flora incense sticks, etc. There is a need to diversify into other premium product segments like spa and wellness; air fresheners, etc. which have huge demand in the domestic as well as in the international markets.

There are substantial bottlenecks in the process of commercialisation of incense stick related products. There is no fixed marketing strategy for the industry as whole with each unit having their own method of penetrating the market.

7.1.4 Intervention by the State Government and NInC

We report some interventions that have taken place at the behest of government agencies like the TBM or the NInC. No doubt, TBM plays an effective role in assessment of technological needs of this cluster and undertakes necessary capacity building programmes. The NInC that sought to create or seed innovation ecosystem on a pilot basis in industry clusters in India has collaborated with TBM to establish the Cluster Innovation Centre (CIC) for this cluster.

The TBM after thorough assessment of the needs of the artisans had earlier developed low-cost hand held (not run on power) tools that are effective in stick making from bamboo. Artisans were also given necessary training. There has, reportedly, been visible benefits and widest community level adoption of these tools. Sticks produced using these semi-mechanised tools are of better quality – uniform length and shape. These uniform bamboo sticks would help the artisans in selling their products at a higher price. Moreover, introduction of these implements has increased the daily production by more than twice. The NInC has been instrumental in bringing on board a CSIR laboratory (Central Mechanical Engineering Research Institute – CMERI) and the National Institute of Technology (NIT), Agartala to develop machines for stick making and rolling. The use of such machines is expected to significantly improve the quality of final products and increase production. The machine being developed by NIT Agartala is near prototype and once validated may be commercialised. Funding for prototype development is being actively sought at this juncture.

Product development at the level of raw materials has been successfully undertaken to ensure steady supply of a particular raw material. The cluster, through CIC, has collaborated with another CSIR lab – Central Institute of Medicinal and Aromatic Plants (CIMAP) to find an alternative to *jigat* or at least reduce the proportion of *jigat* required in making incense sticks. One such composition has been developed by CIMAP and validated by the cluster. The proportion of *jigat* is reduced by 10 per cent in this new composition.[50] Apart from reduction in *jigat* requirement, the new composition has other advantages like increase in the number of incense sticks rolled with the same quantity of premix and increased burning time of the perfumed incense sticks. However, we do not find any evidence to suggest product development for value addition (moving up the value chain).

7.2 Brassware Cluster, Moradabad, Uttar Pradesh

7.2.1 Profile and History[51]

The metal-ware industry cluster in Moradabad, Uttar Pradesh is comprised of small scale production units, large number of unregistered household units and exporters. Small scale manufacturing units receive contracts from exporters and in turn subcontract specific production tasks to household units/artisans. Moradabad has around 9087 registered units and an approx of 22,000 unregistered household units. There are around 1000 exporting units while others are manufacturing units/entrepreneurs (small enterprises) and household units (micro enterprises). This industry provides direct and in-direct employment to around 350,000 people. Moradabad metal ware cluster has an annual turnover of over 0.6 billion US$, of which nearly 0.44 billion US$ are export earnings. Nearly, 80 per cent of India's exports in metal ware come from Moradabad. The product basket of Moradabad is a mix of utility products and decorative items. Around 2000-3000 product varieties are produced in Moradabad. The products range from simple to high value added products with intricate carvings, designs, and colours. The products being produced in Moradabad are lightweight and are internationally recognised for the craftsmanship that goes into making these products. Moradabad was founded in 1625 and named after Murad Baksh, son of Mughal emperor Shah Jahan. Brassware industry flourished during the Mughals as Muslim families who settled in Moradabad during the period brought with them improved tools and mastered intricate Persian designs. The brassware industry in Moradabad experienced a blooming phase in the early 19th century when the British took the art to foreign markets. However, over the recent decades metal ware products made from other metals/alloys like electroplated nickel silver (commonly known as EPNS), iron, aluminium, steel, etc., have been produced in Moradabad.

So far, there has not been any exclusive effort by the State government to address technological or infrastructural needs of the cluster unlike as in the case of the bamboo sector in Tripura. However, the cluster in Moradabad should potentially benefit from some of the schemes of the Central government meant for enterprise development. Some assistance programmes have also been implemented by some of the international organisations over the past several years. The state government however proposes to set up handicraft SEZs – one in Greater Noida and other in Moradabad to boost commercial prospects of such products.

