ISSUES & INSIGHTS
VOL. 25, SR 4

SEPTEMBER 2025

PACIFIC FORUM INTERNATIONAL

Enhancing Semiconductor Technology Protections in India

EDITED BY
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Introduction

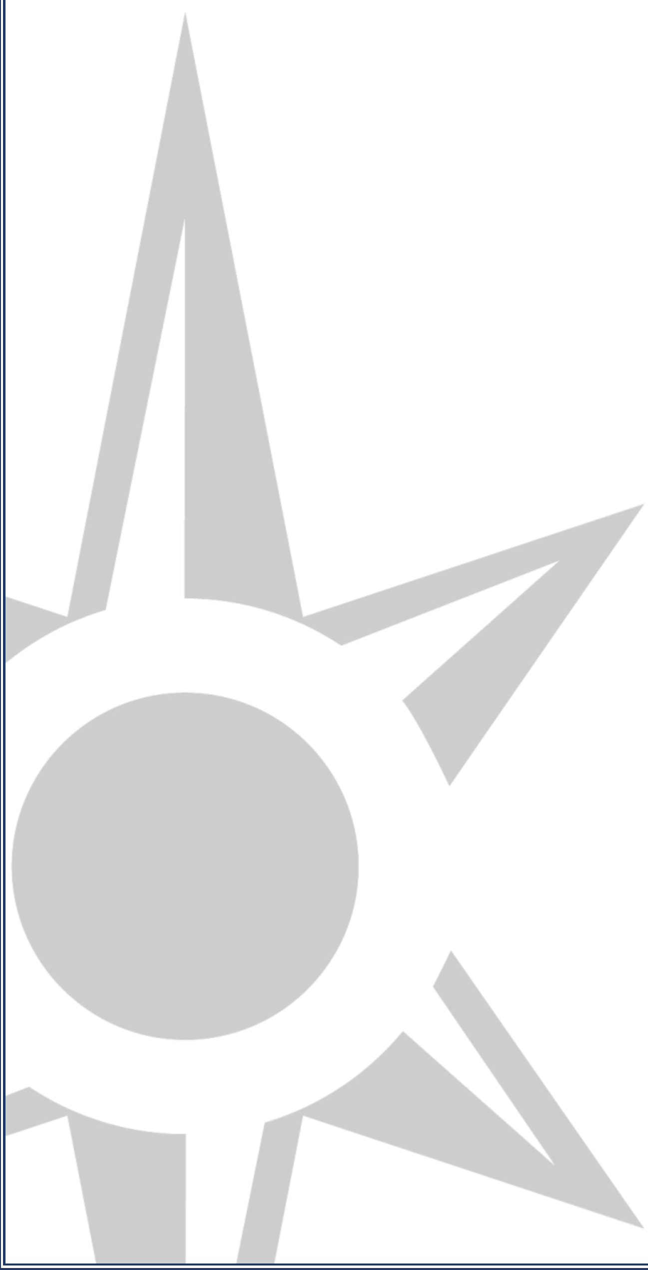
Over the course of 10 months, eight India Technology Policy fellows engaged in substantive research on policies related to India's semiconductor manufacturing ecosystem. The eight fellows engaged in independent primary and secondary research and shared their findings in topical opinion articles in major Indian publications. Toward the end of their fellowship—sponsored by the Export Control and Related Border Security (EXBS) Program at the US Department of State—in summer 2026 Pacific Forum organized a trip to multiple cities in the US, providing the fellows an opportunity to interact and learn from industry, government and academia—informing their research and analysis. Their fellowship concluded with policy papers offering actionable policy recommendations to enhance semiconductor technology protections and thereby trade with India. Find here, eight policy papers covering various areas of US-India semiconductor cooperation.

Akhil Ramesh
Director of India Program & Economic Statecraft Initiative
Pacific Forum

Photo: Workers assembles smartphones at Dixon Technologies factory in Uttar Pradesh, India, on Thursday, Jan. 28, 2021.
Bloomberg | Getty Images

Assessing the Design Linked Incentive (DLI) Scheme for Strengthening India's Semiconductor Design Landscape

By
Harsha Singh



Executive Summary

Harsha Singh

The semiconductor industry in India shows a dichotomy like no other. The Indian government has allocated a whopping ₹76,000 crore ($10 billion) under the Semicon India Programme for the development of a semiconductor ecosystem in India. However, ground realities present a superficial understanding of the industry. The country is home to over 250 fabless companies and approximately 20% of the world's semiconductor design talent, yet the design ecosystem faces significant challenges in securing the financial investments needed for its growth. As of 2024, very little private sector investment is happening in the industry despite the sector being the government's focal point.

For the sector to truly thrive, it must be willing to accept a higher degree of failure and risk. The path to revolutionizing the semiconductor industry is not linear, and it is essential to provide support to companies at all stages of development. Therefore, incentives should be designed to target both established, proven companies and newer startups. A well-rounded approach would allow for a diverse and dynamic innovation landscape, where the possibility of failure is balanced with the immense potential for success and breakthrough technologies. By catering to companies with various levels of risk, the ecosystem can foster a more balanced, progressive approach to technological advancement.

Harsha Singh

Introduction

The semiconductor industry in India shows a dichotomy like no other. The Indian government has allocated a whopping ₹76,000 crore ($10 billion) under the Semicon India Programme for the development of a semiconductor ecosystem in India. However, ground realities present a superficial understanding of the industry. The country is home to over 250 fabless companies and approximately 20% of the world's semiconductor design talent, yet the design ecosystem faces significant challenges in securing the financial investments needed for its growth. As of 2024, very little private sector investment is happening in the industry despite the sector being the government's focal point.

The broader question India must consider is whether its semiconductor ambitions are best served by focusing primarily on large firms or by fostering a vibrant ecosystem of startups and small to medium-sized enterprises (SMEs). While countries like Japan and South Korea have historically prioritized larger companies to scale quickly and meet geopolitical goals, others, such as Taiwan and Israel, opted to build agile, innovation-driven ecosystems around SMEs. Given India's demographic diversity, regional disparities, and vast talent pool, the latter model may be more effective. A thriving startup ecosystem will not only enhance innovation but also foster job creation, regional development, and supply chain resilience—factors that are crucial for a self-reliant semiconductor industry.

The Design Linked Incentive (DLI) scheme was introduced by the Ministry of Electronics and Information Technology (MeitY) in December 2021 under the broader ₹76,000 crore semiconductor program to boost the design sector, with approximately ₹1,000 crore ($11.5 million) allocated specifically for this component.

The scheme's goal was to support the development of 100 domestic semiconductor design companies in fields like integrated circuits (ICs), chipsets, system on chips (SoCs), systems and IP cores, and semiconductor-linked designs, with at least 20 companies achieving a turnover exceeding ₹1,500 crore ($17.32 million) in the next five years from the date of its launch. However, only 12 startups have received approval under the scheme as of September 2024, well short of the five-year target of 100 startups. This gap reveals a troubling trend: While there are opportunities for innovation, the system to turn this potential into real financial and infrastructural support appears lacking, showing a disconnect between policy goals and real-world results. The marked differences in fund allocation between the design and manufacturing sides highlight the problems within India's semiconductor sector. While chip manufacturing companies can successfully use large incentives and are backed by established players, the design side is still lacking funds. The disparity raises urgent concerns about how resources are allocated and what the strategic priorities are. Unequal access to venture capital funding in the design space worsens this issue, hindering innovation and limiting growth options for new companies. In contrast to larger manufacturing operations, which gain from economies of scale and hefty financial reserves, design firms often face major hurdles in obtaining necessary funding, leading to slower progress on new technologies and products. This imbalance hinders existing projects and could threaten India's competitive position in the global semiconductor arena.

The present framework for supporting companies within the semiconductor sector disproportionately benefits established, low-risk businesses, leaving startups with high-potential, but unproven, designs to struggle. The key stipulation of the scheme—requiring that product designs be "demonstrated in an operational environment and ready for volume production"—creates a significant roadblock for startups with innovative concepts that are still in their infancy. While these mature companies may provide stability and security, they are not the ones pushing the boundaries of innovation. It is the early-stage ventures that often come up with groundbreaking intellectual property (IP) that could disrupt and transform the industry.

This focus on lower-risk, established companies ultimately undermines the overall advancement of the semiconductor ecosystem. By excluding startups that may be working on risky but high-reward ideas, the scheme inadvertently reduces the diversity of innovation. Many of the most game-changing products in the tech world have emerged from high-risk ventures, and without the backing of incentive programs, such innovations could be stifled before they even have a chance to take off.

For the sector to truly thrive, it must be willing to accept a higher degree of failure and risk. The path to revolutionizing the semiconductor industry is not linear, and it is essential to provide support to companies at all stages of development. Therefore, incentives should be designed to target both established, proven companies and newer startups. A well-rounded approach would allow for a diverse and dynamic innovation landscape, where the possibility of failure is balanced with the immense potential for success and breakthrough technologies. By catering to companies with various levels of risk, the ecosystem can foster a more balanced, progressive approach to technological advancement.

Another critical factor is the lack of institutional support for intellectual property enforcement. Recent cases of IP violations have shown immense difficulties when attempting to seek recourse, even after credible design theft or data misuse has occurred. The absence of a legal or regulatory mechanism to protect their IP significantly lowers trust in the ecosystem and creates a chilling effect on design innovation. This is particularly dangerous for a sector where proprietary IP is often the primary asset.

Despite a vast talent pool, workforce readiness in India is hampered by gaps in advanced design skills and a misalignment between academic curricula and industry requirements. This challenge is further intensified by declining enrollment in engineering programs and a lack of industry-specific training.

India's heavy dependence on imports for semiconductors and related components significantly contributes to its trade deficit, especially with China. The inability to domestically manufacture critical components underscores fundamental weaknesses within the ecosystem.

Drawing lessons from Taiwan, Israel, and the US, the paper contends that a recalibrated approach that de-risks early-stage innovation and ensures institutional recourse is essential. Without this, India may find itself subsidizing operational capacity without fostering original design capability. The paper concludes with recommendations to restructure the DLI scheme, strengthen IP enforcement, and build public institutions to support market access and compliance. India's strategic autonomy in semiconductors ultimately depends not on fabs alone, but on the ability to produce and protect indigenous design innovation.

Methodology

- **Research Design**

This research employs a qualitative, mixed-methods approach to investigate the policy tools best suited for fostering semiconductor innovation in emerging economies. Combining stakeholder interviews, legal analysis, and comparative policy review, the methodology is designed to capture both the formal structures of policy interventions and the informal, often fragmented, realities of implementation in these economies.

The study covers a historical understanding of policy evolution, institutional learning, and the changing global semiconductor landscape.

- **Data Collection and Sources**

The analysis draws on both primary and secondary data sources, including:

1) Semi-structured interviews with a cross-section of stakeholders: policymakers, startup founders, venture capitalists, trade specialists, and legal experts. These interviews provided grounded insights into policy implementation, private-sector response, and institutional capacity.

2) A policy review of the Design Linked Incentive (DLI) scheme and related government programs aimed at developing India's semiconductor ecosystem.

3) Comparative benchmarking with international semiconductor strategies—specifically:
   - Israel and Taiwan's SME-driven model, and
   - China's state-led subsidy-intensive model.

4) A legal analysis of six prominent IP violation cases in India's semiconductor and telecom sectors, using court judgments and verified legal databases.

5) Review of policy documents, government statistics, industry reports, and media coverage, supplemented with insights from think tank publications, publicly available interviews, and

expert literature, including books such as "When the Chips Are Down: A Deep Dive into a Global Crisis" by Abhiram Manchi and Pranay Kotasthane.

These sources were triangulated to ensure consistency and accuracy in the interpretation of both policy effectiveness and industrial response.

- **Case Selection**

The country cases were selected based on their strategic interest in semiconductor self-sufficiency, ongoing industrial policy reform, and integration (or aspiration to integrate) with the global semiconductor value chain. The selected countries—China, Taiwan, Israel, Japan, South Korea, United States and Vietnam—represent a range of institutional capacities and policy approaches, allowing for cross-contextual learning. Criteria for selection included the presence of national semiconductor programs, availability of legal and policy documentation, and diversity in governance models.

Frameworks for Comparison

The paper draws on the following comparative frameworks:

1. **Design-Led vs. Manufacturing-Led Ecosystems:**

- Taiwan and Israel represent design-led innovation ecosystems that prioritize SMEs and early-stage IP development.
- Japan and South Korea represent manufacturing-heavy models focused on scaling existing industrial players.
- India's current model is more aligned with the latter, but the paper argues for a shift to support design-first, high-risk innovation.

2. **Subsidy vs. Risk-Based Support:**

- China's and the EU's strategies heavily use direct subsidies and state-backed funds.
- India's DLI offers limited capital and has strict eligibility, restricting riskier but innovative ventures.

3. **IP Infrastructure and Enforcement:**

- India lacks a SEP-specific law and enforceable civil judgment treaties with key trade partners like South Korea.

4. **Global Patent Leadership & Innovation Metrics:**

- Global Innovation Index and WIPO data to show India's relative lag in IP commercialization, especially in chip-related patents.

Background of the Semiconductor Industry in India

The semiconductor industry in India has witnessed significant developments over the decades, marked by a series of pivotal legal and policy milestones. It began in the 1960s with the establishment of India's first semiconductor research laboratory, the Central Electronics Engineering Research Institute (CEERI), in Pilani, Rajasthan. This marked India's initial foray into semiconductor research and development. In the 1970s, the government took a more proactive approach by founding the Semiconductor Complex India Limited (SCL) in Chandigarh to manufacture integrated circuits, laying the foundation for domestic production capabilities. Progress continued in the 1980s with the introduction of the Electronics Policy of 1982, which sought to promote the growth of India's electronics industry by encouraging innovation, research, and development in related fields, including semiconductors.

The 1990s marked a transformative era with the introduction of the New Telecom Policy of 1994, which opened the telecom sector to private investment. The liberalization spurred a surge in demand for semiconductors in India, driven by the rapid growth of telecommunications and related technologies. In the 2000s, the government launched the National Policy on Electronics (NPE) in 2006, to position India as a global hub for electronics manufacturing, with semiconductors forming a critical part of this vision. The following decade saw a further boost with the introduction of the Electronics Manufacturing Clusters (EMC) scheme in 2012. This scheme provided financial incentives to companies establishing semiconductor manufacturing facilities, aiming to foster innovation and attract global investment to build an ecosystem for electronics production.

