INDIA'S TRYST WITH TECHNOLOGY: THE WAY FORWARD

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Introduction

- The post-independence technology trajectory for India: *Two* broad objectives
  - Building up strategic technological capability
  - Acquire industrial technological capability through learning and catch-up
- India's strategic technology achievements: an account
  - Space Research: *Aryabhatta 1975, First Satellite Launch Vehicle 1980*
  - Atomic Energy: *Setting up of BARC (Trombay), Fast Breeder Reactor (Kalapakkam), Pokhran I 1974*
- Does achievements on strategic technology and industrial technology give mixed and conflicting signals about India's technological accomplishments ?

India's Industrial Technology

- Soviet model of a planned economy: *inward* looking development strategy
  - Meticulously planned diversified production base: simple consumer goods to sophisticated capital goods
  - Fulfilling the goal of *technological learning* for catch-up
- Flipside of Protectionist policy - No incentive to keep pace with fast changing global technology frontier: *prolonged use of inefficient technologies by the Indian Industry*
  - Discouraged competition, killed prospects for innovations and competitiveness at all levels of production
  - The Public Sector used technologies in the most cost inefficient manner
  - The Private sector lacked both initiative and competence for efficient technology usage
  - India's Technological Capability building remained by and large confined to routine activities of production and trouble shooting

- Exclusive focus of our paper:
  - India's experience with innovations and technology generation for competitiveness and economic growth over the last sixty years

The Role of Technology in Global Economic Emergence

- The Productivity Story: Acknowledging *Technology* (TFP) as an important source of growth since 1950s within the neo-classical paradigm : R&D was recognized as an important source of TFP growth
  - Solow (1957):
    - Physical factors (K & L) contributed to only 1/8th of the growth of the US economy during the first half of the last century; the remaining was due to TFP (residual contribution of technological advancement) growth
  - However, not all countries followed this US trajectory:
    - Not all productivity growth is “pure” technological advancement
    - Productivity growth may arise out of human capital accumulation; enhancing cognitive skills of the labour force
    - An account of TFP contribution to growth for East Asian Tigers (Young 1995): Hong Kong 2.3 percent, Taiwan 2.1 percent, South Korea 1.7 percent and Singapore 0.2 percent
    - Therefore neoclassical understanding of “technological improvement”, was perhaps not that important in facilitating the East Asian Miracle

TFP Calculations for the Indian Economy

- At aggregate industry level
  - Ahluwalia (1991): Long Term TFPG negligible up to mid eighties
  - Balakrishnan and Pushpangadan (1994): TFPG 0.033 during 1970-71 to 1988-89
- At disaggregate industry level
  - Ray et al (1999), Ray and Bhaduri (2002): 29-industry study over 1975-76 to 1994-95
    - Overall TFPG 2.4 percent
    - R&D: significant determinant of TFPG across industries
    - Distinct structural break in 1982
    - Only 8 out of 29 industries recorded positive TFPG
    - E&E 137%, Fertilizer 73%, Telecom 50%
- Technological Progress (a la Solow) did not contribute significantly to India's industrial growth (with the above exceptions); so,
  - How has technology contributed to India's development experience?
  - Is there a need to go beyond neo-classical perspective to understand technological progress in this context?

Beyond Neoclassical Perspectives

- Neoclassical theory
  - Technological progress is identified with major breakthroughs in science and technology resulting in shift of the frontier
  - Technical progress made in diffusion, adaptation and application of new technologies (particularly in case of LDCs) remained under-emphasized
- Beyond Neoclassical Perspectives
  - Stages of technological learning in case of LDCs
    - *Learning by doing*
    - *Learning by adapting or* ***production engineering*** (shop floor adaptation of technologies)
    - *Learning by design and learning by improved design :* ***reverse engineering***
    - *Learning by setting up complete production process*
    - *Acquiring basic (frontier) R&D capabilities*

Cont.