7.2.2 Scope of Innovation

There are two kinds of processes involved in the production of brassware in this cluster. The first one begins with producing brass ingots and converting them into final products through a mechanised process involving sheeting, pressing, hammering and other finishing processes. This process is mainly used to produce very light weight products on a mass scale.

The second involves preparation of *silli*/*gully* at the start of the process. Raw materials used in the manufacture of brass utensils are locally called *silly* and *gully*. These are alloys of many metals namely, copper, zinc, lead, etc. The raw alloy undergoes moulding and is cast in smaller crucibles. Various parts of the product, which are cast separately, are then assembled either by screwing or through soldering/ welding. The product is then subjected to scrapping, filing, engraving or embossing. Finally, it undergoes polishing or electroplating followed by lacquering, final quality testing and packaging.

Attempts have been made to identify the multitude of challenges faced by artisans as well as entrepreneurs (small and medium manufacturers). However, complex socio-economic and political realities almost make it impossible to collectively promote industrial development in this cluster, let alone technological up-gradation. Exporters as well as small scale entrepreneurs are indifferent towards ‘innovation’ and are solely driven by short term business plans.

The scope of technological intervention for improvements in production processes has been identified with respect to three areas. The first is to address concerns around working conditions of workers; second, to address issues of market competition; and third, to implement modifications in production techniques to comply with international standards. The livelihoods and health of the artisans of this cluster are at stake due to continuous exposure to inefficient and polluting coal-based furnaces traditionally used by them. The entrepreneurs need improved technologies, design assistance among others to stay competitive in the global market. Moreover, the electrolyte currently used for plating brass contains cyanide, which is a hazardous chemical. The cyanide content in the production process goes against international standards.

In case of brassware, there is definite scope of product innovations not only in raw material, i.e. alloys used, but also in certain materials used in the process of making finished products. Raw material, i.e. brass, forms the major component of the final product cost. The cost of brass has been fluctuating and rising constantly in the international market.[52] Therefore, there is perceived need for new alloys and product variety in raw materials. Another material that is required in the final stages of production is lacquer, which helps in preserving shine on metal ware and improves shelf life. However, the kind of lacquer currently used needs baking and mixing of thinners. Moreover it takes a significantly long time to dry. Therefore, a ready to use variety that would reduce time consumed in drying was conceived by the NInC when it launched its pilot project at this cluster. Product innovation is often induced by competition from related products emerging from other countries. The Moradabad cluster has moved from products purely made out of brass to products made of glass, brass-wood, brass-ceramic, aluminium/ iron/ galvanised metal, etc. The shift has been induced by market demand and global trends (alternative alloys used elsewhere, i.e. China and Thailand).

7.2.3 Intervention by NInC

The coal based furnaces traditionally used by artisans embody rudimentary technological design. Smoke from furnaces has long been a health hazard and a source of pollution. Although, the most efficient device in this regard would be a gas based furnace rather than a coal based one, poor infrastructure and inadequate gas supply would not permit adoption of gas based furnaces. Moreover, such furnaces can prove to be dearer. The National Metallurgical Laboratory (CSIR-NML), along with the Moradabad Cluster Inclusive Development Society (MCIDS – acting as the Cluster Innovation Centre host) created a new furnace design with 20 per cent reduction in coal consumption and 70 per cent reduction in pollution. The new furnace has also helped increase the daily income per furnace per artisan by an estimated 80 per cent. Commercialisation of this new furnace is undertaken by a local firm recommended by the MCIDS which acts as the recipient agency for this new design (of furnace). This firm would be responsible for industrial production of new furnaces ahead of commercial application.[53]

Secondly, we find that NInC intervention has led to two product innovations. First, a cyanide-free brass electrolyte is being developed by the Central Electrochemical Research Institute (CECRI), a CSIR lab. The new electrolyte is expected to be as effective as its predecessor but devoid of its toxic effects. This would provide artisans a cleaner and a safer working condition and meet international standards. The second is in the form of an improved lacquer composition. This has also been developed by CSIR-NML. The new ready to use lacquer requires minimal addition of thinner; does not require baking and takes only 30 minutes to dry, thus significantly reducing application time. The earlier variety of lacquer could only be sprayed, but the new variety may be dip coated or painted with a paint-brush onto the metal surface.