However, it is in the 2020s that India made one of its most significant commitments to the semiconductor industry by announcing a ₹76,000 crore incentive plan[1] under the broader Semicon India program. The Production Linked Incentive (PLI) scheme under the program seeks to attract global semiconductor manufacturing companies to set up operations in India, strengthen the country's position in the global supply chain, and reduce reliance on imports. The PLI scheme is expected to create over 50,000 jobs and accelerate the growth of India's semiconductor ecosystem by incentivizing innovation, supporting domestic manufacturers, and building critical infrastructure. The DLI scheme,[2] under the Semicon India program, aims to provide financial incentives and infrastructure support to foster the development and deployment of semiconductor designs, including ICs, chipsets, SoCs, systems and IP cores, and other semiconductor-linked designs. Under this scheme, companies can benefit from a "Product Design Linked Incentive" covering up to 50% of eligible expenses, with a maximum cap of ₹15 crore ($1.8 million) per application. Additionally, the scheme offers a "Deployment Linked Incentive" ranging from 6% to 4% of the net sales turnover over a period of five years, subject to a maximum limit of ₹30 crore ($3.6 million) per application.

These efforts underscore India's determination to become a key player in the semiconductor industry, a vital sector for national security and economic growth. Through consistent legal and policy initiatives, India is steadily trying to build the foundation for a self-reliant and globally competitive semiconductor ecosystem.

Current State of Semiconductor Design Landscape in India

India's current semiconductor strategy heavily emphasises large-scale manufacturing, mirroring models seen in South Korea and Japan. While effective for rapid industrial scaling, this model often sidelines startups and SMEs that are essential for grassroots innovation and distributed economic development. In contrast, Taiwan's and Israel's success in semiconductors has been rooted in nurturing dynamic SME ecosystems that emphasise R&D, design, and early-stage innovation. India, with its large youth population and regional diversity, stands to benefit more from an SME-oriented model that catalyses innovation across the country rather than concentrating efforts in a few industrial hubs[3].

Recent trends show that the democratisation of technology has empowered Indian tech startups to expand beyond traditional metropolitan centres, driving growth in Tier II and Tier III cities. The share of tech startups established in emerging hubs rose to 40% in 2023, reaffirming the depth of India's start-up proliferation[4]. With over 63 million Micro, Small, and Medium Enterprises (MSMEs) contributing approximately 30% to India's GDP and accounting for nearly 40% of exports, they are instrumental in job creation, providing employment to about 110 million individuals across urban and rural areas[5].

The semiconductor industry in India stands at an important juncture, particularly in the design field, where there is much potential that remains underutilized. Although it has nearly 250[6] fabless companies and makes up 20% of the world's semiconductor design talent,[7] the design sector has received only a small part of the ₹76,000 crore set aside for the industry. Recent reports show that just 12 startups[8] have made progress under the DLI scheme, well below the goal of supporting 100 companies in five years. This significant gap points to an urgent need for a better framework to encourage growth and investment in the semiconductor design space, making sure that India's strong design talent pool is properly used to boost innovation and competitiveness on the global stage. On the other hand, the chip-manufacturing sector is dominated by larger companies that can manage operations while waiting for government financial help and support. This difference is made worse by the difficulties that design-focused companies face, as they often find it

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[1] "Government Approves Semiconductor and Display Manufacturing Ecosystem," Press Information Bureau, Dec. 15, 2021, https://pib.gov.in/PressReleasePage.aspx?PRID=1781723

[2] Ministry of Electronics and Information Technology (R&D in Electronics Group), *Notification: Design Linked Incentive (DLI) Scheme*, New Delhi, Dec. 21, 2021, https://chips-dli.gov.in/DLI/AbstractFilePathCoded?FileType=RQ==&FileName=R2F6ZXR0ZU5vdGlmaWNhdGlvbl9ETElTY2hlbWUucGRm&PathKey=RE9DVU1FTlRfVEVNUExBVEU=

[3] NASSCOM and Zinnov, India Tech Start-up Report 2023 (New Delhi: NASSCOM, 2023), https://nasscom.in/knowledge-center/publications/india-tech-start-report-2023

[4] Ibid.

[5] Redseer Strategy Consultants, India's Digital SME Credit Gap and Economic Potential, August 2023, https://redseer.com/reports/indias-digital-sme-credit-gap-and-economic-potential/

[6] Environmental, Social and Sustainability Council of India, "Subsector Overview," accessed Dec. 06, 2024, https://essc-india.org/subsector.php

[7] Ibid.

[8] Soumyarendra Barik, "Govt Clears 12 Indian Start-Ups for Incentives under Chip Design Plan," *The Indian Express*, Sept. 9, 2024, https://indianexpress.com/article/business/economy/govt-clears-12-indian-start-ups-incentives-chip-design-plan-9557187/

hard to get enough venture capital for their projects. Consequently, the journey to create a strong semiconductor design environment in India is obstructed by poor financial backing and a lack of investor trust. This issue is highlighted by the tough entry barriers for startups in semiconductor design, where long development times and the need for special skills can discourage funding and growth options, which is in sharp contrast to how bigger manufacturing firms operate.

According to Abhiram Manchi and Pranay Kotasthane in their 2023 book "When the Chips Are Down: A Deep Dive into a Global Crisis," most IP in the semiconductor industry does not belong to Indian companies. They note that the cumulative revenue of domestic semiconductor design firms in India is relatively small, estimated to be less than $50 million (₹415 crore).[9] Manchi and Kotasthane also highlight why there is a lack of investor interest in Indian semiconductor companies. While software product startups in India have thrived, chip design startups have struggled. Unlike the software sector, the semiconductor industry has a much longer gestation period for returns on investment, with a minimum of three years required to bring a final product to market. Consequently, semiconductor design firms face difficulties in attracting investors and venture capital, unlike software companies. Even those firms that overcome these challenges often prefer to raise investments abroad.[10]

Despite the Indian government's efforts to encourage domestic chip design companies, the response has been underwhelming. Manchi and Kotasthane attribute this to two main factors: restrictive access to government grants and unfavorable trade policies. Many promising Indian firms are ineligible for grants because they have foreign investors. Furthermore, anti-dumping policies hinder the import of essential, yet affordable, second-hand chip design tools. These obstacles create significant financial burdens for small and medium-sized enterprises, discouraging their growth within India.

There is therefore a greater need for a detailed plan to develop India's semiconductor design capabilities. A crucial aspect is the DLI scheme, which must shift its focus to tackle the underlying issues that are preventing startups from growing and attracting venture capital in the design area. By creating an environment that fosters innovation and draws in investment, the scheme can help startups change India's semiconductor design scene. Furthermore, making use of India's current design talent and promoting collaboration between universities and the industry will be essential to build a lasting ecosystem. If there are no significant actions taken to improve the design ecosystem, India might not reach its ambitious semiconductor goals, which could hinder its prospects in the fast-changing global semiconductor market.

Subsidies as the Backbone of the Semiconductor Industry

Government support, particularly through subsidies, has played a pivotal role in the growth and development of the semiconductor industry. But industrial policies, such as subsidies, can also lead to inefficiencies by diverting resources to less efficient firms.[11] This can result in the misallocation of resources, hindering overall economic productivity. Subsidies and other forms of government support might favor politically connected or influential firms rather than those with the highest potential for innovation and growth.

China is not an outlier[12] despite its heavy subsidy use; rather, the level of support it offers is comparable to other countries, when considering the size of its market. Other countries, such as the United States, Japan, and South Korea, have also provided significant support to their domestic industries in the early stages of development. China's aggressive state funding for the semiconductor industry has been successful in specific areas, such as legacy chips (>28 nm technology) and semiconductor product design. However, the industrial policy aimed at developing an advanced chip industry has yielded mixed results[13] at best.

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[9] *Million Chips, Billion Dreams - II: Developing Fabless Ecosystem in India*, Invest India, 2021, https://www.investindia.gov.in/blogs/million-chips-billion-dreams-ii-developing-fabless-ecosystem-india

[10] Abhiram Manchi and Pranay Kotasthane, *When the Chips Are Down: A Deep Dive into a Global Crisis* (New Delhi: Bloomsbury, 2023), 136-137

[11] Pinelopi K. Goldberg et al., *Industrial Policy in the Global Semiconductor Sector*, NBER Working Paper No. 32651 (Cambridge, MA: National Bureau of Economic Research, July 2024, revised August 2024), http://www.nber.org/papers/w32651

[12] Ibid.

[13] India Cellular and Electronics Association (ICEA), *ICEA Report to Address the Challenges & Opportunities in Indian Semiconductor Industry*, April 2024, 24

But governments around the world continue to develop targeted incentives and strategies[14] to attract semiconductor investment. Here is a look at some of them:

China is heavily investing in its domestic semiconductor capabilities, with $47 billion in funding from government and state-owned investors as part of its National IC Fund. Beyond production, China is also creating demand for domestically produced chips through local content preferences, domestic standards, and informal government directives.

The European Union (EU) enacted the EU Chips Act in September 2023, aiming to mobilize $47 billion to enhance Europe's semiconductor ecosystem. A key objective is to double Europe's global semiconductor market share to 20% by 2030, fostering both production and design innovation.

Japan is investing around $25 billion to develop its domestic semiconductor industry, with significant focus on supporting cutting-edge chip design through Rapidus, a domestic manufacturer that plans to produce 2nm chips by 2027. This funding will also be directed toward semiconductor fab construction.

Korea announced a support package totaling $19 billion in May 2024 to strengthen its domestic chip design and manufacturing capacity. This builds on an earlier announcement in January 2024 about the establishment of the world's largest semiconductor mega cluster, involving an investment of $472 billion over the next 20 years.

Taiwan passed the Taiwan Chips Act in 2023, providing incentives for the semiconductor industry, including investment tax credits for R&D and equipment, aimed at encouraging design and innovation in the sector.

Southeast Asia is actively working on semiconductor sector development, with countries like Vietnam planning to train 50,000 chip engineers by 2030 to support design and manufacturing. Malaysia's New Industrial Master Plan (NIMP) 2030 includes a focus on encouraging semiconductor design activities such as integrated circuit design.

Latin America is also making strides in semiconductor design. Costa Rica's national semiconductor strategy, announced in March 2024, focuses on building out its assembly, test, and packaging infrastructure while laying the groundwork for future design activities. In Panama, a new Advanced Semiconductor Technology Center is being developed, and Mexico has introduced tax incentives for semiconductor design and manufacturing. Brazil's "More Innovation Semiconductors" scheme, launched in February 2024, offers $20 million in subsidies for investments in semiconductor design, manufacturing, and testing.

The DLI scheme is important for India's goal to build a strong semiconductor design sector. India is home to about one-fifth of the world's semiconductor design talent, yet the design part of the semiconductor industry is equally disadvantaged as the chip manufacturing sector, which has larger firms that can continue operations while waiting for government incentives. Unlike manufacturing, which enjoys considerable financial aid, the design sector suffers from a lack of venture capital, making it difficult for innovative companies to emerge. Investors often favor established businesses with proven track records, leaving new design firms at a disadvantage. This gap highlights the need for the DLI scheme to not just support component assembly but also target more resources towards helping startups that can develop advanced designs. Additionally, the present direction of the DLI scheme could threaten India's long-term goals for leadership in the global semiconductor field, especially as the domestic market is expected to expand exponentially[15] in the next few years. The low participation of micro, small, and medium enterprises (MSMEs) in the design field can hinder competition and innovation, leading to a market dominated by a few companies. A shift in policy is crucial in fostering an environment where startups are supported to innovate. By tackling the lack of venture funds and allocating larger capital towards India's skilled design workforce, the scheme can help create a vibrant semiconductor design ecosystem, allowing India to gain a larger share of the global market and effectively use its capabilities.

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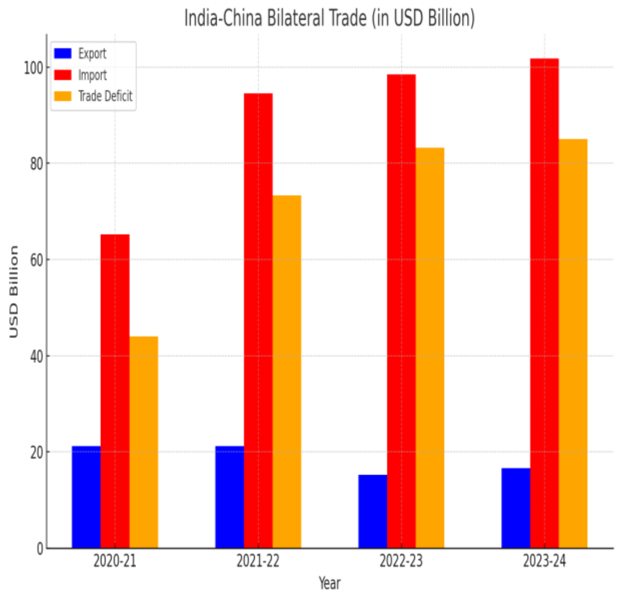
[14] Semiconductor Industry Association, *2024 State of the U.S. Semiconductor Industry*, Washington, DC, 2024, 19, https://www.semiconductors.org/2024-state-of-the-u-s-semiconductor-industry/

[15] India Semiconductor Market Research Report Forecast: 2025-2030, January 2025, MarkNtel Advisors, https://www.marknteladvisors.com/research-library/india-semiconductor-market.html

India's Trade Imbalance: Growing Dependence on China for Semiconductor Imports

The sluggish implementation of the DLI scheme is exacerbating India's dependence on China for semiconductor imports posing a significant challenge for its economy and technology sector, as reflected in the bilateral trade figures[16] from 2020 to 2024. These figures highlight a consistent trade imbalance, driven primarily by India's reliance on China for critical components like semiconductors, which are vital for a wide range of industries, including electronics, telecommunications, automotive, and defense.



Source: Department of Commerce, Ministry of Commerce and Industry, India

Despite efforts to reduce this dependency, the widening trade deficit underscores the structural and strategic gaps in India's domestic semiconductor ecosystem.

From 2020-21 to 2023-24, India's exports to China have remained relatively stagnant, fluctuating between $15 billion and $21 billion. On the other hand, imports from China have surged, crossing the $100 billion mark in 2023-24. This has resulted in an ever-widening trade deficit, which reached a staggering $85.08 billion in 2023-24, up from $44.03 billion in 2020-21. A significant portion of these imports comprises semiconductors and related electronic components, which India has not yet been able to produce domestically at scale.

India's semiconductor imports rose[17] by 18.5% to ₹1.71 lakh crore ($19.777 billion) in 2023-24, reflecting a significant increase in demand. According to data from the Directorate General of Commercial Intelligence & Statistics portal, the country imported 18.43 billion semiconductor chips during fiscal 2024. In comparison, 14.64 billion chips were imported in 2022-23, valued at ₹1.297 lakh crore ($1500 billion). In 2021-22, imports stood at 17.89 billion chipsets worth ₹1.071 lakh crore ($12.387 billion).

