

Managing Complexity:

India's Semiconductor Ambitions &
New Industrial Policy

Vikash Yadav

Department of International Relations, Asian Studies

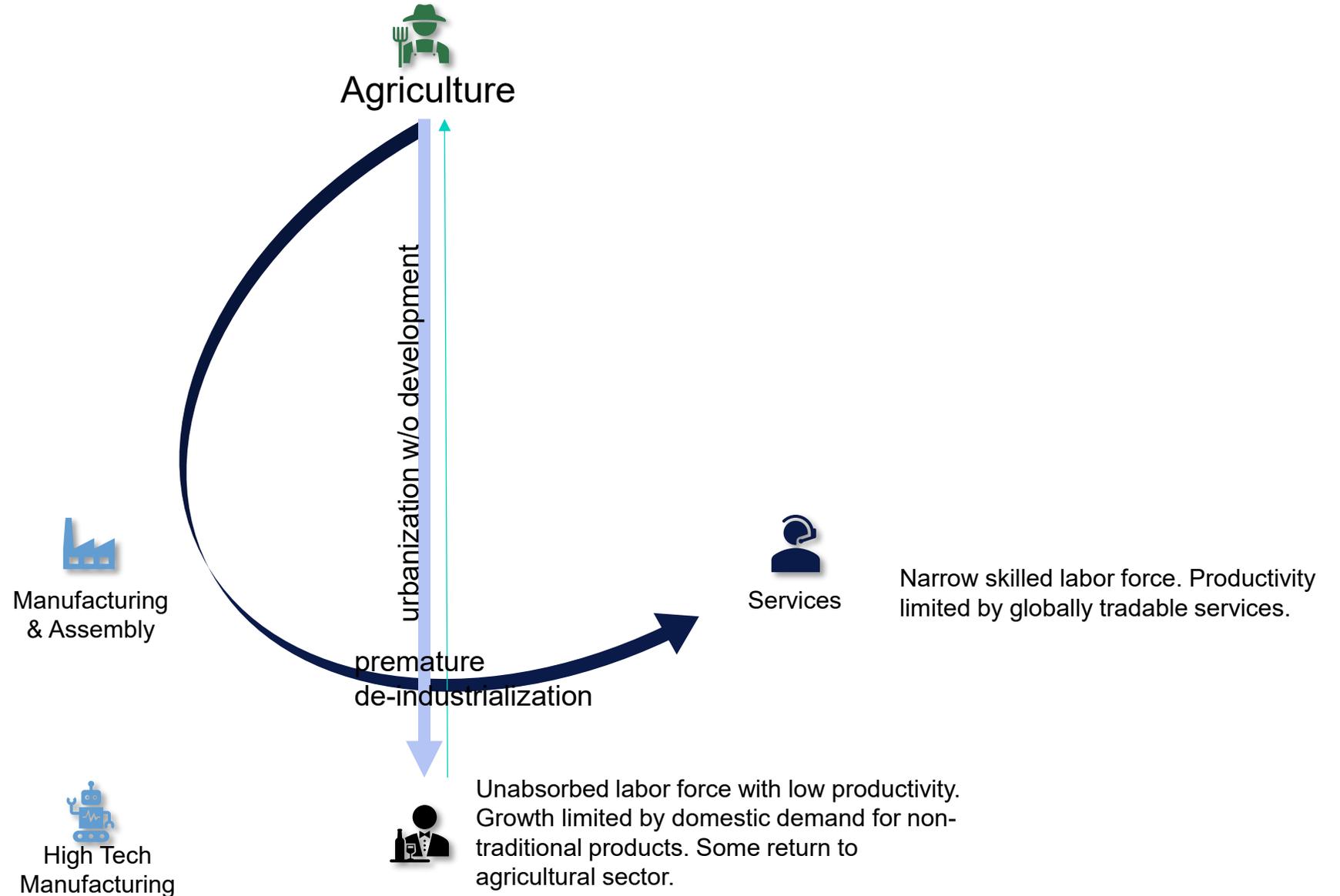
Hobart & William Smith Colleges

Geneva, NY



India's New Industrial Strategy

India's economic development strategy since economic liberalization in 1991 has not spurred manufacturing, particularly prestigious high-tech manufacturing.



India's has developed a new industrial strategy in 2020-2021 to create more manufacturing jobs and particularly more high-tech manufacturing.