- Lall (1985) categorize technological capability of LDCs as:
  - *Know-how* is acquired through "not only assimilation of imported techniques but also quality control, improved plant layout and production practices, slight modifications to equipment and tooling, troubleshooting, the use of different raw materials and so on"
  - *Know-why* is the next stage of technological development, which involves the understanding the nature of the process and product technologies, leading to the development of new improved designs

Therefore for LDCs know-how is expected to bring about rapid and immediate productivity growth, while know-why is absolutely necessary (but by no means sufficient) to create and strengthen the technological foundation of LDCs

India's Tryst with Technology: Role of the government

- India's Technology Policy: a brief overview
  - Pre-1990
    - Objective : "the development of indigenous technology and efficient absorption and adaptation of imported technology appropriate to national priorities and resources" GOI (1983)
    - Build up *search-,selection-,implementation-* and *absorptive*-capability
    - Go for *adaptation* and *minor innovation* through reverse engineering
    - However, import of technologies in the form of licensing as well as FDI was severely restricted to promote indigenous technology (self-reliance)
  - Post-1991
    - With liberalization of the Indian economy, restrictions on imports, FDI and technology transfer have been progressively removed
    - Formulation of dynamic and flexible Science and Technology Policy which can readily adapt to rapidly changing world order (S&T Policy 2003) has been actively pursued

Cont.

- Channels of Technology Generation in India through Government initiative

  1)Applied Industrial Research, 2) Science Education and Fundamental Academic Research, 3) Public Sector Production and 4) Offering fiscal and non-fiscal R&D incentives to the private sector

1. ***Applied Industrial Research*** : Share of R&D expenditure in GNP increased steadily from 0.17 percent in 1958-59 to 0.98 percent in 1987-88, the major share of which was borne by the government
   - Public sector research laboratories under the auspices of CSIR (Council of Scientific and Industrial Research) are engaged in applied research in a wide range of fields including areas like aeronautics, experimental medicine, environment, oceanography and structural engineering
   - Pre 1990 it was through this channel that technological effort went into creating technologies first time in the country rather than breakthroughs first time in the world (predominantly in the public sector institutions)
   - However, two issues remain unresolved: 1) Whether these technological development had impacted technological development in large scale organized industry beyond small scale enterprises and 2) Whether these indigenously developed "new" technologies were efficient by international standards of costs and quality

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2. ***Science Education and Fundamental Research***
   - Objective of higher education policy post independence: Imparting science education to the coming generations to constitute a large pool of highly skilled workforce and also improve the conditions for fundamental research in the country - Setting up of IITs, Regional Engineering Colleges and several Central Universities
   - IITs went a long way in providing the country with highly skilled manpower over decades to come
   - However, it remains debatable whether these institutions were equally focused on fundamental or cutting-edge research
3. ***Public Sector Production***
   - Objective: mimic the development trajectories of advanced industrialized nations by meticulously planning a diversified industrial production base
   - This implied heavy investments on import substituting industries across the board on the part of the government
   - However, through direct intervention in industrial production on the basis of *a priori* planning, the government seemed to ignore the notion of natural comparative advantage
   - No incentive to keep pace with the fast changing global technology frontier; public sector manufacturing was rendered inefficient and therefore remained technologically backward

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4. *R&D incentives to the private sector*
   - Prior to the 1990s the main thrust of the R&D incentives was to generate indigenous technologies primarily in the institutional sector and facilitate its effective commercialization and technology transfer for use in the industrial sector;
   - There were very few incentives at the firm level; in-house R&D was encouraged only to facilitate acquisition of technological capabilities of absorption, adaptation and assimilation
   - The decade of 1990s saw a departure from earlier policy stance: shift of focus of fiscal incentives from national R&D institutions to R&D carried out by the industry either in in-house R&D units or in the SIROs (Scientific and Industrial Research