A report[18] from the think tank Global Trade Research Initiative (GTRI) highlights a dramatic surge in the imports of diodes, transistors, and similar semiconductor devices, which increased from $113.3 million in 2007-2010 to $2,334.8 million in 2020-2022. During this period, China's market share in these imports rose to 67.5%, underscoring a significant reliance on Chinese semiconductor technology.

The same report highlighted that the import of integrated circuits rose from $166.1 million in 2007-2010 to $4.18 billion in 2020-2022, an increase of 2,415.1%.

Trade imbalance with China places a significant strain on India's foreign exchange reserves and contributes to its overall current account deficit. Heavy reliance on imports also shows the strain on India's domestic manufacturing sector, as local industries are unable to source critical components internally. Dependence on a single country, particularly one with which India has geopolitical tensions, exposes vulnerabilities that could be exploited during conflicts or crises.

As the US-China chip conflict intensifies, global semiconductor supply chains are undergoing major restructuring. India is positioning itself as a potential alternative to China, adopting the "China plus one" strategy.[19] While this offers a strategic advantage, it also places India in a delicate position. Managing its relationships with both the West and China, without

[16] Department of Commerce, Export Import Data Bank: Country-Wise Data (China P RP), accessed Dec. 31, 2024, https://tradestat.commerce.gov.in/eidb/iecnt.asp

[17] "Semiconductor Chip Imports Rise 18.5% to Rs 1.71 Lakh Crore in Fiscal 2024," NDTV Profit, Dec. 6, 2024, https://www.ndtvprofit.com/economy-finance/semiconductor-chip-imports-rise-185-to-rs-171-lakh-crore-in-fiscal-2024

[18] Global Trade Research Initiative (GTRI), *India's Growing Industrial Sector Imports from China*, Report ID 39, May 1, 2024, 14, https://gtri.co.in/gtriFlagshipReportsd.asp?ID=39

[19] Ravi Dutta Mishra and Aggam Walia, "India Had 'Limited Success' in Capturing 'China Plus One' Opportunity: NITI Aayog," *Indian Express*, Dec. 5, 2024, https://indianexpress.com/article/business/india-limited-success-china-plus-one-opportunity-niti-aayog-9706290/

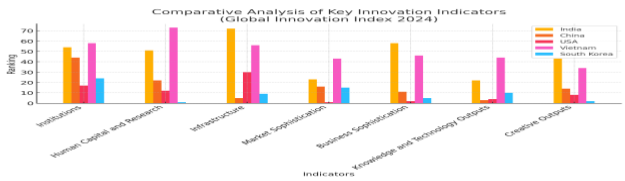
alienating either party, requires careful diplomatic handling.

India's role as an intermediary in the global semiconductor supply chain is also becoming increasingly precarious. A recent Bloomberg report[20] highlighted that a pharmaceutical company in Mumbai exported 1,111 server units to Russia between April and August 2024. For a country like India, positioned at the intersection of global export controls, such situations are a potential risk.

State of Intellectual Property Creation in India

India secured the 39th position among 133 global economies in the Global Innovation Index (GII) 2024, improving from its 40th rank out of 132 economies in 2023.

The table below highlights the 2024 rankings of selected countries across various innovation indicators, including Institutions, Human Capital and Research, Infrastructure, Market Sophistication, Business Sophistication, Knowledge and Technology Outputs, and Creative Outputs.



Source: Global Innovation Index (GII) 2024

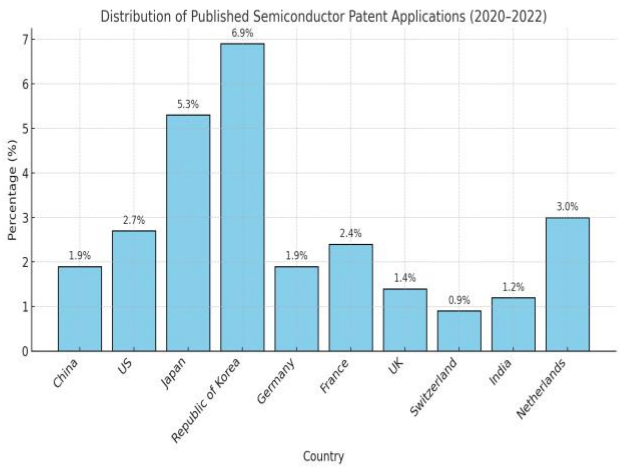
India's strongest performance is in knowledge and technology outputs, where it ranks 22nd, while its weakest ranking is in infrastructure, at 72nd. In the institutions category, India is ranked 54th, pointing to opportunities for improvement in this area.

China outperforms India in most indicators, achieving an impressive fifth rank in infrastructure and third in knowledge and technology outputs. The United States continues to lead globally in market sophistication, business sophistication, and knowledge and technology outputs, underscoring its position as a global innovation powerhouse.

Meanwhile, Vietnam's performance across various indicators signals its emergence as a strong competitor to India in the global innovation landscape.

One of the most relevant GII indicators is Knowledge and Technology Outputs, which measures the generation and commercialization of innovation. Under this indicator, several sub indicators show that India has seen a rise in patent filings and is becoming a strong player.

According to the World Intellectual Property Indicators 2024 report, India ranked sixth globally in patent applications, with 64,480 filings[21] in 2023, with resident filings accounting for 55.2% of all submissions[22]. However, India's contribution to the global semiconductor patent applications[23] during 2020-2022, was 1.2% compared to leading countries like South Korea (6.9%) and Japan (5.3%), showcasing room for growth in this critical technology sector. See the table below.



Source: World Intellectual Property Indicators 2024

The GII report also shows that India continues to lag in IP receipts,[24] ranking 47th, with only 0.2% of its total trade attributed to IP receipts, indicating that India is not yet fully monetizing its innovations.

IP receipts refer to the income that a country generates from licensing its intellectual property to foreign entities. This includes royalties, licensing fees, and payments for the use of patents, copyrights,

[20] Andy Lin, Shruti Srivastava, Advait Palepu, and Viktoria Dendrinou, "Russia is Getting Nvidia AI Chips from an Indian Pharma Company," *Bloomberg*, Oct. 27, 2024, https://www.bloomberg.com/news/features/2024-10-27/russia-is-getting-nvidia-ai-chips-from-an-indian-pharma-company

[21] World Intellectual Property Organization, *World Intellectual Property Indicators 2024* (Geneva: WIPO, 2024), 31, https://www.wipo.int/wipogreen/en/

[22] Ibid.

[23] Ibid.

[24] World Intellectual Property Organization, *Global Innovation Index 2024: The Innovation Frontier*, 17th edition (Geneva: WIPO, 2024), 168, https://www.globalinnovationindex.org

trademarks, and other proprietary assets. A higher percentage of IP receipts in relation to total trade signifies that a country is successfully capitalizing on its innovations and exporting its intellectual property to generate revenue.

Additionally, the Annual Report – Intellectual Property India 2022-23[25] reveals that the applications for Semiconductor Integrated Layout Designs (SCILD), increased from one in 2021-22 to 23 in 2022-23. SCILD involves designing the chip layout which ultimately feeds into the fabrication (fab) process. The increase in applications shows some improvement but there is still significant room for growth in this domain.

IP Violation Case Studies In India's Semiconductor Sector

India's semiconductor design ecosystem faces not only funding and policy challenges but also serious intellectual property (IP) vulnerabilities. Multiple cases over the past two decades highlight systemic gaps in enforcement, litigation infrastructure, and protection. For instance, Analog Devices successfully obtained an injunction[26] from the Delhi High Court in the early 2000s to stop the import and sale of counterfeit energy metering chips by an Indian-based distributor for a Chinese chip maker.

Similarly, in the mid-2000s, Intel secured legal recognition under the Semiconductor Integrated Circuits Layout-Designs Act, 2000 (SCILD), when it sued[27] HCL Infosystems for copying proprietary chip layouts. Intel alleged that HCL had reproduced and distributed semiconductor products containing unlawfully copied layout designs. This case emphasized the importance of clear regulations and effective enforcement mechanisms to address instances of infringement and protect the interests of semiconductor companies in India.

However, the Semiconductor Integrated Circuits Layout-Designs Act, 2000 (SCILD)[28], while well-intentioned, is largely outdated in today's semiconductor ecosystem. Since its implementation, registration rates have remained extremely low. The Act only protects the physical layout of chips and does not cover important innovations like how the chip works, its overall design, or system-level features. This makes it outdated for today's technologies like AI chips, chiplets, and 3D integrated circuits. Moreover, SCILD has not been integrated with key national programs like the Semicon India Programme, making it irrelevant for companies seeking financial and policy support.

Recent cases highlight ongoing challenges in the current regulatory environment. The Standard Essential Patent (SEP) disputes initiated by Ericsson in India, alleging infringement of its 2G and 3G SEPs by companies such as Xiaomi, Micromax, and Intex, underscore key systemic challenges within India's legal and policy framework for intellectual property and technology standards. A key issue is the absence of a SEP-specific legal framework[29], which forces courts to rely on general IP and competition law without clear statutory guidance on Fair, Reasonable, and Non-Discriminatory (FRAND) licensing. This has led to legal uncertainty and inconsistent judicial interpretations.

Ericsson alleged patent infringement on mobile communication standards and sought injunctions and royalty payments from the Indian firms. The Delhi High Court, in several such disputes (including Ericsson vs. Micromax), granted an ex parte injunction without hearing the other party, prompting concerns[30] over procedural fairness and potential abuse of dominant market position, as raised under India's Competition Act, 2002.

Another major point of contention was the royalty calculation method. Ericsson demanded royalties based on the entire mobile device price, while Indian companies argued for the smallest saleable patent-practicing unit (typically the chipset), aligning with international best practices. This led to accusations of excessive royalty demands and unfair licensing terms, particularly harmful to local manufacturers[31].

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[25] Annual Report – Intellectual Property India 2022-23, Government of India, 4, accessed Dec. 6, 2024, https://ipindia.gov.in/writereaddata/Portal/IPOAnnualReport/1_114_1_ANNUAL_REPORT_202223_English.pdf

[26] Ramamoorthy, R. Colin. "Analog Devices Wins Indian Injunction in Counterfeiting Case." EE Times, February 14, 2002. https://www.eetimes.com/analog-devices-wins-indian-injunction-in-counterfeiting-case

[27] *HCL Infosystems Ltd. v. Intel Corporation*, Delhi High Court, 2008 (India)

[28] *Semiconductor Integrated Circuits Layout-Design Act, 2000*, Act No. 37 of 2000 (India)

[29] Payal Malik, Saloni Dhadwal, and Harishankar Thayyil Jagadeesh, *Navigating SEP Licensing: Cellular Standard Essential Patents*, Policy Brief 1 (Indian Council for Research on International Economic Relations, 2025), https://icrier.org/pdf/Cellular-Standard-Essential-Patents_Policy-Brief-1.pdf

[30] *Telefonaktiebolaget LM Ericsson v. Competition Commission of India & Anr.*, W.P.(C) 464/2014, Delhi High Court, judgment dated March 30, 2016, https://indiankanoon.org/doc/64182738/

[31] *Telefonaktiebolaget LM Ericsson v. Intex Technologies (India) Ltd.*, CS(OS) No. 1045/2014, Delhi High Court, order dated March 13, 2015, https://indiankanoon.org/doc/74163100/

The InterDigital–Xiaomi dispute[32] highlights the jurisdictional challenges in enforcing standard essential patents (SEPs) in India. In 2020, after InterDigital filed patent infringement suits against Xiaomi in the Delhi High Court, the Wuhan Intermediate People's Court in China issued an anti-suit injunction restraining InterDigital from pursuing those proceedings. This created a legal deadlock, as the Chinese court asserted jurisdiction over the global FRAND licensing dispute, effectively blocking the Indian litigation. The case underscores the difficulty of adjudicating cross-border SEP disputes in the absence of international legal coordination.

Cross-border challenges are also evident in the 2025 case of Canada-based Communication Components Antenna (CCA) vs. Ace Technologies[33], where the Delhi High Court ordered ₹290 crore (approximately $34.8 million) in interim security, reflecting the difficulty of enforcing judgments against foreign firms without attachable Indian assets.

CCA argued that Ace Technologies had very limited assets in India and was based in South Korea, a country that does not have a formal agreement with India to enforce civil court judgments under Section 44A of the Civil Procedure Code, 1908. To prevent the risk that any final judgment might be difficult to enforce, the Delhi High Court used its special powers under Section 151 of the CPC to issue a temporary protective order.

The decision is expected to serve as a precedent in IP cases, particularly those involving defendants from countries such as China and South Korea, where the absence of treaty-based enforcement mechanisms poses substantial obstacles.

Challenges Faced by the Semiconductor Design Ecosystem

While India's semiconductor design ecosystem struggles with low funding, established companies in manufacturing can weather financial challenges until they gain access to incentives and grants. Despite a large budget of ₹76,000 crore set for the semiconductor industry, only a small portion of ₹1,000 crore goes to the design companies. On the other hand, the design sector lacks big players, making emerging startups more vulnerable and with fewer chances to survive. Without considerable venture capital and strong institutional backing, small firms cannot effectively grow or put money into essential research and development that drives innovation. The unequal support highlights an industry system where large manufacturing companies benefit from government policies, creating a divide that hinders the progress of design-focused firms that are key to the competitiveness of India's semiconductor sector. The current scheme, while beneficial for established and safer companies, tends to favor those that have already reached a certain level of maturity, often overlooking the immense potential of early-stage startups with breakthrough IP. By placing the requirement that product designs must be "demonstrated in an operational environment and ready for volume production," the scheme inadvertently places a significant barrier to entry for many companies. As a result, startups with promising yet untested designs—typically those that are riskier but have the potential to revolutionize the industry—are excluded from receiving support.

This preference for lower-risk companies ultimately stifles innovation, as it restricts the support to those already in the production phase while ignoring the ideas and technologies in the conceptual or development stages. The world of semiconductors is constantly evolving, and to stay competitive, fostering new ideas and taking calculated risks on emerging technology is critical. However, the current incentive structure puts less emphasis on startups with groundbreaking, though unproven, designs that could play a pivotal role in the future of the industry. Furthermore, problems with intellectual property and a lack of a supportive environment for cooperation between firms and academic institutions add to the difficulty of growth opportunities. The DLI scheme's emphasis on infrastructure support points to the need for a cooperative ecosystem that connects academia with industry. Tackling these various challenges is crucial, not only for the success of individual companies but also for meeting India's long-term goals in the semiconductor sector, which are vital for economic progress and national security. A truly forward-thinking semiconductor ecosystem should be one that supports high-risk ventures,

[32] Josh Zumbrun, "China Wields New Legal Weapon to Fight Claims of Intellectual Property Theft," *Mint* (Wall Street Journal), September 27, 2021, https://www.livemint.com/technology/tech-news/china-wields-new-legal-weapon-to-fight-claims-of-intellectual-property-theft-11632659529493.html

[33] "₹290 Crores Security Directed in Patent Infringement Case: SIM and SAN Leads for Communication Components," *Republic World*, accessed July 24, 2025, https://www.republicworld.com/initiatives/290-crores-security-directed-in-patent-infringement-case-sim-and-san-leads-for-communication-components

acknowledging that failure is an inevitable part of innovation. By accepting and embracing this risk, the sector can create an environment conducive to creativity and advancement. Incentive schemes should therefore aim to strike a balance between mature companies that have proven their viability and startups that are still working through the early stages of product development. Only by addressing both ends of the spectrum can we ensure a healthy ecosystem where innovation thrives and the most revolutionary ideas are given the chance to succeed.