The CSIR under this collaboration with NInC is committed to transfer technology/know how without a fee and on non-exclusive terms. The NInC on the other hand is mandated by its policy to employ methods that would ensure collective adoption of a technology and promote widest diffusion of innovations. Cluster approach of industrial development should cater to both these objectives. Accordingly, despite deep social and political fault lines within the industry community at Moradabad, NInC through its implementation agency IL&FS Cluster Development Initiative has set up a Special Purpose Vehicle (SPV) – Moradabad Cluster Inclusive Development Society (MCIDS) with representation from stakeholders belonging to different tiers and groups. This ensures that new technologies can reach widest spectrum of entrepreneurs and artisans of this cluster and the knowledge is not restricted to a few.

8. Concluding Remarks

India's industrial competitiveness arising out of technological depth (and technological value addition) does not compare well with other NICs in Asia. However, such broad brush comparisons say little about India's key strengths in some of the skill-intensive sectors. High-end skill, that is critical for knowledge intensive sectors, has emerged out of sustained focus on technical education. Technological learning in some of the industries, backed by commensurate policies, has over time made them global players (generic drug industry). Low cost advantages coupled with elements of skill and capability has ushered in natural comparative advantage in some of the other knowledge-based industries (ICT and software). Finally, India is well placed to undertake industrial activities that require both engineering skills and raw materials (automobiles and auto-components). These have scripted the emerging economy story for India to a large extent. However, as discussed earlier, India's technological efforts and its ability to undertake skill intensive tasks does not necessarily spur innovation outcomes.

Recent innovation policies by the Government of India have been adopted at various levels and have the following broad objectives. First, address issues of skill shortage and ensure supply of quality human capital for scientific research. Second, improve world ranking in science. Third, develop innovative solutions for commercial applications – to bridge science-society divide and urgently address concerns of inclusion. And finally, establish an effective innovation system by linking S&T stakeholders both in the public and the private sectors. Parallel policies have emphasised on innovation clusters, large scale digital information networks and funding of innovation initiatives.

However, none of these policy frameworks draws upon immediate innovation challenges that may be specific to India, particularly when developmental priorities are overwhelming. It is particularly lamentable that technology's role in addressing developmental challenges has been dismal on the face of a very poor show that India puts up when it comes to societal welfare and human development. Evolving paradigms of the Indian innovation system must promote Government's role in pro-poor innovations (in health and habitat) as the private sector (guided by market demand) would never be able to trace those needs. A strategy for entrepreneurship ecosystem around new and relevant technologies needs to be promoted in a manner where small and medium enterprises would develop and market such technologies. This requires effective government intervention through collaborative research, consortia and risk-funding (for technology development at the industry end).

Innovation policies in India that claim to cater to firm level technological capability misses out on economics that largely define the scope of innovative activities and narrates demand conditions. At best, such issues are addressed through ad-hoc policy making in the spirit of sectoral approach. But these have failed to put the overall agenda in perspective and, therefore, do not generate the required impetus. Finally, innovation policies in India are ambivalent towards global production networks. Comparative advantages driving production networks are not static and it is often argued that some of the East Asian countries are losing out on the low cost advantage or abandoning the part of the production chain they were responsible for. It is here that India sees opportunity. However, we observe that unaware integration with the world economy and production networks would adversely affect specialisation and technological capability building. While, economic policies should ensure sustained demand for innovations, innovation policies in India at this juncture should cater to two definite goals. First, streamline availability of broad-based skills to seize opportunities of specialisation, industrial development and knowledge economy. And, second, achieve frontier R&D focused on pro-poor innovations, niche knowledge and green technologies.

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Endnotes

1 Also highlighted in Abrol (2013).

2 NISTADS (2013) – *India Science and Technology (Vol. 2)* points out that the main drawbacks of the present policy space of Indian Innovation System are weak governance, multiplicity of S&T goals and absence of S&T audit.

3 Market failures in a more generic form suggest that when one or more conditions of perfect competition are violated, equilibrium is not Pareto efficient. The kinds of violations that are rampant in knowledge creation arise out of presence of externalities, indivisibilities, information asymmetries and uncertainty.

4 Metcalfe (1995) identifies that missing or distorted markets arise out of uncertainty in knowledge creation. Uncertainty leads to market failures because future markets for contingent claims in an uncertain world do not exist and individuals cannot trade risks in an optimal fashion and establish prices which support the appropriate marginal conditions.

5 Recent studies (Blundell *et al.* 1999, Greenhalgh and Rogers 2006) have tried to empirically ascertain the role of market power in innovations and offer insights to suggest that returns to innovations are closely linked to stock market valuations, where higher market share might increase the stock market valuation of an innovation.