- *Trends in R&D Expenditure and R&D Outcomes in India*
  - Macro Trends
    - Share of R&D expenditure in GNP increased steadily from 0.17 percent in 1958-59 to 0.98 percent in 1987-88, the major share of which was borne by the government
    - Thereafter it started declining reaching a low of 0.71 percent in 1995-96 and finally it has settled around 0.8 percent
    - Government expenditure on R&D gets distributed as:
      - *Central government 62.6 percent*
      - *State government 8.5 percent*
      - *R&D in Public Sector Enterprises 4.5 percent*
    - Outputs (as classified by Ray 2003 from DST statistics):
      - Type I : patents, product development, process development, designs and import substitutes
      - Type II : consultancies, books, papers and reports
      - Observation:
        - Institutional sector type II – industrial sector type I.
        - The share of import substitutes in Type-I output produced by the institutional sector declined from around 0.81 in the 1980s to around 0.3-0.4 in the 1990s; the industry however maintained its share of Type I at 0.2

- *IPR Policy and Technological Learning in India*
  - Weak IPR policy is sometimes preferred over a stronger one in the initial stages of technological learning and development; however, transition to strong IP regime might take place once a country reaches technological maturity to achieve major breakthroughs
  - This essentially reflects that IPR policy can not remain static or invariant over time
  - The Patent Act of 1970
    - Did promote considerable technological learning through *reverse engineering* activities
    - Allowed only process patents – led to process revolution in Indian Pharmaceutical industry
  - India opted a stronger IPR regime in 2005 to comply with the TRIPS agreement – this transition, is thought will boost innovative capacity and basic research

Understanding the process of technological capability acquisition by the Indian industry

- Econometric results in Ray and Bhaduri (2001) shows:
  - Learning, both experience-based as well as interaction (or spillover) based, proved to be the most important determinant of research production process (the other explanatory variables accounted for were firm size, technology import, ownership and research effort)
  - Conclusion : technological learning has been the most important determinant of technology generation in Indian industry
  - Two types of technological learning evident : case for Electrical and Electronics (E&E) industry and the Pharmaceutical industry
    - E&E: characterised by "screw-driver" technology i.e. assembly operations, production engineering and shop-floor practices; *know-how* type
    - Pharmaceutical: learning based on reverse engineering – decoding an original process for producing a bulk drug; *know-why* type
  - Therefore, Pharmaceutical is more dependent on formal R&D than the E&E

- Implications for Export Competitiveness
  - Econometric results in Bhaduri and Ray (2004) captures various facets of *technological capability* on export performance
    - It is shown that *know-how* (or production engineering) augments export performance in both E&E and Pharmaceutical while *know-why* (or reverse engineering) was important for pharmaceutical exports, not E&E
    - Long prospects of pay-off from *know-why* do not exist in case of E&E because of high rate of product obsolescence according to international standards, which is probably not the case with pharmaceutical industry

Concluding Remarks: The Way Forward

- India missed the opportunity to join the other labour surplus Asian economies in the so called Asian Miracle – spearheaded by massive expansion of labour intensive manufactured exports
- India was left behind when these east Asian nations were getting integrated with the world economy riding on low labour cost advantages
- However, India's low labour cost advantage extends beyond labour intensive manufacturing
  - To skill based services like software and IT, biotechnology, and long-distance communication based services
  - And also to, few industries within the manufacturing sector which requires process, product and capital engineering skills such as auto-components, pharmaceuticals, forgings, power and transport machinery, high-end electrical and electronics and speciality chemicals – leading India to be considered a design house, a tooling centre, a components base and a manufacturing hub

- However, India’s technological advantages in these skill intensive areas have still by and large remained confined to the domain of minor as opposed to major innovative capabilities
  - India has demonstrated significant competitive strength in routine (though skill intensive) tasks like coding (in software) or process development (in pharmaceuticals), and perhaps not so in creativity and innovativeness
- The Way Forward
  - Critical juncture : India is imminently poised for a successful transition to a knowledge economy
  - Need to revitalise India’s technological capability building through the most appropriate coupling of creative pursuits (especially through public funded research) with applications for industrial R&D
  - Need to harness the “rich” research potential of the huge pool of premier universities and institutions to make for a successful transition to a knowledge driven economy
  - However, while carving out appropriate (optimum) technology strategy for India one cannot ignore the labour intensive manufacturing where productivity augmentation through *know-how* may prove to be crucially important for sustained TFP growth and industrial development
  - Finally, there is every need to focus on “inclusive” technology strategy for the sustainability of India’s growth process

Thank you