India's New Industrial Strategy
(Production Linked Incentive Scheme 2020 +
Semicon India Programme 2021)

Aims:

1. Emulate China's "bird-cage" strategy and hope that "friendshoring" and geopolitical tensions will make India relatively more attractive.

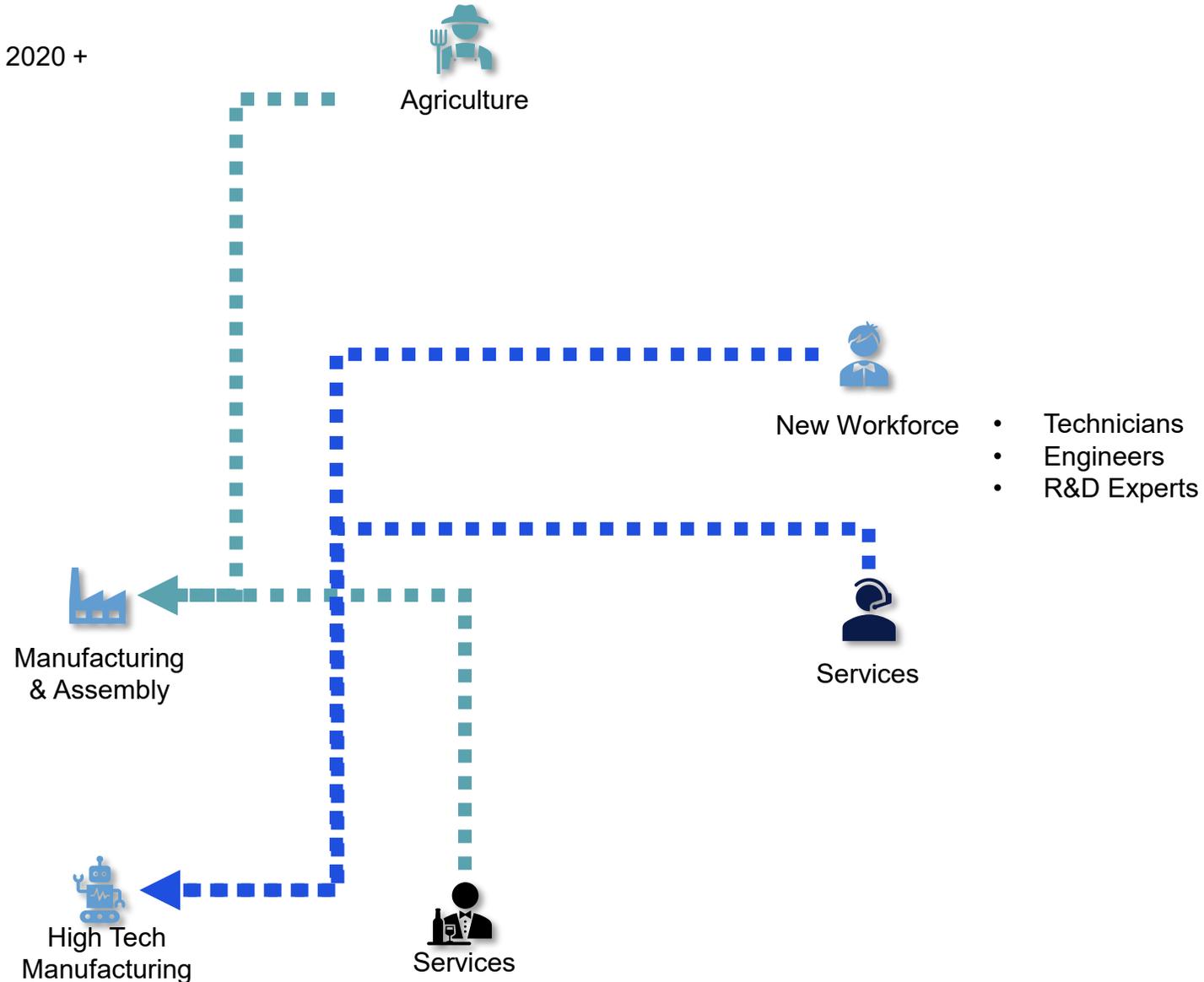
2. Achieve autarchy in the entire supply chain.