6 This follows the seminal work by Arrow (1962) where he shows that a monopolist who already earns an above normal profit would have less incentive to innovate because the new profit that she can earn from a new innovation would be less compared to what she could have achieved with similar innovation under perfect competition. This is because under perfect competition she would not have been earning any super-normal profit and hence the 'replacement effect' in terms of profit (due to the same new innovation) would be greater. However Arrow abstracts away from immediate chances of imitation which effectively allows a firm to enjoy temporary monopoly over the innovation outcomes.

7 Moreover, they are expected to facilitate a market of technology by allowing for transactions in codified innovation outcomes.

8 It has often been found that patent holders are reluctant towards new innovations. Such allegations are common in the pharmaceutical industry.

9 Sutton (1996) and Symeonidis (1996) as reported in Greenhalgh and Rogers (2010), p. 140.

10 Highlighted in Lall (1986); other relevant studies are Pavit (1984); Dahlman and Westphal (1982), Katz (1984) and Bell *et al.* (1984).

11 Parts of this section draw upon an undated and unpublished manuscript by Biswajit Dhar and R K Joseph, RIS, New Delhi.

12 It has been suggested that from an innovation system perspective, what matters is not the number of new inventions that have been patented, but the number of new technologies that have benefited the society.

13 Ray (2008) offers an elaboration of technological learning along the 'know-how' and 'know-why' route, which he argues are the available alternatives for the LDCs but may not be mutually exclusive. As he points out that the process involves the following stages. First, bring in latest imported technology (exploit the global frontier) and focus on *know how* to reap maximum productivity gains (production engineering). And as a second step concentrate on *know why* and applied research to create capabilities to generate new technology and attempt to catch-up with the advanced nations on their own footing (reverse engineering).

14 It promoted adoption of advanced technology through reverse engineering. It established a mode of working which depended upon continuing dialogue on questions of technological development, both with industrial R&D people and with university scientists and technologists.

15 The vertical element in international division of labour, specialisation and international trade in East Asia goes beyond resource based patterns of international trade and horizontal production differentiation. See Kimura and Obashi (2011).

16 See Industrial Policy Resolution of 1956.

17 See Scientific Policy Resolution 1958.

18 "Scientific research foundations in the areas of medical, agriculture, natural and applied sciences and social sciences seek DSIR approval as Scientific and Industrial Research Organisations (SIRO) under the DSIR scheme of granting recognition to SIROs. The approved SIROs are eligible for availing customs duty exemption on imports and central excise duty exemption on indigenous purchase of essential scientific and technical instruments, apparatus, equipment (including computers), accessories, spare parts thereof and consumables, required for research and development activities" (DSIR Annual Report 2004-05).

19 DSIR Annual Report 2011-12.

20 In 2006-07, tax concession for supporting R&D was less than Rupees 15 billion; in 2012-13, it was more than Rupees 64 billion.

21 Allowed under Section 35 (2AB) of the Income Tax Act of 1961 and applicable to 'in-house R&D units' engaged in R&D in the area of chemical, drugs pharmaceuticals, (including clinical trials), bio-technology, electronic equipment, computers, telecommunication equipment, aircrafts and helicopters.

22 Patents (on embedded technology) in any two of the following countries outside India, namely, the European Union, the US and Japan is a requirement. The waiver is applicable for a period of three years.

23 Industrial Policy Statement of 1991 shifted focus away from an inward looking and strict regulatory regime towards FDI, technology acquisition, de-licensing and competitiveness.

24 Apparently, while private firms have better marketing network, public sector R&D institutes are better equipped with necessary infrastructure and skills. However, government participation in such projects is also guided by their motivation to keep knowledge in the public domain, limit chances of monopolisation and ensure affordable pricing.

25 However, as the programme has matured to an extent that the funding requirements have gone up substantially, it was recommended that a separate agency/institute be identified for funding projects conceptualised under CAR.

26 The programme nurtures and mentors innovative and emerging technologies/ entrepreneurs to assist new enterprises to forge appropriate linkages with academia and the government.

27 This is arguably India's largest open innovation network programme.

28 SIDBI: Small Industries Development Bank of India.

29 See National Manufacturing Competitiveness Programme (NMCP). Also note, this programme is implemented in PPP mode.

30 Venture capital firms do not consider supporting grassroots innovators due to limited fund requirement of a few thousand rupees to a maximum of 25,00,000 Indian

rupees (approx. 4660US$) while banks may not be ready to risk loans without proper documentation or without collateral or a guarantor.