High Costs and Funding Constraints

One of the most significant challenges for India's fabless companies is the high cost of operations, particularly the expense of taping out chips. This process in India costs 50-80% more than in other countries, putting immense financial pressure on startups.[34] For instance, creating even a basic chip requires an average investment of $10 million, far exceeding the resources of most Indian firms. Additionally, widely used technologies like Bluetooth IPs can cost close to $1 million, further burdening these companies.

Another rising cost is that of photomasks. In semiconductor manufacturing, a mask set is a collection of photomasks, each representing the layout of a specific layer in the integrated circuit. These photomasks are fundamental to the photolithography process, which projects the circuit design onto silicon wafers. Each photomask corresponds to a single layer of the chip, and the total number of masks in a mask set reflects the number of layers in the chip design.

Photomasks are essential components of semiconductor product development, tailored specifically for individual chip designs. The tape-out process delivers the design data required to create these photomasks. Whenever a company aims to manufacture a new chip type, it must create a new photomask. The cost of producing these photomasks is substantial, ranging from $1 million to $20 million,[35] depending on the design complexity and the manufacturing technology. This high cost poses a significant entry barrier for smaller companies and hinders the development of new chip designs.

As technology nodes shrink, moving from larger nodes like 28 nm to advanced nodes such as 7 nm, the process of creating photomasks becomes increasingly intricate[36] and expensive. This shift demands significant capital investment in developing new mask sets, also referred to as master templates. Consequently, the cost associated with photomasks becomes a considerable obstacle for small companies or for prototyping innovative designs.

Access to photomasks is crucial within the semiconductor design ecosystem. Without them, it is impossible to produce integrated circuits, which are the foundation of all electronic devices. Thus, for the industry to thrive and innovate, ensuring affordability and accessibility of photomasks is imperative.

Funding winters exacerbate the problem. Venture capitalists often hesitate to invest in semiconductor startups until products are fully developed and approved by customers, creating a catch-22 situation for companies in need of initial capital. While government schemes like the DLI aim to support the industry, their structure demands substantial upfront investments, which many startups cannot afford. The DLI scheme's allocation of ₹1,000 crore pales in comparison to the ₹76,000 crore set aside for manufacturing incentives, leaving the design segment underfunded.

Investor interest in the Indian semiconductor design sector has been subdued, reflecting challenges unique to this complex and capital-intensive industry. Global venture funding for semiconductor chip startups showed some signs of recovery in 2024, following a lackluster 2023. So far, these startups raised nearly $5.3 billion across 175 deals through Q2,[37] according to Crunchbase data. This marked a significant improvement compared to last year, when funding totaled under $8.8 billion in 490 deals. In 2022, chip startups secured nearly $10.9 billion in 447 deals. This sharp downturn is indicative of the

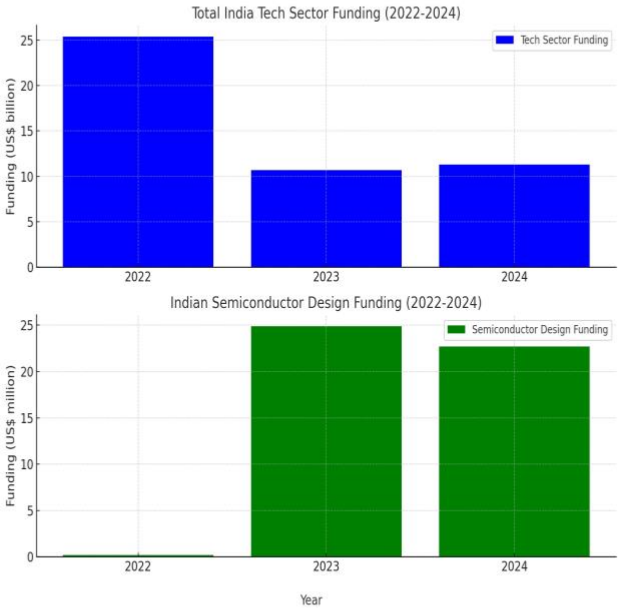
[34] Shristi Achar, "India Wants a Thriving Semiconductor Industry—If Only It Could Keep Chip Designers Happy," *The Ken*, Jan. 3, 2025, https://the-ken.com/story/india-wants-a-thriving-semiconductor-industry-if-only-it-could-keep-chip-designers-happy

[35] India Cellular and Electronics Association (ICEA), *ICEA Report to Address the Challenges & Opportunities in Indian Semiconductor Industry*, April 2024, 70-71

[36] Anton Shilov, "New Chip Crunch Looming? Booming Demand from Chinese Chipmakers Causing Shortage of Critical Photomask Element," *Tom's Hardware*, Nov. 27, 2023, https://www.tomshardware.com/tech-industry/new-chip-crunch-looming-booming-demand-from-chinese-fabs-could-cause-shortage-of-critical-photomask-element

[37] Chris Metinko, "Semiconductor Startup Funding Looks to Bounce Back After Lackluster 2023," *Crunchbase News*, June 20, 2024, https://news.crunchbase.com/semiconductors-and-5g/chip-startup-funding-bounces-back-ai-nvda/

broader challenges faced by the semiconductor ecosystem, particularly the lengthy development cycles and the need for sustained funding over extended periods. These barriers are especially pronounced in India, where nascent design startups struggle to establish a foothold.



Source: Tracxn, The Ken

While the overall Indian tech sector attracted billions in funding ($25.4 billion in 2022 alone), semiconductor design companies managed to secure a meager $0.2 million during the same period. This disparity is alarming, especially when considering that the sector is projected to play a crucial role in India's technological advancement and economic growth. See table above.

Experts say that a combination of factors contributes to the limited investor interest in this sector. One major issue is market volatility, which undermines confidence in long-term investments. The semiconductor industry is inherently cyclical, with demand often subject to unpredictable shifts caused by geopolitical tensions, technological advancements, and global economic conditions. These fluctuations make it challenging for startups to present a stable and predictable growth trajectory, deterring investors who seek more secure opportunities.

High sunk costs are another deterrent. Developing semiconductor designs requires expensive licenses for electronic design automation tools, essential for the design and simulation of ICs. These tools represent a significant upfront investment that most startups find prohibitive, particularly when compounded by the lack of substantial domestic demand for indigenous ICs. In India, strategic sectors such as defense, aerospace, and telecommunications have yet to fully adopt locally designed chips, further limiting opportunities for startups to scale and attract investment.

Adding to these challenges is a pervasive lack of product conceptualization expertise. Designing a successful semiconductor product requires a deep understanding of market needs, end-user applications, and global trends. Many Indian startups lack this critical knowledge, often resulting in designs that fail to meet market expectations or align with strategic priorities. This gap underscores the need for enhanced industry-academia collaboration, mentorship programs, and knowledge-sharing initiatives to foster a more robust ecosystem.

The financial barriers to entry in semiconductor design are immense. Developing a single chip can cost anywhere between $2 million and $20 million,[38] depending on its complexity and intended application. This cost includes not just design and prototyping but also testing and verification, which are critical to ensuring reliability and performance. For startups, these expenses can be crippling, especially in the absence of a steady revenue stream. Venture capital (VC) funding for deep-tech hardware startups, including those in the semiconductor space, remains scarce. Unlike software startups, which can often demonstrate quick returns and scalability, hardware ventures require longer timelines and substantial initial investments before yielding profits. Consequently, most VCs shy away from such high-risk investments, leaving startups to rely on alternative funding sources. Grants from government programs, angel investors, and a small number of early-stage investors willing to take a gamble on unproven technologies become the primary sources of capital.

To address these challenges, India must adopt a multi-pronged approach. Policies that incentivize local manufacturing and design, such as subsidies for EDA tool licenses, photomasks, taping out processes

[38] India Cellular and Electronics Association (ICEA), *ICEA Report to Address the Challenges & Opportunities in Indian Semiconductor Industry*, April 2024, 55

and grants for R&D, can help lower the entry barrier for startups. Strengthening the demand for indigenous chips through government procurement programs and fostering partnerships between startups and established players in the semiconductor value chain can create new opportunities for growth. Additionally, building a strong talent pipeline through education and training programs focused on semiconductor design can equip the workforce with the skills needed to drive innovation in this field.

In conclusion, while the Indian semiconductor design sector faces significant hurdles, there is potential for growth if these challenges are systematically addressed. With targeted policy support, industry collaboration, and sustained investment in talent and infrastructure, India can position itself as a key player in the global semiconductor ecosystem. For now, however, the road ahead remains challenging, requiring concerted efforts from all stakeholders to unlock the sector's full potential.

Supply chain and ecosystem challenges

The supply chain and ecosystem in India are underdeveloped, adding logistical and operational difficulties for fabless companies. Securing wafers from foundries is particularly challenging due to high minimum order requirements[39]. Companies often find themselves unable to match the large-volume purchase orders of global competitors like Nvidia and Mediatek, making production less cost-effective. Moreover, optimizing wafer orders and dealing with variable costs linked to chip complexity and integrated circuits further complicate operations.

The ecosystem's inefficiencies extend to collaboration with fabs and foundries, which are crucial for manufacturing chips. Indian fabless companies also underestimate the importance of managing the supply chain, including testing, packaging, and shipping, which significantly adds to costs.

Limited adoption and market perceptions

Indian fabless companies are often perceived as risky by large Original Equipment Manufacturers (OEMs), who prefer established global vendors for the majority of their business needs. This perception limits the market opportunities for Indian startups, relegating them to secondary roles. Even when companies secure marquee clients, like ISRO, the projects are often small and financially unviable, requiring firms to invest heavily upfront in hopes of future opportunities.

Increasing skill gap

Alongside financial issues, India's semiconductor design ecosystem is hampered by skill deficit. Although the talent pool is large, many lack the advanced design skills that global companies need. The World Economic Forum added that only one in five engineers[40] and one in ten graduates entering the workforce are considered employable.

The semiconductor industry may face a significant skills shortage of 250,000 to 300,000 professionals by 2027, as revealed by a recent report[41] from TeamLease Degree Apprenticeship. Meanwhile, the 2023 All India Survey on Higher Education (AISHE), released by the Ministry of Education, shows concerning trends in engineering education. Enrollment in traditional engineering programs declined from 39.4 lakh (394,000) in 2017-18 to 38.45 lakh (3.8 million) in 2021-22[42].

Additionally, a report by the Graduate Record Examinations (GRE) revealed that engineering has lost its status as the most preferred degree among Indian students[43], overtaken by physical sciences. The report noted a steep decline[44] in the number of students pursuing engineering through the GRE, dropping from 24% in 2019-20 to just 13% in 2023-24. The AISHE report attributed this decline to several factors, primarily the introduction of new courses that present alternative career paths. Among undergraduate programs, Bachelor of Engineering (BE) and Bachelor of Technology (BTech) were

[39] Shristi Achar, "India Wants a Thriving Semiconductor Industry—If Only It Could Keep Chip Designers Happy," *The Ken*, January 3, 2025, https://the-ken.com/story/india-wants-a-thriving-semiconductor-industry-if-only-it-could-keep-chip-designers-happy

[40] "India Is Failing 175 Million of Its Young People," *World Economic Forum*, April 10, 2019, https://www.weforum.org/stories/2019/04/india-is-failing-175-million-of-its-young-people/

[41] "India's Semiconductor Industry to Face 300,000 Professionals Shortage by 2027: Report," *Live Mint*, June 11, 2024, https://www.livemint.com/industry/indias-semiconductor-industry-to-face-300-0070-professionals-shortage-by-2027-report-11718089993861.html

[42] Ministry of Education, *All India Survey on Higher Education 2021–2022*, 42, https://www.aishe.gov.in

[43] Educational Testing Service, *A Snapshot of the Individuals Who Took the GRE® General Test: July 2019–June 2024*, 60, https://www.ets.org/s/gre/pdf/snapshot-individuals-took-gre-general-test-2019-2024.pdf

[44] Ibid., 61

uniquely affected, with both experiencing a consistent drop in enrollment over the last five years. This decline aligns with shrinking job opportunities in core engineering sectors.

Neeti Sharma, co-founder and the President of TeamLease Edtech, highlighted[45] that the hiring of fresh graduates by IT companies sharply fell—from 26% of total graduates in FY22 to 15% in FY23 and just 10% in FY24.

Further underscoring the issue, a recent media report[46] based on Right to Information (RTI) data from IIT Kanpur revealed that around 8,000 graduates from 23 IIT campuses remained unplaced in 2024.

Industry experts highlight that graduates often require one to two years of on-the-job training before being fully equipped to contribute to the industry. This skill gap is worsened by the slow alignment of educational programs with what the industry requires, essential for training the next generation of designers.

Policy Recommendations

India's semiconductor design industry represents a critical juncture in its journey toward becoming a global technological powerhouse. Despite hosting over 250 fabless companies and accounting for 20% of the world's semiconductor design talent, India's design ecosystem remains underfunded and underutilized. The DLI scheme, launched in 2021 under the broader ₹76,000-crore Semicon India program, was intended to bridge this gap. However, with only 12 startups approved as of 2024—far from the five-year goal of 100 startups—the scheme's implementation reveals a troubling disconnect between policy objectives and ground realities. The disproportionate allocation of funds between manufacturing (₹75,000 crore) and design (₹1,000 crore) reflects a prioritization of large-scale, low-risk projects over innovative, high-risk ventures. Design startups, typically operating with limited financial reserves, struggle to meet the scheme's requirement for "operational environment" demonstration, effectively excluding nascent, high-potential ideas.

Venture capital interest in semiconductor design is also minimal due to the industry's lengthy gestation periods and high costs. Developing a single chip can cost up to $20 million, with additional expenses for photomasks and design tools. The absence of substantial private investment further hampers the growth of startups.

Despite a large talent pool, gaps in advanced design skills and limited alignment of academic curricula with industry needs hinder workforce readiness. This issue is compounded by declining enrollment in engineering programs and a shortage of industry-specific training.