BJP Strategy



Bird = Subsidized firm

Cage = Strongman "stability"

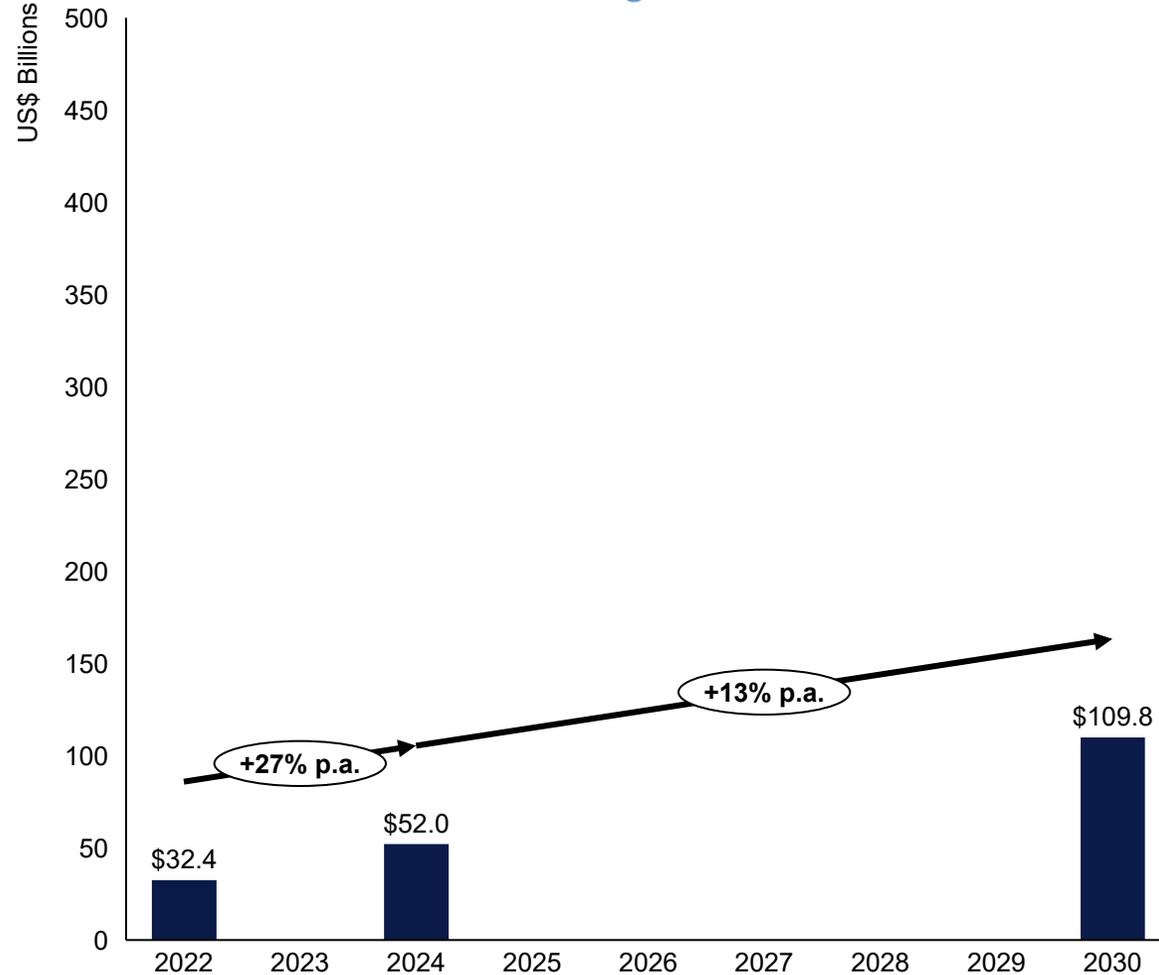




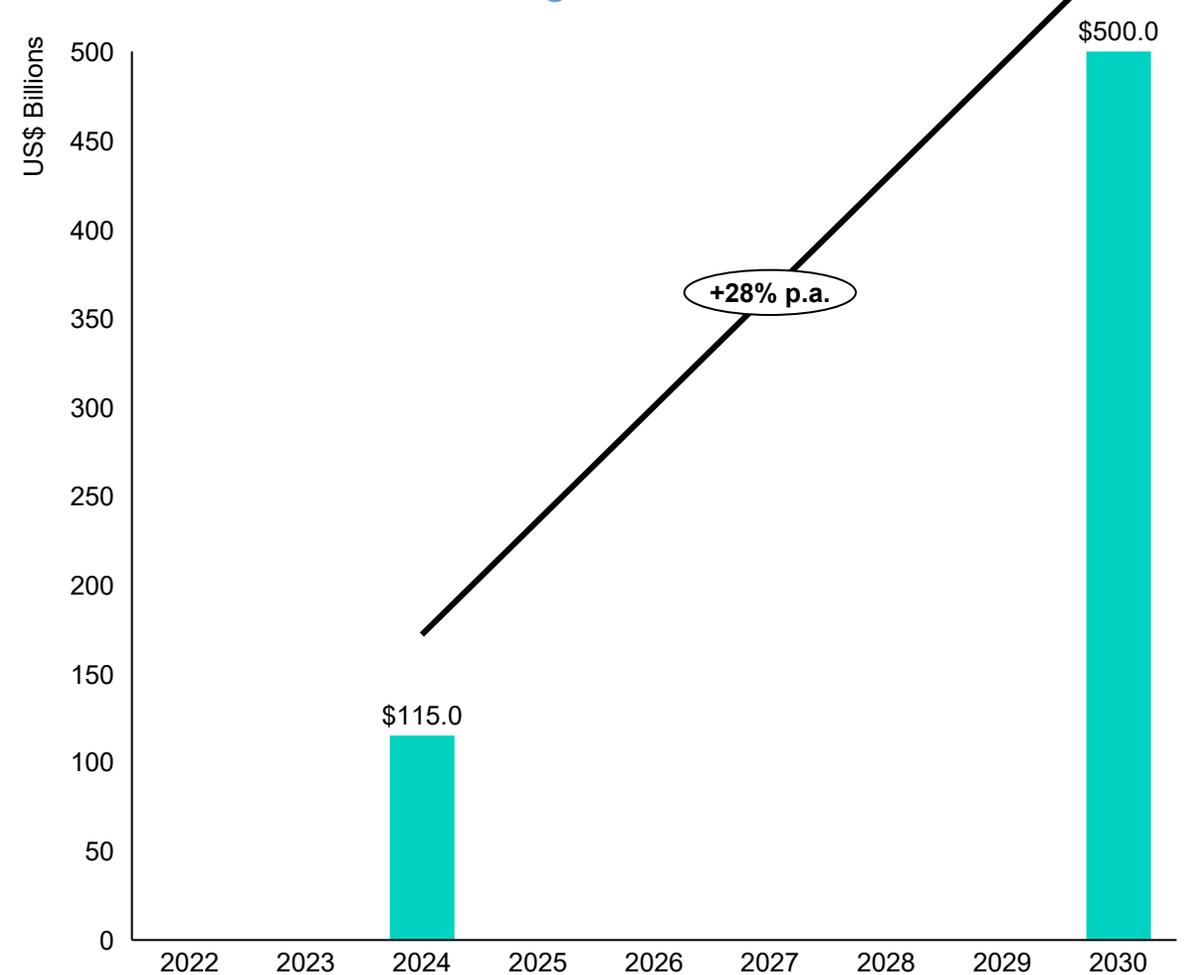
India's Semiconductor Industry

India wants its semiconductor industry to grow to be worth \$109.8 billion by 2030, which implies a 13% CAGR. The target for the electronics industry is \$500 billion (or 28% CAGR).