31 UNCTAD Technology and Innovation Report (2012).

32 The patent regimes in these countries are uniform to the extent that all are signatories to the TRIPS agreement. Uniformity in IPR regimes has been achieved with integration of world markets. Multinational corporations seek protection of their intellectual property at all locations they wish to establish their warehouse of technology led products. Therefore, overall patenting activity for a country would include patenting activity by foreigners as well as by residents.

33 Lall (1985) offers a pioneering exposition of technological learning by categorizing it as 'know-how' and 'know-why'.

34 Despite R&D investments, it has come to be known that India's technology capability lies in process development and not in product development. The pharmaceutical industry, the most successful knowledge based industry, so far has not developed a new chemical entity.

35 The study further suggests that India's emergence in the world economy in the recent decades is critically linked to the Indian expertise on such skill-intensive tasks arising out of sustained efforts towards technological learning and capacity building through higher education in S&T.

36 Highlighted in Ray and Saha (2009).

37 The Report of the Working Group to Review the existing Institutional Mechanisms and Structures as well as the Management and Governance of S&T Sector for the 12th Five Year Plan, Government of India.

38 High tech materials; high end electronics including special sensors/detectors, several probing diagnostic and characterization equipment and a variety of software and codes fall under such dual use category which should be available within reach to serve wide-ranging needs of the country on the strategic and the economic front. For this, mission oriented projects will be conceptualised in each of these sectors, recognising the fact that a mission on solar energy has already been launched under the National Action Plan on Climate Change.

39 It recommends special focus to be given to machine tools, heavy electrical equipment, heavy transport, and earth moving and mining equipment.

40 The rationale is upfront. Given very high tech nature of these industries it is only natural that production of high technology intermediate inputs like advanced materials would spur much wider industrial development.

41 FDI in R&D is less than 1 per cent of total FDI in India. See Basant and Mani (2012).

42 See Ray and Saha (2012) for a detailed analysis of science-industry interface in India. The study sheds light on IP culture, IP management, technology transfer and industry interface for publicly funded science research in India.

43 Attempts to bridge the academia-industry divide by providing platforms of

interactions and knowledge exchange have so far not been very successful. Nevertheless, the NSTEDB of the DST under its scheme Science & Technology Entrepreneurs Park (STEP) lists such facilities at 17 odd locations, mostly around public funded institutions and universities, and has reportedly promoted nearly 788 units generating annual turnover of around 21 million US$ and employment for 5000 persons. More than 100 new products and technologies have been developed by the STEPs / STEP promoted entrepreneurs. In addition, over 11000 persons have been trained through various skill development programmes conducted by STEPs.

44 Innovation surveys are inspired by the fact that the traditional S&T indicators used in the assessment and planning of national scientific resources have limitations in capturing the multidimensional innovation process. Such surveys are being undertaken in many industrialized countries and of late, in some of the developing countries. Such surveys cover formal R&D set-ups, large firms and small enterprises.

45 Further, 42 per cent of the large firms and 17 per cent of the SMEs covered under the survey were clubbed as 'highly innovative' firms (i.e. firms who have introduced 'new to world' Innovations during the course of business in the last five years.)

46 See Arora (2011).

47 According to some estimates almost the entire MSME sector in India (85-86 per cent) uses traditional knowledge in its production units. *See* NISTADS (2008) – *India Science and Technology* report section on Entrepreneurship in MSME.

48 We rely extensively on internal reports prepared by Infrastructure Leasing and Financial Services (IL&FS) Clusters that were made available to us. We also make use of all information available online on http://innovationclusters.gov.in/ of the National Innovation Council. Some insights did emerge out of personal interviews/ interactions at the National Innovation Council and IL&FS Clusters. Nevertheless, we (the authors) are solely responsible for the analysis presented in this section.

49 Information compiled from NInC website and internal reports prepared by IL&FS Clusters that were made available to us.

50 As noted in IL&FS reports, full cost advantages of the new composition can be ascertained once key components are cultivated/sourced locally.

51 Information compiled from NInC website and internal study reports prepared by IL&FS Clusters that were made available to us.

52 The rates of the metal are fixed in accordance with London Metal Exchange (LME) rates.

53 Workers and artisans have received training from CSIR for manufacture and installation of the new furnace.

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