Another issue is that India's reliance on imports for semiconductors and related components is exacerbating its trade deficit, particularly with China. The inability to produce critical components domestically highlights structural weaknesses in the ecosystem.

The current framework prioritizes mature companies over startups, stifling innovation. Additionally, insufficient collaboration between academia, industry, and government limits knowledge transfer and the commercialization of research.

This following policy recommendation proposes actionable measures to realign the DLI scheme, fostering an inclusive, innovative, and globally competitive semiconductor design ecosystem in India. The DLI scheme's limited impact stems from structural and strategic shortcomings in addressing the unique challenges faced by India's semiconductor design sector. To address these challenges, the DLI scheme must be recalibrated to foster a balanced, inclusive, and innovation-driven ecosystem. The following measures are proposed:

Enhancing financial support and incentive structures

Enhancing financial support and incentive structures is crucial to fostering growth and innovation in India's semiconductor industry. One key step is to increase the budget allocation for design-focused initiatives under the Semicon India program, particularly by directing a larger share of funds to the DLI scheme. Establishing a targeted fund of ₹5,000

[45] "Is the Craze for Engineering Dwindling in India? An In-depth Look at Recent Trends," *Times of India*, September 13, 2024, https://timesofindia.indiatimes.com/education/news/is-the-craze-for-engineering-dwindling-in-india-an-in-depth-look-at-recent-trends/articleshow/113326855.cms

[46] "38% of IITians Across 23 Campuses Remain Unplaced in 2024: Report," *India Today*, May 23, 2024, https://www.indiatoday.in/education-today/news/story/38-of-iitians-across-23-campuses-remain-unplaced-in-2024-report-2542897-2024-05-23

crore specifically for design companies would ensure a more equitable distribution of resources and provide the necessary financial backing for high-risk ventures, enabling startups to bring innovative solutions to market.

Flexible funding models should also be introduced to ease financial pressures on early-stage startups. Milestone-based funding, for example, would allow for initial seed grants to validate concepts, followed by incremental funding tied to specific development achievements. This approach would not only reduce the upfront financial burden but also encourage accountability and sustained progress.

Additionally, providing tax incentives for private sector investments can significantly enhance the flow of capital into the industry. Tax breaks for venture capital firms and angel investors supporting semiconductor design startups would encourage greater participation from private players, creating a robust funding ecosystem. Together, these measures would strengthen India's semiconductor design landscape, attract private investment, and position the country as a global hub for innovation.

Building a robust venture capital ecosystem

Establishing a semiconductor innovation fund and encouraging foreign investment are essential steps to strengthen India's semiconductor ecosystem. A government-backed fund designed to co-invest with private venture capitalists in semiconductor design startups would play a pivotal role in de-risking investments, thereby attracting more private players to the sector. Such a fund would not only provide financial support but also foster confidence in high-potential, early-stage startups, enabling them to scale and innovate more effectively.

In addition, relaxing restrictive grant conditions that disqualify companies with foreign investors is crucial to broadening the pool of eligible participants. These restrictions often deter much-needed foreign capital and expertise from entering the market. By creating a more inclusive framework, India can attract global investors and strategic partners, boosting resources, technology transfer, and market access for domestic startups. Together, these measures would create a vibrant innovation ecosystem, stimulate growth in semiconductor design, and position India as a competitive player in the global semiconductor industry.

Addressing skill gaps

Addressing skill gaps in the semiconductor sector requires a multi-pronged approach that bridges academia and industry, promotes upskilling, and supports talent development. Encouraging partnerships between universities and semiconductor companies can help align academic curricula with industry requirements while introducing specialized programs in semiconductor design and offering hands-on internships with leading design firms. Such initiatives would ensure that students and professionals are equipped with the necessary skills to meet industry demands.

In addition, launching national training programs focused on advanced design tools and techniques is crucial for building a skilled workforce. These programs should include subsidies for small and medium enterprises and startups to make upskilling more accessible and affordable. This would help smaller players contribute meaningfully to the ecosystem while enhancing their competitiveness.

To further strengthen talent pipelines, the government and industry stakeholders can offer scholarships and fellowships for engineering students specializing in semiconductor design. Such incentives will encourage students to pursue careers in this field, fostering talent retention and creating a robust foundation for long-term growth in India's semiconductor industry.

Promoting innovation and reducing barriers

While global models vary, India would benefit from emulating SME-friendly ecosystems like Taiwan and Israel rather than large-firm-focused models such as Japan and South Korea. Unlike manufacturing giants, fabless design startups are often lean, agile, and highly innovative. Their success is vital not just for IP creation, but for generating employment, driving regional development, and reducing overreliance on a few large players.

Promoting innovation and reducing barriers would require targeted efforts to support startups, foster collaboration, and strengthen research and development (R&D). Revising eligibility criteria for government support is a critical first step. The requirement for demonstrating products in operational environments should be modified to include startups working on high-potential, early-stage designs. Grants, incubation programs, and other support mechanisms can provide these innovators with the resources they need to advance their projects. To further drive innovation, fostering collaboration between fabless companies, manufacturing firms, and academic institutions is essential. Establishing a centralized platform for knowledge sharing, resource pooling, and joint ventures can streamline these efforts and create a vibrant ecosystem of innovation. Additionally, dedicated funding for R&D in emerging technologies such as AI chips, quantum computing, and advanced SoC designs is vital. Public-private partnerships should be encouraged to accelerate breakthroughs and position India as a global leader in next-generation semiconductor technologies.

Strengthening domestic supply chains

To strengthen domestic supply chains, the government could incentivize local foundries to collaborate with fabless companies, enabling affordable wafer fabrication and reducing reliance on imports. Additionally, establishing semiconductor-focused logistics hubs would streamline access to critical resources like photomasks, wafers, and testing equipment, effectively addressing supply chain bottlenecks.

Boosting market adoption

To drive market adoption, the government could mandate that a percentage of contracts in sectors like defense, aerospace, and telecommunications include locally designed chips, ensuring a steady demand pipeline for domestic companies. Additionally, offering export subsidies for semiconductor products would enhance India's global competitiveness and support greater market penetration.

Strengthening the IP Framework for semiconductor design

To build a globally competitive semiconductor design ecosystem, India must urgently modernize its IP policy and enforcement frameworks. First, the government must establish a dedicated legal framework for Standard Essential Patents (SEPs) with statutory guidance on Fair, Reasonable, and Non-Discriminatory (FRAND) licensing terms. The absence of clear SEP norms has created legal uncertainty, as seen in the Ericsson-related cases, where royalty calculations, jurisdictional overlaps, and abuse of dominance concerns complicated litigation. Codifying FRAND obligations into law will provide clarity for courts, prevent licensing abuse, and encourage greater R&D activity among domestic design firms. Second, India should pursue treaty-based civil enforcement agreements with key countries such as South Korea and China, to ensure enforceability of judgments in cross-border IP disputes. The 2025 CCA vs. Ace Technologies case exposed the legal vacuum that currently exists in the absence of reciprocal arrangements, where even successful plaintiffs face significant barriers to recovering damages from foreign infringers. Entering into bilateral IP enforcement treaties would strengthen India's legal standing and send a signal to international partners that India takes cross-border IP protection seriously. Third, such treaties would offer much-needed clarity to Indian courts when dealing with foreign entities, especially in situations involving injunctions, interim security, and conflict of laws. Providing a clear statutory route would reduce dependence on the discretionary use of inherent powers under Section 151 of the CPC and contribute to the development of consistent judicial standards in cross-border IP enforcement.

In addition to SEP regulation and treaty-based enforcement, two complementary measures are critical. First, the Semiconductor Integrated Circuits Layout-Designs Act, 2000 (SCILD) must be revised to reflect current technological realities. The Act's limited scope—focused solely on physical layout designs—excludes system-level innovations such as chiplets, 3D ICs, and AI processing units. Integrating SCILD into the broader Semicon India Program would ensure that eligible firms receive both financial and legal support for advanced design work. Second, India should create a centralized IP Intelligence & Enforcement Cell for the semiconductor sector under MeitY, with legal, technical, and diplomatic experts. This unit would monitor violations, assist in foreign filings (e.g., under the Patent Cooperation Treaty), coordinate with customs and judiciary, and support MSMEs in asserting and defending their IP. Together, these reforms will not only address existing loopholes but also create a robust institutional infrastructure capable of supporting the high-value, IP-driven nature of semiconductor design.

Expected Outcomes

Implementing these recommendations is expected to foster innovation by enabling startups to pursue high-risk, high-reward projects, thereby enriching India's semiconductor design ecosystem with greater diversity and dynamism. It will enhance the country's competitiveness by reducing reliance on imports, strengthening domestic supply chains, and positioning India as a critical player in the global semiconductor value chain. Additionally, these initiatives will create significant employment opportunities across design, manufacturing, and allied sectors, driving economic growth. They will also address skill gaps by developing a highly skilled workforce capable of advancing innovation in cutting-edge semiconductor technologies. Furthermore, building a self-reliant semiconductor ecosystem will strengthen national security by ensuring robust support for critical industries such as defense and telecommunications. Collectively, these outcomes will lay the foundation for a sustainable, innovative, and globally competitive semiconductor industry in India.

Conclusion

India's semiconductor design industry stands at a pivotal moment. While the country possesses deep pools of engineering talent and is home to hundreds of fabless design firms, the policy and institutional ecosystem has yet to meaningfully support their growth. The existing framework, anchored by the Design Linked Incentive (DLI) scheme, has been instrumental in placing semiconductor design on the national agenda but it remains structurally misaligned with the needs of early-stage innovation. To realize India's ambition of becoming a global semiconductor hub, the sector requires not just funding, but also institutional reform, legal safeguards, and a risk-calibrated approach to innovation policy.

The DLI scheme, under India's broader ₹76,000 crore Semicon India program, was envisioned as a mechanism to catalyze a thriving chip design industry. However, only ₹1,000 crore has been earmarked for design, compared to the substantial support directed toward manufacturing. This disparity reflects a larger strategic miscalculation—one that underestimates the role of IP-led design in achieving true technological autonomy. Design innovation is not simply a technical challenge but a strategic one, requiring both capital and confidence from founders and investors alike. In its current form, the DLI scheme inadvertently filters out precisely those startups that could create original IP and foundational technologies.

By requiring design firms to "demonstrate operational readiness" and be "ready for volume production," the scheme heavily favours mature, low-risk companies—those already past the riskiest stages of development. This model may offer stability, but it comes at the cost of dynamism. Most breakthrough innovations occur in the pre-revenue or prototype phase, where support is scarcest and risk is highest. When early-stage companies are excluded from eligibility, the result is a shallow innovation pipeline and a stagnation in domestic IP creation.

This bottleneck is made worse by a chronic underinvestment in Indian chip startups. Venture capital firms are hesitant to enter the sector, citing long development cycles, high capital intensity, and unclear market pathways. With the cost of taping out a single chip exceeding $10 million, and photomasks and IP blocks demanding additional millions, startups struggle to survive the early years. Without public mechanisms to share this risk, such as milestone-based grants, first-loss guarantees, or targeted R&D subsidies, private capital remains reluctant to engage. Consequently, promising firms either stagnate or relocate to ecosystems that offer better institutional support.

However, capital scarcity is only part of the problem. A more pressing issue lies in the weak legal and institutional infrastructure for protecting intellectual property. Recent cases involving IP theft and design misappropriation reveal a fragmented enforcement landscape in India. The inability to enforce civil judgments across borders, due to a lack of treaty arrangements under Section 44A of the CPC, further disincentivizes innovation. This legal vacuum makes companies acutely vulnerable, weakening investor confidence and eroding trust in the system.

To address this, India must institutionalize protections for IP holders through targeted reforms. Updating the Semiconductor Integrated Circuits Layout-Designs Act (SCILD), integrating it with the DLI scheme, and developing SEP-specific legislation for FRAND licensing are necessary first steps. At the same time, the creation of a centralized IP Intelligence and Enforcement Cell within MeitY could provide startups with accessible, state-backed legal support, while coordinating enforcement across borders.

Without these reforms, India risks building a design ecosystem that generates value but cannot retain it.
In parallel, the semiconductor workforce pipeline also requires urgent attention. While India is home to 20% of the world's chip design talent, the employability of engineering graduates remains low. Reports show that only one in five engineers is industry-ready, while enrollment in traditional engineering disciplines continues to fall. This disconnect between academic curricula and real-world design challenges weakens India's ability to deliver on its technical potential. Industry-academia partnerships, government-backed apprenticeships, and direct investment in EDA tool training are all needed to rebuild this pipeline.

Supply chain constraints further compound the challenge. Indian fabless companies lack access to affordable prototyping infrastructure, wafer fabrication, and packaging services. With limited domestic foundry collaboration and high global minimum order quantities, startups face long timelines and high costs for even basic design validation. Without intervention, such as dedicated design-test-shuttle programs, public access to photomasks, and state-procured prototyping services, these constraints will continue to restrict design experimentation and slow product cycles.

At the same time, India's overdependence on semiconductor imports, particularly from China, continues to fuel trade imbalances and strategic vulnerabilities. Between 2020 and 2024, trade figures reveal a steep rise in chip imports, even as India's own fabless companies struggle to scale. The current trajectory risks reinforcing a model in which India designs for global firms but owns none of the upstream value. A self-reliant design strategy must therefore be embedded within the broader economic and security logic of the semiconductor mission.

Despite these headwinds, India is well-positioned to lead if it reforms now. India has the advantage of scale, talent, and geopolitical relevance but it must design its policies to foster originality, not just execution.

This paper recommends five core interventions. First, restructure the DLI scheme to fund high-risk ventures using milestone-based or phase-gated models. Second, modernize IP enforcement through treaty frameworks, SEP regulation, and institutional support for litigation. Third, establish public infrastructure to lower design costs especially for taping out, EDA tools, and photomasks. Fourth, boost demand for indigenous chips by mandating domestic sourcing in strategic sectors and offering tax incentives for Indian IP adoption. Finally, build a semiconductor-specific talent development plan aligned with industry needs, including scholarships, reskilling programs, and faculty exchange with global leaders.

Each of these steps can be implemented incrementally but should be seen as part of a larger strategic pivot. India's chip design challenge is not one of capacity, but of confidence that the state will support and protect those who innovate. Without this, design-led firms will continue to underperform, and the country will miss its window to leapfrog into the top tier of semiconductor nations.

In conclusion, the success of India's semiconductor strategy will depend not just on building fabs or attracting global capital, but on creating an environment where design talent can take risks, own their IP, and scale their ideas. This requires moving beyond generic industrial policy toward an ecosystem that funds risk, protects innovation, and builds institutional trust.