Semiconductor Manufacturing



Electronics Manufacturing

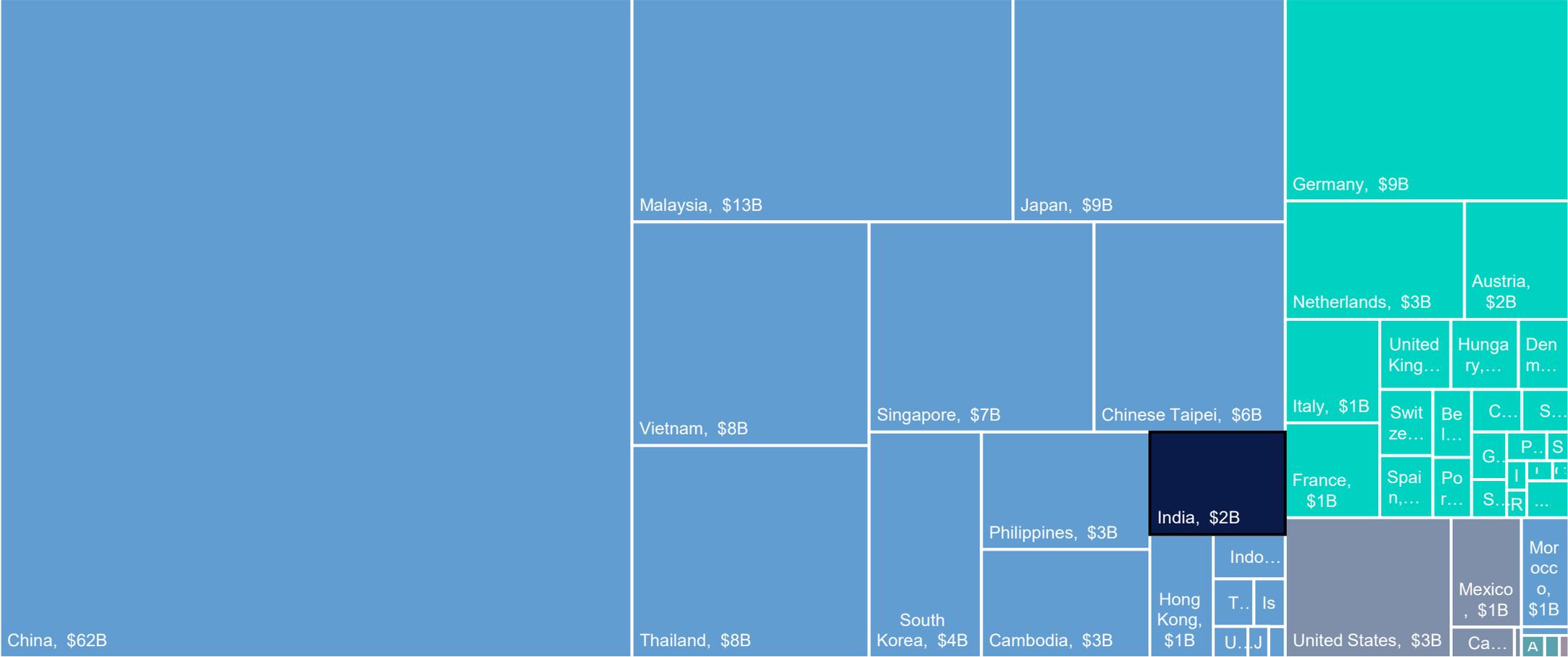


Source: Anoop Verma, "India's Electronics Ambition Grows to \$500 Billion: PM Modi Sets the Target for next 6 Years - ET Government," Blog, ETGovernment.Com, September 30, 2024, <https://government.economictimes.indiatimes.com/blog/indias-electronics-ambition-grows-to-500-billion-pm-modi-sets-the-target-for-next-6-years/113788757>.

