Technological Challenges and Opportunities of India

Mains: *GS III – Science and Technology*

Why in News?

In recent years, despite technological advancement, India has not been able convert technological innovation into globally dominant enterprises and industrial ecosystems.

What is India's history of technological vision?

- **Semiconductor Ambitions –** In the 1970s, India established the *Semiconductor Complex Limited (SCL).*
- It recognized the transformative potential of integrated circuits long before semiconductors became the backbone of the digital economy.
- This early vision reflected a deep understanding of future technological trends.
- However, while countries such as Taiwan and South Korea developed globally competitive semiconductor industries through firms like TSMC and Samsung, India failed to build a large-scale manufacturing ecosystem.
- The reasons included inadequate capital investment, limited access to global markets, policy inconsistencies, and excessive dependence on a public-sector-led model.
- **Electronics Corporation of India Limited (ECIL) –** Established in 1967, ECIL played a crucial role in developing indigenous computers, strategic electronics, and control systems during a period of international technology restrictions.
- It strengthened India's technological self-reliance and contributed significantly to strategic sectors.
- Nevertheless, ECIL largely focused on government and strategic requirements rather than commercial scalability.
- Consequently, technological excellence remained confined within institutions and did not translate into globally competitive businesses capable of driving industrial growth.
- **The Simputer –** It was, developed in 1998 by Indian technologists, and sought to create an affordable computing device for the masses.
- It incorporated several features that later became common in smartphones and tablets.
- Despite its innovative design, the Simputer failed to achieve widespread adoption.
- The supporting ecosystem, including venture capital, software platforms, supply chains, and consumer demand—was insufficiently developed.
- In contrast, companies such as Apple successfully combined technology, design, ecosystem development, and market strategy to create globally dominant products like the iPhone.
- The Simputer illustrates a fundamental lesson, technological innovation without

ecosystem support rarely achieves global success.

Why India often struggled to scale innovation?

- **Limited Commercialization –** Many innovations emerged from research institutions and public-sector organizations but lacked pathways for commercialization.
- Research excellence did not consistently translate into market leadership.
- **Weak Industrial Ecosystems –** Technological industries require interconnected ecosystems comprising manufacturers, suppliers, investors, research institutions, skilled talent, and consumers.
- India often developed technological capabilities without simultaneously nurturing these complementary structures.
- **Inadequate Risk Capital –** The absence of robust venture capital and long-term investment mechanisms constrained the growth of technology-intensive industries.
- Scaling innovation requires substantial financial support over extended periods.
- **Policy and Regulatory Constraints –** Frequent policy changes, regulatory bottlenecks, and limited integration with global value chains hindered the emergence of globally competitive enterprises.
- As a result, India frequently succeeded in creating prototypes and pilot projects but struggled to transform them into world-leading industries.

What are the other Indian success stories?

- **Pharmaceutical Industry –** India’s pharmaceutical sector evolved into a global manufacturing powerhouse.
- Through investments in scientific capability, cost-effective production, and export competitiveness, India became known as the *“pharmacy of the world.”*
- The country now supplies affordable medicines and vaccines to numerous nations.
- **PARAM Supercomputing Programme –** India’s indigenous supercomputing initiative demonstrated the country's ability to overcome technological restrictions and develop advanced computing capabilities.
- It highlighted the importance of strategic investment and long-term commitment.
- **Aadhaar and UPI –** More recently, Aadhaar and the Unified Payments Interface (UPI) have emerged as *globally recognized examples of digital innovation at scale.*
- These platforms transformed financial inclusion and digital governance by serving hundreds of millions of users.
- Their success demonstrates a critical principle, scale creates ecosystems, ecosystems create industries, and industries generate global leadership.

What are the emerging opportunities for India?

- **Artificial Intelligence –** AI is expected to transform economies, governance, healthcare, education, and manufacturing.
- India possesses significant advantages, including a large pool of software engineers, vast digital datasets, and robust digital infrastructure.
- The emergence of efficient AI models has shown that leadership in AI is not solely determined by building the largest systems.
- Cost efficiency, accessibility, and widespread adoption are equally important.

- India can leverage its strengths to develop affordable and energy-efficient AI solutions tailored to developing economies.
- Just as UPI democratized access to financial services, India can aspire to democratize access to artificial intelligence for billions of people globally.
- **Quantum Computing –** Quantum computing has the potential to revolutionize drug discovery, materials science, cryptography, and climate modeling.
- Instead of merely replicating existing global approaches, India should focus on reducing the cost of quantum infrastructure and developing practical applications that address societal and industrial challenges.
- Strategic investments in research, talent development, and industry-academia collaboration will be crucial.
- **Space Technology –** India's achievements through Chandrayaan and Mangalyaan missions have established its reputation for cost-effective innovation in space exploration.
- The next phase should involve building commercially viable space enterprises.
- Emerging concepts such as space-based data centers, orbital computing infrastructure, satellite-enabled AI systems, and quantum communication networks present new opportunities.
- Given its expertise in frugal engineering, India is well-positioned to lead the development of affordable space technologies that can serve global markets.

What measures could be taken?

- **Strengthening Innovation Ecosystems –** Research institutions, startups, investors, manufacturers, and universities must operate within integrated innovation ecosystems.
- Collaboration among these stakeholders is essential for transforming ideas into products.
- **Encouraging Private Sector Participation –** The private sector must play a leading role in commercializing technology.
- Government support should focus on creating enabling conditions rather than solely operating enterprises.
- **Expanding Access to Capital –** Technology-intensive industries require patient capital and long-term investment.
- Strengthening venture capital networks, sovereign funds, and public-private financing mechanisms can accelerate growth.
- **Integrating with Global Value Chains –** Participation in global supply chains enhances competitiveness, technology transfer, and market access. India must position itself as a key player in emerging technological industries rather than remaining a peripheral participant.
- **Promoting Mission-Oriented Policies –** Long-term and stable policy frameworks are necessary to support sectors such as semiconductors, AI, quantum technologies, and space.
- Consistency in implementation is critical for attracting investment and building confidence.

What lies ahead?

- India’s technological history is not a story of failure but of unrealized potential.
- The experiences of SCL, ECIL, and the Simputer demonstrate that innovation without scale is insufficient.
- Conversely, the success of pharmaceuticals, Aadhaar, and UPI illustrates how technological capabilities can be transformed into impactful and globally relevant systems.
- The challenge is no longer merely to invent new technologies but to build ecosystems, industries, and enterprises capable of competing on a global scale.
- Nations that lead the future will not necessarily be those that innovate first, but those that successfully scale innovation into transformative economic and technological power.
- For India, the goal must be clear, to combine scientific ingenuity with global ambition and emerge not only as a creator of technology but also as a leader in shaping the industries of the future.

To take mains test click *here*

Reference

The Hindu| India’s Technological Challenge