Glossary of Key Terms
Technical Terms:

Term	Definition
Integrated Circuits (ICs)	Miniaturized electronic circuits combining components like transistors and capacitors onto a single chip to perform specific electronic functions.
Chipsets	A group of ICs designed to work together to manage data flow between hardware components in devices like computers or smartphones.
System on Chips (SoCs)	Highly integrated chips that combine processors, memory, I/O interfaces, and more into a single chip, optimized for power and space efficiency.
Systems and IP Cores	Pre-designed, reusable blocks (e.g., processors, memory controllers) that are integrated into chip designs. 'Systems' are full modules; 'IP cores' are modular, licensable blocks.

Term	Definition
EDA Tools	Electronic Design Automation software used to design, simulate, and verify chip designs (e.g., Synopsys, Cadence).
RTL (Register Transfer Level)	A design abstraction used in digital circuits where operations are defined in terms of data flows between registers.
ASIC (Application-Specific Integrated Circuit)	A customized IC designed for a specific application or product.
Photolithography	A fabrication process used to transfer geometric patterns onto a silicon wafer using light.
Node Size (e.g., 7nm, 5nm)	Refers to the process technology used in semiconductor fabrication; smaller nodes allow for denser, more power-efficient chips.
Tape-out	The final stage in chip design where the completed layout is sent for fabrication.
Packaging (Chip Packaging)	The protective housing and interface structure that surrounds a semiconductor die.
Yield	The percentage of functional chips produced from a semiconductor wafer.
Fab (Fabrication Facility)	A factory where semiconductor devices are manufactured.
Fabless Model	A business model where companies focus on design while outsourcing manufacturing to foundries.
Foundry	A company that manufactures semiconductors designed by other firms.
Design IP	Intellectual property blocks related to chip functionality that can be reused in other designs.
IP Core Reuse	The practice of integrating existing IP blocks into new chip designs to save time and cost.
Mixed-Signal ICs	Integrated circuits that combine both analog and digital components.
Design Verification	The process of checking whether a chip design meets functional and performance specifications.
Simulation Tools	Software tools that mimic the behavior of chips before physical fabrication.
Netlist	A textual description of the components and their connections in an electronic design.
Logic Synthesis	The process of converting high-level design into a gate-level representation.
System Design Kit (SDK)	A collection of tools and files needed for SoC development.
Taping out	Final step in chip design, when the design is deemed ready for fabrication.
Photomask	A glass plate with etched patterns used in semiconductor manufacturing to transfer designs onto wafers.

Legal and Regulatory Terms:

Term	Definition
SCILD (Semiconductor Integrated Circuits Layout-Design Act, 2000)	India's legislation to protect chip layout designs (Act No. 37 of 2000).
SEP (Standard Essential Patent)	A patent essential to implementing a technical standard (e.g., 3G, 5G). Owners must license it on FRAND terms.
FRAND	Fair, Reasonable, and Non-Discriminatory – licensing terms under which SEPs must be made available to ensure wide access.
Anti-suit Injunction	A court order preventing a party from initiating or continuing litigation in another jurisdiction.
Cross-border IP Enforcement	Legal mechanisms used to execute and uphold IP judgments across national boundaries.
Section 44A, CPC	A section of India's Civil Procedure Code that governs the enforcement of foreign civil judgments.

Term	Definition
IP Receipts	Revenue a country or company earns from licensing its IP internationally.
IPR (Intellectual Property Rights)	Legal protections granted to creators of inventions, designs, and creative works.
IP Audit	A systematic evaluation of an organization's IP assets, liabilities, and protection mechanisms.
Reverse Engineering	The practice of analyzing a competitor's product to replicate its functionality—can raise IP concerns.
Export Control	Government restrictions on the export of sensitive technologies, including advanced semiconductors.

Policy and Institutional Terms:

Term	Definition
DLI Scheme	Design Linked Incentive scheme to support domestic semiconductor design startups.
Semicon India Programme	India's umbrella policy framework to promote chip design and manufacturing with a budget of ₹76,000 crore.
PLI (Production Linked Incentive)	A government subsidy scheme rewarding firms for incremental domestic production.
TRL (Technology Readiness Level)	A scale used to assess the maturity level of a technology, from concept to deployment.
Import Substitution	An economic policy strategy to replace foreign imports with domestically produced goods.
Domestic Value Addition	The share of value generated within a country during the production process.
Talent Pipeline	The supply of skilled workers needed to sustain growth in semiconductor design and manufacturing.
Venture Capital (VC)	Funding provided to startups and early-stage companies with high growth potential.
Technology Transfer	The process by which technology or know-how is transferred from one organization or country to another.
National Semiconductor Mission (NSM)	The body under MeitY tasked with executing India's semiconductor initiatives.
Make in India	A national campaign launched in 2014 to promote domestic manufacturing across sectors.
PCT (Patent Cooperation Treaty)	A mechanism that allows inventors to file a single international patent application valid in multiple countries.
MeitY (Ministry of Electronics and Information Technology)	The nodal ministry of the Government of India responsible for policies relating to IT, electronics, and semiconductor development.

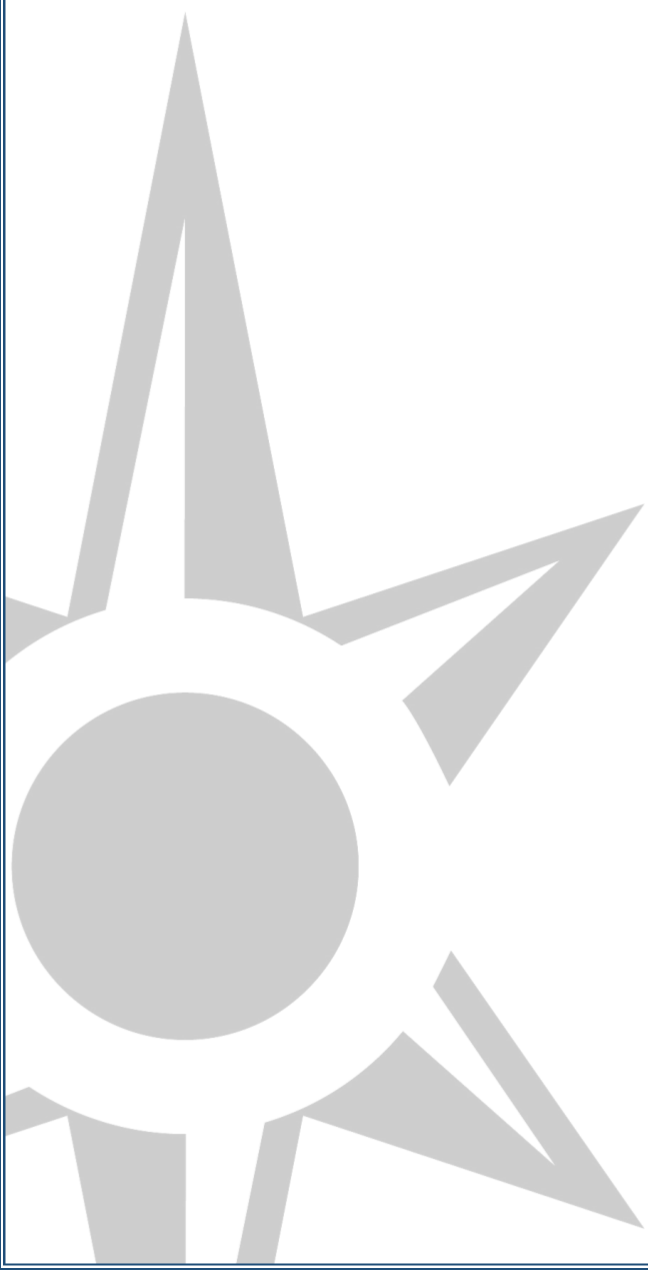
About the Author

HARSHA SINGH is a journalist and a researcher with extensive experience in various newsrooms, having spent more than four years in financial and tech newsrooms across India. Her career includes time spent in legacy media such as *Times of India*, *Economic Times* as well as in niche newsrooms like *The Morning Context*. Throughout her career, Singh has contributed as a reporter, feature writer, audience engagement specialist, and video producer. With a well-rounded perspective on India, she bring a deep understanding of the business, finance, and tech landscape, offering valuable insights into these critical areas.

PACIFIC FORUM INTERNATIONAL

Securing India's Technological Future: A Framework for Semiconductor R&D Policy

By
Nidhi Singh



Executive Summary

Nidhi Singh

Semiconductors have become the bedrock of all defining technology in the 21st century, powering artificial intelligence, autonomous vehicles, and critical defense systems while driving a global market projected to reach $1 trillion by 2030. The industry's concentration to a few nations creates profound vulnerabilities exacerbated by geopolitical tensions and supply chain disruptions. Governments worldwide are responding with unprecedented investments, signaling a fundamental shift from market-driven to more strategically guided semiconductor development.

India stands at a critical inflection point. The country possesses formidable design capabilities and over 120 multinational R&D centers, yet it imports approximately 85% of its chip requirements. India has launched the INR 76,000 crore (USD$10 billion) India Semiconductor Mission to catalyze domestic capabilities. However, current approaches risk perpetuating dependency: the mission allocates only 2.5% to R&D while India's overall R&D intensity at 0.7% of GDP ranks among the world's lowest for emerging economies.

This paper argues that India's path to semiconductor leadership requires strategic specialization in research, development, and intellectual property creation rather than attempting comprehensive value chain dominance. The paper proposes a comprehensive R&D-centered strategy built on four interconnected components:

National Semiconductor Technology Roadmap: A dynamic strategic framework aligning R&D priorities with national security objectives, de-risking private investment through clear government commitments, and providing measurable milestones for technological sovereignty. This roadmap would function as more than a technology list, serving as a strategic tool for resource allocation and signaling national intent to both domestic and international stakeholders.

Triple Helix Innovation Ecosystem: Deep integration among government, industry, and academia through outcome-oriented partnerships that address India's critical industry-readiness gap. This requires creating compelling semiconductor career propositions that compete effectively with AI and data science opportunities attracting India's top engineering talent.

Strategic Specialization in R&D and Talent: Focusing on high-value, less capital-intensive segments rather than attempting to compete across the entire value chain. India should leverage its existing human capital strength to control critical intellectual property, positioning itself as an indispensable partner in geopolitically driven supply chain diversification efforts.

Enhanced Legal and IP Framework: Comprehensive modernization of the outdated Semiconductor Integrated Circuits Layout-Design Act (2000), which has registered fewer than 25 designs in over two decades. The Act's narrow focus on physical layout protection neglects the broader architecture and complex algorithms crucial for modern semiconductor applications.

India's window of opportunity is narrow but significant. Export control volatility, friend-shoring imperatives, and China's inward-looking approach create strategic openings for India to position itself as a stable, democratic partner in diversified global supply chains. However, realizing these potential demands coordinated action across government, industry, and academia, supported by consistent policy implementation and sustained political commitment across electoral cycles. The paper lays down a strategy to align the R&D policy with the current and projected developments in India’s semiconductor ecosystem.

Introduction

The demand for semiconductors is growing. Semiconductors are the bedrock of the 21st-century global economy and an irreplaceable enabler of virtually all technology sectors, from smartphones and data centers to automobiles, medical devices, and critical defense systems.[1] The rise of technologies like generative artificial intelligence, electric vehicles, autonomous all contribute to driving up the need for countries to enter the semiconductor arena.

Incumbent and new companies entering the semiconductor space are aggressively expanding their operations across the entire value chain, from wafer manufacturing and chemical supply to packaging and capital equipment. Global trends including the rise of artificial intelligence, vehicle electrification, and autonomous driving are broadening demand and driving it to even greater heights over the next decade. Companies plan to invest about USD$1 trillion in semiconductor fabs through 2030, with most investment concentrated in Asia and the United States, though funding for European projects is also increasing. The financial opportunity is compelling: the global market for semiconductors is projected to reach USD$1 trillion by 2030, up from USD$600 billion in 2021.

The semiconductor supply chain is highly complex and globally integrated. However, this integration also introduces significant vulnerabilities: the concentration of production capacity, especially in Taiwan and South Korea, makes the supply chain sensitive to geopolitical tensions, natural disasters, and pandemics.[2] Today's investment decisions are driven by more than just profit margins. Semiconductor companies now focus on three key factors, sustainability, supply chain security, and subsidies, as they select new sites, reflecting broader concerns about climate change, geopolitical disruptions, and economic uncertainty. This shift has prompted governments worldwide to offer unprecedented incentives, with the United States allocating over USD$50 billion through the CHIPS Act, the European Union providing USD$47 billion in public funding, and Japan announcing USD$6.8 billion in public investment to attract semiconductor manufacturing and reduce dependence on foreign suppliers.[3][4]

The US-China chip war highlights the role of semiconductors in hegemonic competition between superpowers.[5] The strategic importance of semiconductors has grown exponentially since 2020, with pandemic-induced spikes in consumer demand boosting semiconductor requirements by 17% between 2019 and 2021. Global sales reached USD$555.9 billion in 2021, representing a 26.2% increase from the previous year.[6] This has led to a global recalibration of the semiconductor supply chain, driven by economic decoupling between China and the United States. The US is actively seeking to reduce its reliance on China while forging collaborations with allies including the European Union, Japan, Australia, and India through various strategic frameworks.

India's Position and Aspirations

India, a major growth market for semiconductors, currently imports almost all its commercial semiconductor products. While India possesses a strong foundation in chip R&D and design, thanks to its large talent pool of approximately 125,000 semiconductor design engineers, it remains weak in manufacturing. India's semiconductor market is rapidly growing and is expected to reach USD 110 billion by 2030, making it roughly 10% of global chip demand.[7]

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[1] *Ensuring Economic Security and Redefining Supply Chains Underpin the Future of Semiconductor Procurement* (EY Japan, n.d.), accessed May 29, 2025, https://www.ey.com/en_jp/insights/supply-chain/a-new-blueprint-for-supply-chain-resilience-and-economic-safety.

[2] *McKinsey on Semiconductors* (McKinsey and Company, 2021), https://www.mckinsey.com/~/media/mckinsey/industries/semiconductors/our%20insights/mckinsey%20on%20semiconductors%20issue%208/mck_on_semiconductors_08_2021.pdf.

[3] "The Greenfield Opportunity in Semiconductor Trends," McKinsey, accessed July 10, 2025, https://www.mckinsey.com/industries/semiconductors/our-insights/exploring-new-regions-the-greenfield-opportunity-in-semiconductors.

[4] "Semiconductors Have a Big Opportunity—but Barriers to Scale Remain," accessed September 6, 2025, https://www.mckinsey.com/industries/semiconductors/our-insights/semiconductors-have-a-big-opportunity-but-barriers-to-scale-remain.