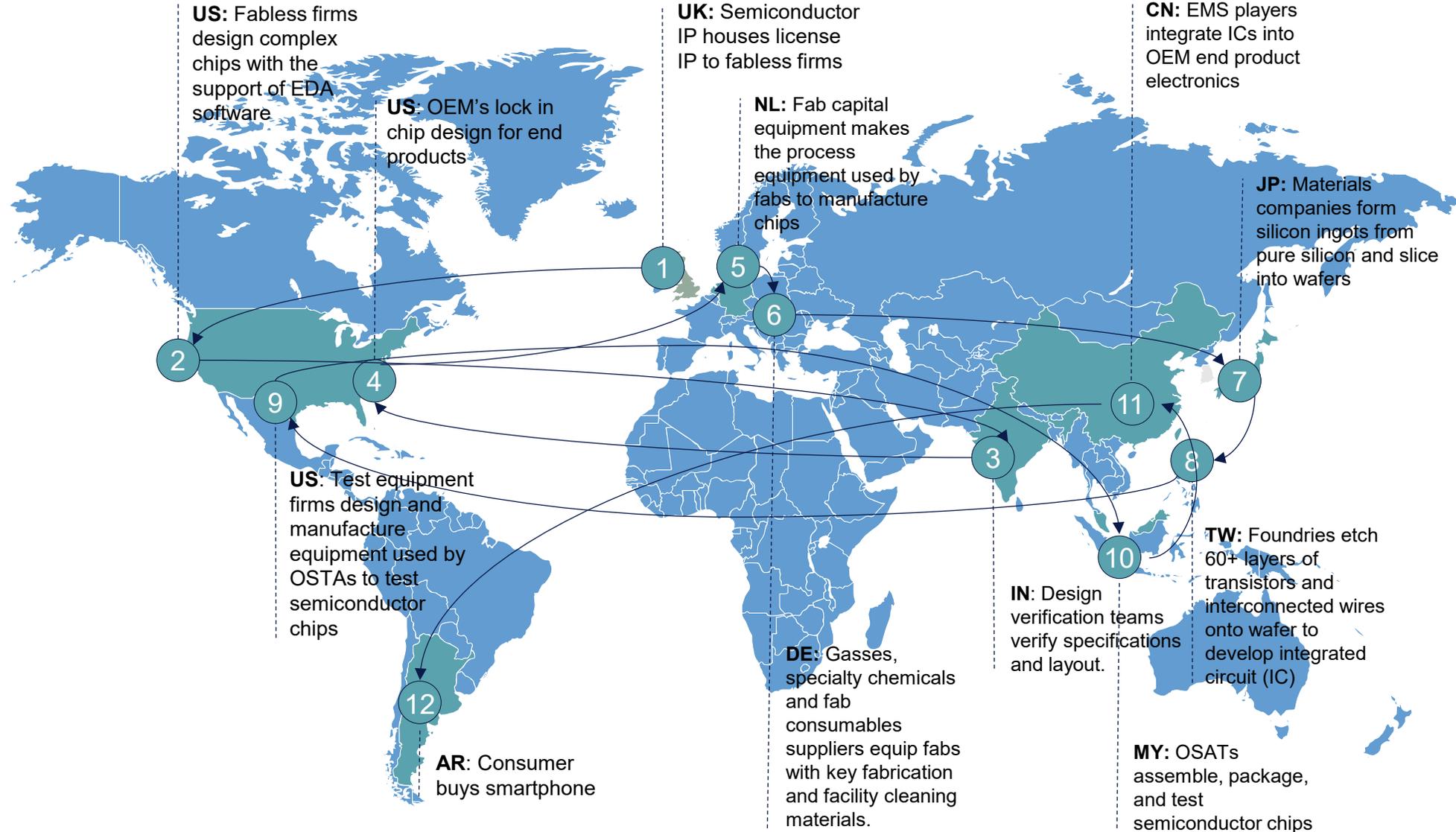


However, India has lagged relative to Asian countries in high-tech manufacturing. It has only 1% of market share in global semiconductor exports.