[5] Yongshin Kim and Sungho Rho, "The US–China Chip War, Economy–Security Nexus, and Asia," *Journal of Chinese Political Science* 29, no. 3 (2024): 433–60, https://doi.org/10.1007/s11366-024-09881-7.

[6] Arjun Kharpal, "Global Semiconductor Sales Top Half a Trillion Dollars for First Time as Chip Production Gets Boost," CNBC, February 15, 2022, https://www.cnbc.com/2022/02/15/global-chip-sales-in-2021-top-half-a-trillion-dollars-for-first-time.html.

[7] "How India Is Spreading Itself across the Chip-Making Value Chain - The Economic Times," accessed June 1, 2025, https://economictimes.indiatimes.com/industry/cons-products/electronics/how-india-is-spreading-itself-across-the-chip-making-value-chain/articleshow/108492622.cms?from=mdr.

Recognizing the strategic importance of semiconductors and the risks associated with import dependency, India has launched the India Semiconductor Mission (ISM) and the Semicon India Programme, an INR 76,000 crore (USD$ 10 billion) package of incentives for fabs, display plants, and assembly/test facilities. The Indian government is committed to developing the semiconductor industry and has approved the country's first state-of-the-art semiconductor fab.[8]

However, India currently has limited domestic fabrication and advanced manufacturing capacity. To translate its existing assets into supply chain security, India must build would have to build complementary capabilities across the value chain, especially through R&D and innovation.[9] As noted by the Ministry of Electronics and Information Technology (MeitY), building a robust semiconductor ecosystem will "require fostering R&D in the semiconductor area."[10]

Additionally, while these policies have helped to start the semiconductor ecosystem in India, the impact remains limited. In 2022-2023, Qualcomm, Samsung, and Huawei were the top three foreign patent applicants in India holding 3482, 979, and 936 patent applications respectively at the India Patent Office.[11] This demonstrates that while thousands of patent applications come from the Indian affiliates of foreign technology, India still does not hold many semiconductor IP assets. The overall benefit to India's domestic semiconductor ecosystem remains limited.

Research Objectives and Paper Structure

This paper undertakes a comparative analysis of the global semiconductor landscape and India's place within it, drawing on policy documents, industry reports, and academic literature. It examines how leading semiconductor nations have leveraged R&D strategies to strengthen technological sovereignty and identifies lessons relevant for India. The analysis is guided by four central questions: What are the vulnerabilities of global supply chains? Where does India currently stand in terms of capabilities and gaps? What would an effective R&D policy framework for self-reliance look like? And how can international best practices be adapted to accelerate India's progress?

The paper is organized into six sections. The paper is organized into six sections. Following the introduction, Section 2 evaluates India's semiconductor ecosystem, including government initiatives, talent, infrastructure, and legal frameworks. Section 3 analyzes the structure of the global semiconductor industry and highlights opportunities for international cooperation. Section 4 distills global best practices from leading semiconductor nations and their R&D strategies. Section 5 proposes a comprehensive R&D and ecosystem development strategy tailored to India's strengths and constraints. The conclusion synthesizes these insights into concrete policy recommendations and outlines a long-term roadmap for India's semiconductor future.

India's Semiconductor Ecosystem

The semiconductor ecosystem in India is undergoing a significant transformation as the nation positions itself to become a global hub for electronics manufacturing and design.[12] India has some comparative strengths: it hosts roughly 20% of the world's semiconductor design engineers, and many multinational firms have R&D centers in Bangalore and elsewhere.[13] The country's electronics market is growing rapidly and is now the world's second-largest mobile phone producer. However, India remains a net importer of semiconductors.[14] Nearly all cutting-edge chip fabrication is done abroad, making India's industry dependent on foreign supplies.

[8] "India Injects $15 Billion Into Semiconductors - IEEE Spectrum," accessed June 1, 2025, https://spectrum.ieee.org/indian-semiconductor-manufacturing.

[9] "India's Semiconductor Ambitions: How to Move up the Value Chain?," KPMG, accessed June 1, 2025, https://kpmg.com/in/en/blogs/2024/06/indias-semiconductor-ambitions-how-to-move-up-the-value-chain.html.

[10] "Accelerating Innovation: Government Spending on Semiconductor Research & Development Crosses ₹2859 Crore in Last Decade," Press Information Bureau, accessed June 1, 2025, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=2080844.

[11] "India's Semiconductor Dilemma: Powering Global Giants Or Nurturing Homegrown Innovation?," The Secretariat, accessed July 11, 2025, https://thesecretariat.in/article/india-s-semiconductor-dilemma-powering-global-giants-or-nurturing-homegrown-innovation.

[12] "The Dawn of India's Semiconductor Era," accessed June 1, 2025, https://thediplomat.com/2024/03/the-dawn-of-indias-semiconductor-era/.

[13] ITIF, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains |," accessed May 31, 2025, https://itif.org/publications/2024/02/14/india-semiconductor-readiness/.

[14] Sarat Chinta, "India's Semiconductor Growth: Opportunities, Comparisons, and the Case for Local Manufacturing," SSRN Scholarly Paper no. 5116567 (Social Science Research Network, January 29, 2025), https://doi.org/10.2139/ssrn.5116567.

India's technological prowess has largely been built on software expertise.[15] The country currently relies heavily on imports, with approximately 85% of its chip requirements met through global markets.[16] This dependency not only poses security risks but also impedes India's aspirations for technological independence. The domestic semiconductor market, projected to reach USD$100.2 billion by 2032 from USD$34.3 billion in 2023, presents a compelling case for establishing local manufacturing capabilities.[17]

Market dynamics present a compelling growth trajectory, with projections indicating that India's semiconductor market will reach USD$55 billion by 2026, potentially doubling to USD$110 billion by 2030.[18] This remarkable expansion is primarily driven by increasing domestic demand across various sectors, including smartphones, automotive electronics, data storage solutions, and other electronic devices.

India Semiconductor Mission

The Indian government has demonstrated strong commitment to fostering semiconductor industry growth through comprehensive policy initiatives. Central to this effort is the India Semiconductor Mission (ISM) and the Semicon India Programme.[19] The ISM was established as a "specialized and independent Business Division within the Digital India Corporation that aims to build a vibrant semiconductor and display ecosystem to enable India's emergence as a global hub for electronics manufacturing and design."[20] The Semicon India Programme, approved by the Union Cabinet in 2021, is a "comprehensive program with a financial outlay of INR 76,000 (USD$ 10 million) crore for the development of a sustainable semiconductor and display ecosystem in India." These programs provide substantial financial incentives for companies engaged in various aspects of semiconductor production.[21]

The Indian government's approach to developing semiconductor manufacturing capabilities has evolved significantly over the years. Previous attempts in 2007 and 2013 failed to gain traction, primarily due to inadequate infrastructure and bureaucratic hurdles.[22] However, the December 2021 semiconductor policy marks a more comprehensive and strategic approach.[23]

The government has demonstrated its commitment through substantial financial support, including a USD$10 billion incentive scheme under the Semiconductor Mission. Additionally, the Production Linked Incentive scheme, introduced in February 2021 with an initial outlay of approximately USD$24 billion, has previously shown encouraging results in related sectors, particularly mobile phone manufacturing.[24] The establishment of the India Semiconductor Research Centre (ISRC) further underscores the nation's commitment to advancing research and development capabilities.[25]

Workforce Development

Despite progress, several challenges need to be addressed for India to realize its semiconductor ambitions. The talent pool remains a critical concern, with a significant gap between theoretical knowledge and practical industry requirements. India's semiconductor ecosystem faces a significant talent paradox. Despite producing approximately 2.5

[15] ITIF, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains |."

[16] "India's Semiconductor Push: Building a Robust Chip Manufacturing Ecosystem," India Brand Equity Foundation, accessed June 1, 2025, https://www.ibef.org/research/case-study/india-s-semiconductor-push-building-a-robust-chip-manufacturing-ecosystem.

[17] Wright Research, "The Growth of India's Semiconductor Industry to $110 Billion By 2030," Wright Research, accessed June 1, 2025, https://www.wrightresearch.in/blog/the-growth-of-indias-semiconductor-industry-to-110-billion-dollar-by-2030/.

[18] The Hindu Bureau, "India's Semiconductor Market to Reach $55 Billion by 2026: Deloitte," Technology, *The Hindu*, February 28, 2023, https://www.thehindu.com/sci-tech/technology/india-semiconductor-market-reach-55-billion-2026-deloitte/article66563055.ece.

[19] "Overview | About ISM," accessed June 1, 2025, https://www.ism.gov.in/about-ism.

[20] "India Semiconductor Mission," Press Information Bureau, accessed June 1, 2025, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1808676.

[21] Press Information Bureau, "India Semiconductor Mission."

[22] Himank Sharma, "India Dials Back Chip Ambitions as Investors Spurn Plant Funding," Technology, *Reuters*, June 15, 2016, https://www.reuters.com/article/technology/india-dials-back-chip-ambitions-as-investors-spurn-plant-funding-idUSKCN0Z10XR/.

[23] Sankalp Phartiyal and Aditi Shah, "Exclusive: A Billion for Every Chip-Maker Who 'makes in India,' Sources Say," India, *Reuters*, March 31, 2021, https://www.reuters.com/article/world/india/exclusive-a-billion-for-every-chip-maker-who-makes-in-india-sources-say-idUSKBN2BN12G/.

[24] "Is India 'Ready' for Semiconductor Manufacturing?," Carnegie Endowment for International Peace, accessed June 1, 2025, https://carnegieendowment.org/research/2023/05/is-india-ready-for-semiconductor-manufacturing?lang=en.

[25] "India Semiconductor R&D Committee Submits Report on India Semiconductor Research Centre (ISRC)," accessed June 1, 2025, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1969400.

million engineering graduates annually, with 600,000 in electronics-related fields, the industry is heading toward a severe skill gap of 250,000-300,000 professionals by 2027. [26]

The core challenge lies in attracting and retaining talent specifically for semiconductor work. Engineering students increasingly gravitate toward fields like data science, AI, and machine learning, which offer faster paths to employment compared to semiconductor engineering, which typically requires advanced degrees and extensive experience. This trend is particularly problematic for India's manufacturing ambitions, while the country has built a strong foundation in chip design, it lacks the specialized workforce needed for semiconductor manufacturing, with an estimated shortfall of 10,000-13,000 skilled workers in manufacturing roles by 2027. [27]

This talent shortage becomes even more critical when viewed against the backdrop of global semiconductor workforce demands, which are projected to require an additional one million skilled workers by 2030. The government's Chips to Startup scheme, aimed at training 85,000 engineers, represents an important step, but more emphasis is needed on making graduates industry-ready and connecting them with prospective employers.[28]

Institutional collaboration has been a focus of India's semiconductor strategy. In 2022 the government created the India Semiconductor Mission to coordinate industry–academy partnerships. Industry news indicates that ISM has signed a series of MoUs with global partners: for instance, in mid-2023 a MoU with Purdue University was announced to develop semiconductor curricula and training programs for Indian students. International equipment-makers have also partnered with Indian institutions for workforce development. For example, Lam Research signed an MoU with the Indian Institute of Science (IISc) in Bangalore in 2023 to train up to 60,000 Indian engineers on its virtual fabrication platform ("Semiverse"). Applied Materials and others have likewise pledged investments in Indian research centers. Domestically, large chip-design firms like Synopsys and AMD are expanding their India R&D centers and collaborating with IITs and IISc on research and education. These initiatives mirror global best practices, recognizing that bridging the industry–academic gap is critical for semiconductor innovation.

Infrastructure and Ecosystem Development

While manufacturing capabilities are still in their developmental stages, significant progress is being made in this field. Notable developments include the establishment of an ATMP facility in Gujarat by Micron and Tata Electronics.[29] The current focus is on producing chips at the 28 nm node and above, with strategic plans to advance to more sophisticated nodes in the future.[30]

The development of semiconductor manufacturing facilities requires sophisticated infrastructure, including reliable power supply, ultra-pure water, and specialized industrial zones. The Dholera Special Investment Region, developed through innovative land pooling mechanisms, has emerged as a potential location equipped with the necessary infrastructure to support semiconductor fabrication facilities.[31] This approach to land acquisition and development represents a more cooperative and self-financing mechanism compared to traditional methods.

Another significant development is the partnership between Tata Electronics and Taiwan's PowerChip Semiconductor Manufacturing Corporation

[26] Harsha Singh, "Chipping In: The Need to Expand India's Semiconductor Talent Pool," *The Times of India*, n.d., accessed June 1, 2025, https://timesofindia.indiatimes.com/blogs/point-of-view/chipping-in-the-need-to-expand-indias-semiconductor-talent-pool/.

[27] "India Lacks Talent for Chip Manufacturing; Requires 10-13k Resources by 2027: Meity Official," *The Times of India*, March 17, 2023, https://timesofindia.indiatimes.com/india-lacks-talent-for-chip-manufacturing-requires-10-13k-resources-by-2027-meity-official/articleshow/98740588.cms.

[28] "MeitY Invites Applications under the Chips to Startup (C2S) Programme from Academia, R&D Organisations, Startups and MSMEs," accessed June 1, 2025, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1790350.

[29] H. T. Correspondent, "Micron Begins Construction of $2.75 Billion Semiconductor Plant in Gujarat," Hindustan Times, September 23, 2023, https://www.hindustantimes.com/business/micron-begins-construction-of-2-75-billion-semiconductor-plant-in-gujarat-101695478422567.html.

[30] "Can 28 Nm Catapult India to Semiconductor Manufacturing Leadership? - BusinessToday," Business Today, June 19, 2024, https://www.businesstoday.in/tech-today/news/story/can-28-nm-catapult-india-to-semiconductor-manufacturing-leadership-433902-2024-06-19.

[31] India Briefing, "Dholera SIR, Gujarat: From Sleepy Town to Semiconductor Base," *India Briefing News*, March 2, 2023, https://www.india-briefing.com/news/dholera-special-investment-region-key-information-for-foreign-investors-in-india-27310.html/.

(PSMC).[32] This collaboration marks PSMC's fourth 12-inch fabrication plant, focusing on manufacturing 28-nanometre chips used in power management integrated circuits, display drivers, and microcontrollers.[33] The initial production target of 50,000 wafers per month, with production scheduled to begin in 2026, represents a significant step forward in India's manufacturing capabilities.

The government's comprehensive approach extends to supply chain development, with initiatives such as the Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors providing incentives for local production of essential components, raw materials, chemicals, and gases.[34] This is further supported by strategic global partnerships, particularly with the US Semiconductor Industry Association, and engagement with international semiconductor manufacturing leaders.