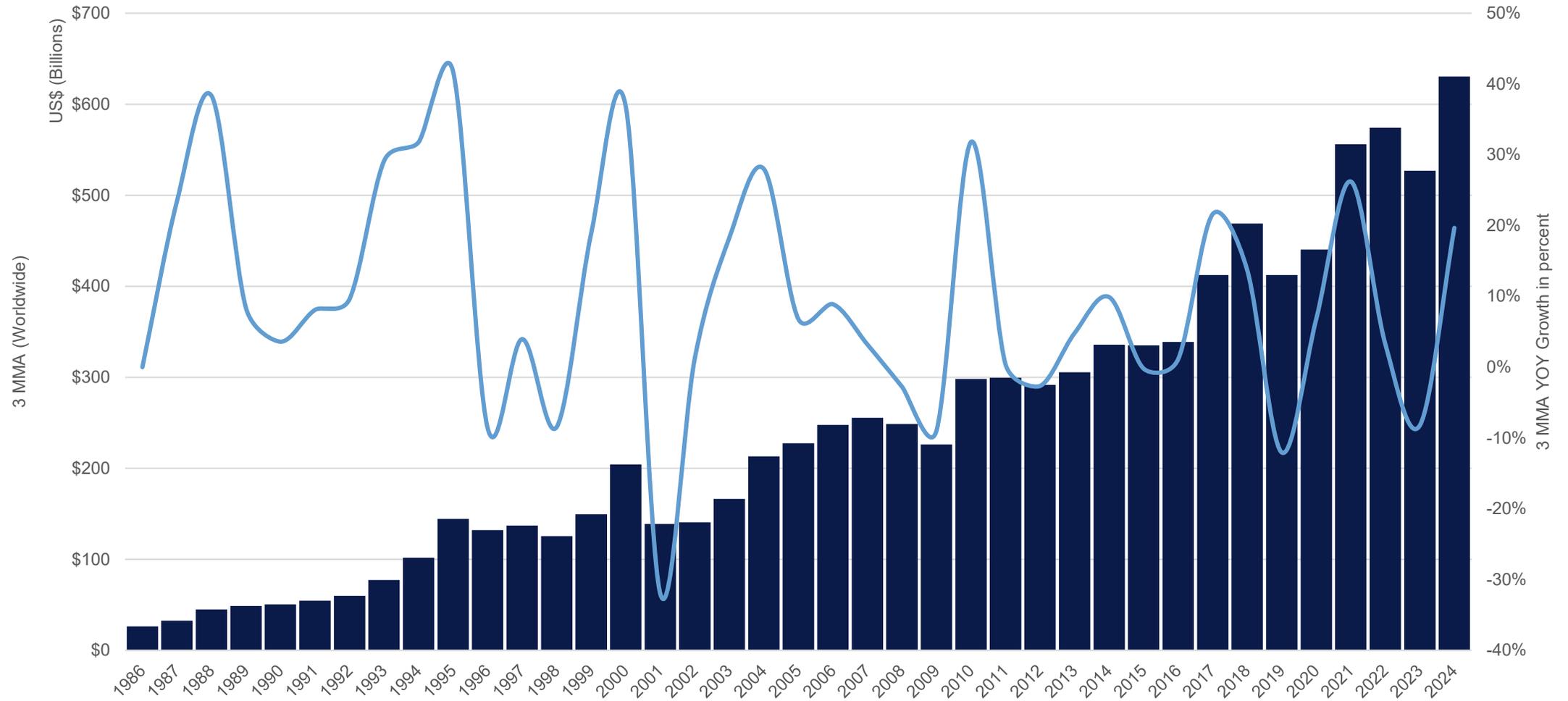
Export of Semiconductor Devices, 2023 (US\$ billions)



Semiconductor supply chains are among the most complex and globalized of any industry.



The global semiconductor industry is lucrative but extremely cyclical making centralized planning a fraught exercise.





A Complex System

1. Complex systems emerge organically and without design; they evolve and expand to generate a durable, coherent structure beyond individual elements.

1945 Theorization of solid-state valve

1948 Development of transistor

1955 Establishment of 1st semiconductor firm

1958 Creation of first integrated circuit or chip

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2025 Ten of thousands of firms in the value chain; 3 valued over \$1 trillion dollars (NVIDIA, Broadcom, and TSMC)

- The **global semiconductor industry is unplanned, highly decentralized** (despite some key sites of agglomeration), composed of a wide variety of agents, and interactions between agents are generally mediated through market relations.
- The **market provides the primary feedback loop** which helps to shape the evolution of the order as a whole.
- The **industry has persisted, innovated, and continuously evolved** since the mid-20th century.
- It is reasonable to describe the semiconductor industry as a **persistent spontaneous order**.
- While elements of this spontaneous order may be replicable the whole is **too complex to capture and funnel into one country**.



2. Knowledge is fragmented in a complex system; no one entity can have a comprehensive view of the totality.

Immense Number of Actors



In the semiconductor manufacturing space there is **an immense range of actors and networks**, including universities, research laboratories, financial organizations, venture capital firms, government agencies, military bureaucracies, aerospace firms, telecommunications companies, automotive manufacturers, personal computer producers, video gaming programmers, television manufacturers, etc.

Modularity Increases Competition



Moreover, semiconductor design has been increasingly decoupled from manufacturing allowing specialist firms to enter in both the design and manufacturing areas. In fact, the use of standardized Electronic Design Automation (EDA) tools, **standardized interfaces between components**, and a market in intellectual property licensing has **allowed a modular system to emerge in which “blocks of intellectual property (‘design blocks’) could be exchanged and licensed across products and companies.”**

Demand for Tailored Products



Given variable product life cycles due to constantly shifting consumer demand, the stable architectural standard became impractical. **Firms increasingly demanded tailor made rather than standardized semiconductors** to gain market share over rival firms.

Start-up Fabless Firms Compete with IDMs



Thus, **startup “fabless” firms (i.e., chip design firms) and silicon foundries (i.e. chip makers) could compete with established Integrated Device Manufacturers (IDMs)** to meet user demand for customized chips. In such a fragmented and ever shifting sector, the notion of creating a vertical monopoly in manufacturing is deeply misguided.

3. Complex systems are often built on tacit knowledge. This allows dynamic adaptation but also complicates efforts at replication.

Codified Knowledge Facilitates Globalization



In the semiconductor industry, a great deal of knowledge on the supply side has gradually shifted from tacit to **codified to make it more transferrable across borders**.

Tacit Knowledge Needed to Tailor Products



Applied knowledge is needed to adapt devices to the specific needs of an increasingly wider variety of final products requires knowledge of complex systems and hence often remains tacit.



Greater flexibility and **customization** of semiconductor chips also **increases the design complexity** of the end products.



The **“stickiness”** of knowledge spurs rapid **innovation** because stickiness allows the benefits of innovation to remain high, there is greater incentive to innovate.

4. Institutions evolve to facilitate and stabilize coordination within a complex system.

State Intervention



Complexity does not rule out the **possibility of beneficial state intervention**, but state intervention does not necessarily facilitate **enhanced complexity**.

Although states might be able to intervene to create more space for dynamic corporations that are responsive to consumer demand, it is questionable whether highly bureaucratic control over state-subsidized firms will lead to beneficial outcomes in this industry.

“Liberalism recognizes that **there are certain other services** which for various reasons **the spontaneous forces of the market may not produce** adequately, and that for this **reason it is desirable to put at the disposal of government a clearly circumscribed body of resources with which it can render such services to the citizens** in general.”

-Friedrich Hayek, “The Principles of a Liberal Social Order,” *Il Politico* 31, no. 4 (1966)



India's Developmental State Ambitions

India faces four distinct challenges in guiding its semiconductor manufacturers.

1. Nationalist Desires + Risk Aversion + Bureaucracy



The Modi administration created “public venture capital” to fund fabless firms.

Firms that participated in the DLI program had to agree to **remain domestic** for three years after receiving funding – meaning they could not raise more than half of their capital via foreign direct investment.

The **funding caps** on the public venture capital were quite modest

Bureaucratic hurdles in the application and disbursement processes deterred many firms

2. Undeveloped Intangible Infrastructure



Modern semiconductor fabrication requires not only cleanroom precision but also near-flawless **alignment across regulatory norms, customs efficiency, land and water provisioning, skilled labor availability, and energy reliability.**

3. Quantification Bias + Impatience



There is often a **bias** in public investments **toward short-term projects whose contribution can be easily quantified.**

Long-term strategic investments are not only riskier, but also difficult to measure.

India has devoted resources to build the proposed \$2.5 billion Bharat Semiconductor Research Center (BSRC) on the model of Taiwan’s Industrial Technology Research Institute (ITRI, est. 1973).

Whether India’s government has the **patience** to invest in a public research institute for a quarter century at rates approaching their current levels of military spending, is doubtful.

4. Political Connections



The **allocation of subsidies based on political connections** and corruption in India is not new but the prestige of semiconductor manufacturing is adding intensity to this dynamic.

A prominent example was the decision to establish the International Semiconductor Consortium and the Vedanta-Foxconn factories in Prime Minister Modi’s home state of Gujarat just ahead of elections in December 2022, even though the company had been in prolonged negotiations with the state of Maharashtra.

India has yet to learn from its own earlier efforts to guide the development of an indigenous semiconductor industry.

Although larger scale integrated circuits have market value, India's SCL was always far behind the cutting edge.

1976

Parliament Approves Plan

- public-sector undertaking to build a Semiconductor Complex Ltd. (SCL) in Mohali, Chandigarh
- Joint-venture with America's Advanced Microsystems
- **5 micron (5,000nm chip)**

1984-1989

SCL Operational

- Factory burns down in 1989

1997-2005

SCL Operational again...

- Makes \$400k profit in 1999

2005-2023

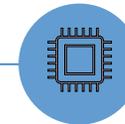
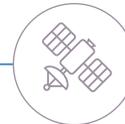
SCL → Department of Space

- **Produces 180nm chips**
- Renamed: Semi Conductor Laboratory
- Mars Orbiter Mission (MOM)

2023-Present

SCL → Ministry of Electronics and Information Technology

- Gov. plans to invest \$2b to modernize facilities.
- **Hope to develop 28nm**



International Benchmarks