However, the success of semiconductor manufacturing depends heavily on the development of a robust supplier ecosystem capable of providing raw materials, components, and machinery. The building of a robust semiconductor ecosystem should prioritize obtaining the equipment and materials in that order. Most of the grant money provided by the government usually goes towards importing equipment, and is consequently transferred outside of India, affecting the economic cycle.[35] If companies could buy some of this equipment from within India, it would allow for a greater boost to the ecosystem development by allowing the money to circle within the Indian ecosystem.

Legal framework

At the heart of India's semiconductor ambitions lies a less discussed but foundational component, the legal infrastructure. The Semiconductor Integrated Circuits Layout-Design (SICLD) Act, 2000,[36] represents India's dedicated legislation for protecting intellectual property in chip design. Passed in consonance with India's obligations as a signatory to the TRIPS Agreement and influenced by the WIPO IPIC Treaty, the Act aims to grant exclusive rights to creators of original and distinctive layout designs for integrated circuits.

It provides registration, which is mandatory for protection, and grants the registered proprietor rights to reproduce, import, sell, and distribute products embodying the protected design for a period of ten years. This was intended to provide a *sui generis* form of protection, recognizing that traditional IP laws like patents, copyrights, and trademarks were ill-equipped to safeguard the unique nature of integrated circuit topographies, which are functional rather than ornamental, and often combine known elements in novel ways. The Act even allows for criminal sanctions against infringement, a feature that distinguishes it from some other regimes.[37]

However, despite its intent, the SICLD Act, 2000, suffers from significant shortcomings that limit its effectiveness in fostering a thriving semiconductor industry in India. Its scope remains notably narrow, focusing predominantly on the physical layout, neglecting the broader architecture, complex algorithms, or integrated chipsets crucial for today's advanced Deep Tech applications. This limited purview is starkly reflected in the abysmal registration figures; fewer than 25 layout designs registered under the Act in over two decades as of early 2024.[38]

A critical flaw is the Act's isolated nature, operating with no effective overlap with the Patent Act, Copyright Act, or Trademark Act, leading to fragmented and insufficient protection for sophisticated chip IP. For instance, while the Patent Act demands a high bar of inventiveness that the spatial arrangement of commonly known circuit

[32] "India Injects $15 Billion Into Semiconductors - IEEE Spectrum," accessed June 1, 2025, https://spectrum.ieee.org/indian-semiconductor-manufacturing.

[33] "India Injects $15 Billion Into Semiconductors - IEEE Spectrum."

[34] "Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) | Ministry of Electronics and Information Technology," accessed June 1, 2025, https://www.meity.gov.in/offerings/schemes-and-services/details/scheme-for-promotion-of-manufacturing-of-electronic-components-and-semiconductors-specs.

[35] Raja Manickam, *Building Resilient and Adaptive Semiconductor Supply Chains in India - ET Edge Insights*, Technology, November 30, 2024, https://etedge-insights.com/technology/building-resilient-and-adaptive-semiconductor-supply-chains-in-india/, https://etedge-insights.com/technology/building-resilient-and-adaptive-semiconductor-supply-chains-in-india/.

[36] Semiconductor Integrated Circuits Layout Design Act (2000), https://sicldr.gov.in/sicw/actsrules.

[37] admin, "Protecting Innovation: A Guide to India's Semiconductor Layout-Design Act (SICLD), 2000," *Corpotech Legal*, February 29, 2024, https://corpotechlegal.com/semiconductor-layout-design-act-2000/.

[38] "Why India's Semiconductor Strategy Is A National Security Imperative," BW Businessworld, accessed July 24, 2025, https://www.businessworld.in/article/why-indias-semiconductor-strategy-is-a-national-security-imperative-554396.

components often fails to meet, the Copyright Act is too broad to specifically protect scientific design concepts, and trademark law is irrelevant for functional designs. Furthermore, the absence of a dedicated appellate mechanism and effective IP enforcement strategies tailored to the high-value, short-lifecycle nature of chip innovation further diminishes its practical utility.

This legislative structure is poorly suited for modern chip design and creates a less attractive environment for fabless startups and IP-heavy players compared to nations like the US, which have cultivated comprehensive IP ecosystems around chip design, encompassing patent pools, export controls, and robust trade secrets regimes to protect system-level innovation. There is a pressing need for a comprehensive overhaul of the SICLD Act or the introduction of a new Semiconductor Innovation and Protection Bill that integrates layout protection with system-on-chip architecture rights, recognizing the unique commercial and national security value of semiconductor IP.

India's Semiconductor R&D Ecosystem

The Indian government has responded with a comprehensive policy package. In 2022 it launched the INR 76,000 crore (USD$ 10 billion) "Modified Programme for Semiconductors and Display" to catalyze the entire ecosystem. [39] This package explicitly allocates up to 2.5% of the outlay for R&D, skills, and training programs, and earmarks INR 1,000 (USD$ 120 million) crore for a "Design Linked Incentive" scheme to support fabless design (including R&D activities). In addition, India's National Policy on Electronics 2019 and its Production-Linked Incentive (PLI) schemes provide financial support for chip fabs, ATMP (assembly, testing, packaging), and semiconductor materials suppliers. The government's official press releases emphasize R&D: for example, MeitY (India's electronics ministry) supports dedicated semiconductor R&D projects in nanotechnology, chip design, materials, processes, and IP cores.

These efforts have begun to move the needle: India's annual government funding for electronics R&D (including semiconductors) grew from under INR₹200 crore (USD$ 24 million) in 2017–18 to over INR₹500 crore (USD$ 60 million) in 2021–22. The 2.5% R&D set-aside in the new program means hundreds of crores more will go toward semiconductor research.

Although India excels in IC design, most of this work is done for foreign multinationals and has not yet built a large domestic design ecosystem. As of early 2023 India had only 20 semiconductor startups in design/manufacturing, a number projected to reach 50 by year's end.[40] At present, India's share of global semiconductor patents and breakthrough research is negligible compared to leaders. This reflects broader weaknesses: India's corporate R&D spending is low, and its venture capital scene has been wary of long-payback semiconductor projects. Without a mindset change toward high-risk, long-term investment, India's ecosystem will struggle to incubate new chip technologies.

India's Semiconductor R&D Ecosystem: Strengths, Gaps, and Opportunities

Category	Description	Relevance / Implication
Strengths	**Chip Design Talent Pool:** ~125,000 engineers (20% global share); 120+ R&D centers; 80% global design firms have R&D in India.	Provides a strong human capital foundation for high-value R&D and design services.
	Growing Domestic Market: Projected $110 billion by 2030 (10% global demand).	Creates a significant demand-side pull, de-risking indigenous R&D and manufacturing efforts.

[39] "Year End Review 2024 of Ministry of Electronics & Information Technology Part-2," Press Information Bureau, accessed May 31, 2025, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=2088990.

[40] ITIF, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains |."

Gaps	**Limited Advanced Manufacturing:** Virtually no commercial fabs for advanced nodes; reliance on imports for ~85% of chip requirements.	Major vulnerability to supply chain disruptions; hinders technological sovereignty.
	Talent Skill Gap: Projected 250,000-300,000 professional shortfall by 2027; qualitative mismatch in industry-ready skills, especially manufacturing.	Constrains growth and ability to scale domestic production; requires targeted education reform.
	Weak Domestic IP Generation: Few semiconductor IP assets held by India; low startup count (20 in early 2023).	Limits value capture from design talent; hinders long-term technological leadership.
	Flawed IP Legal Framework: SICLD Act, 2000, narrow in scope (physical layout only); <25 registrations in 20+ years.	Undermines incentive for R&D and original design; deters IP-heavy foreign investment.
	Low Overall R&D Investment: R&D intensity at 0.7% of GDP (one of the lowest among emerging economies); corporate/VC wariness for long-payback projects.	Insufficient funding for foundational research; reflects a systemic challenge to high-risk, long-term investment.
Opportunities	**Geopolitical Reorientation:** Global shift to resilience, national security, and supply chain diversification ("friend-shoring").	Creates a strategic opening for India to become a reliable, secure partner in the global ecosystem.
	US Export Control Volatility: Unpredictable policy changes drive global companies to seek stable R&D environments.	India can position itself as a reliable "third pole" offering stability and talent unaffected by electoral cycles.
	Democratic Alignment: Strong ties to Western countries controlling critical segments of the value chain.	Facilitates strategic partnerships and access to advanced technologies within "friend-shoring" frameworks.
	Past Indigenous	Demonstrates India's

	Success: History of overcoming export controls in space and nuclear technology.	capacity for self-reliance and indigenous capability development.

The Semiconductor Landscape

In this we examine the current landscape of the semiconductor industry and the opportunities India can create within it.

Regional Specialization and Dependencies

The global semiconductor value chain is geographically dispersed, with the main stages being R&D and chip design, fabrication, and advanced testing and packaging.[41] This intricate value chain, while fostering innovation and cost savings through specialization, has also created vulnerabilities.[42] More than 50 points in the value chain have a single region holding more than 65% of the global market share, making them potential single points of failure.[43] Approximately 75% of global semiconductor manufacturing capacity is concentrated in China and East Asia, a region exposed to geopolitical tensions and seismic activity.[44]

The global semiconductor value chain represents a highly complex and geographically fragmented ecosystem, where specific regions have developed distinct competitive advantages through decades of targeted investment and policy support. The United States maintains leadership in chip design and intellectual property development, leveraging its robust research institutions and vibrant private sector. Taiwan has established dominance in advanced manufacturing nodes through systematic government support and strategic industry development, while South Korea's excellence in memory chip production demonstrates the effectiveness of focused industrial policy and sustained investment.

This regional specialization extends deep into the supply chain, creating critical bottlenecks and dependencies. The Netherlands holds a crucial monopoly through ASML's exclusive production of extreme ultraviolet (EUV) photolithography equipment, essential for manufacturing advanced chips.[45] Japan maintains significant control over the photoresist market, with four companies, JSR, Tokyo Ohka Kogyo, Shin-Etsu Chemical, and Fujifilm Electronic Materials, commanding approximately 75% of the high-end market and near-total dominance in EUV lithography photoresists.[46]

In raw materials, Germany has emerged as the leading net exporter of high-purity silicon, with companies like Wacker Chemie controlling one-third of global exports, while the United States contributes another quarter through manufacturers like Hemlock.[47] China, despite being a major producer of purified industrial silicon, remains the largest net importer of high-purity silicon while establishing significant market share in germanium and silicon carbide exports.[48] The European Union's broader contribution spans equipment manufacturing and materials research, while also facing strategic challenges around critical raw materials like

[41] Emily Benson et al., "Securing Semiconductor Supply Chains in the Indo-Pacific Economic Framework for Prosperity," *CSIS*, May 30, 2023, https://www.csis.org/analysis/securing-semiconductor-supply-chains-indo-pacific-economic-framework-prosperity.

[42] "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," *Semiconductor Industry Association*, n.d., accessed June 1, 2025, https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era/.

[43] "Ajai Chowdhry's 5-Point Strategy to Make India a Semiconductor Manufacturing Hub," *Financialexpress*, June 8, 2023, https://www.financialexpress.com/business/industry-ajai-chowdhrys-5-point-strategy-to-make-india-a-semiconductor-manufacturing-hub-3118137/.

[44] "Ajai Chowdhry's 5-Point Strategy to Make India a Semiconductor Manufacturing Hub."

[45] Katie Tarasov, "ASML Is the Only Company Making the $200 Million Machines Needed to Print Every Advanced Microchip. Here's an inside Look," CNBC, March 23, 2022, https://www.cnbc.com/2022/03/23/inside-asml-the-company-advanced-chipmakers-use-for-euv-lithography.html.

[46] Sujai Shivakumar et al., *Japan Seeks to Revitalize Its Semiconductor Industry*, August 25, 2023, https://www.csis.org/analysis/japan-seeks-revitalize-its-semiconductor-industry.

[47] Kan Ji Powell Lize Nauta, Jeffrey, "Mapping Global Supply Chains – The Case of Semiconductors," Rabobank, accessed June 1, 2025, https://www.rabobank.com/knowledge/d011371771-mapping-global-supply-chains-the-case-of-semiconductors.

[48] Saif Khan et al., *The Semiconductor Supply Chain: Assessing National Competitiveness* (Centre for Security and Emerging Technology, 2021), https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf.

germanium, which the European Commission has identified as at risk of supply shortages.[49]

This intricate web of regional specializations and dependencies underscores both the industry's vulnerability to supply chain disruptions and the significant barriers to entry for new players seeking to establish domestic semiconductor capabilities. The concentration of critical technologies and materials in specific regions highlights the importance of international cooperation while also exposing potential geopolitical risks in the global semiconductor ecosystem.

India's ambition to become a major player in the global semiconductor industry is commendable but attempting to master the entire value chain - from design and fabrication to assembly, testing, marking, and packaging (ATMP) - is likely to be inefficient and unsustainable. The semiconductor industry is characterized by intense regional specialization and enormous barriers to entry, making a comprehensive, "full-stack" approach exceedingly difficult for new entrants.

Instead of broadly investing in all segments, India should leverage its existing strengths and focus strategically on areas like Research and Development (R&D) and design. India already possesses a significant pool of skilled engineers, with over 120 semiconductor R&D centers and more than 50,000 VLSI engineers working in the country, and 80% of global semiconductor design firms having R&D operations in India. By concentrating its efforts and investments on strengthening R&D, fostering talent acquisition and retention, and developing intellectual property, India can carve out a crucial niche that aligns with global specialization trends. This focused strategy, rather than diluting resources across capital-intensive manufacturing segments where established players have decades of lead, offers a more viable and efficient path for India to become a globally competitive and innovative force in the semiconductor ecosystem, mirroring the success seen in countries that specialized in specific, high-value parts of the chain.

The Geopolitical Imperative

The semiconductor industry has rapidly ascended to a critical strategic asset, fundamentally shaping global economic competitiveness and national security in the twenty-first century. This elevation is largely driven by escalating geopolitical tensions, particularly the intense technological competition between the US and China. [50] These tensions manifest through stringent export controls, technology restrictions, and strategic alliances, forcing nations worldwide to urgently reevaluate their semiconductor supply chain vulnerabilities and aggressively pursue greater technological autonomy. [51] The strategic importance of semiconductors was underscored by pandemic-induced demand spikes and has led to a global scramble to secure reliable access to these foundational components.

This geopolitical realignment has dramatically transformed the global semiconductor landscape. The concentration of advanced chip production, with Taiwan alone accounting for nearly 90% of the world's advanced chip manufacturing, creates significant supply chain vulnerabilities and is a focal point of regional security dynamics, especially given China's strategic interest in the island. [52] [53] In response, the concept of "friend-shoring" has emerged, emphasizing collaboration among ideologically aligned nations to reduce dependence on potentially hostile powers while maintaining efficient production networks. [54] [55]

This shift has manifested in increasingly complex trade dynamics and security measures. The US-China trade dispute has reverberated throughout the global semiconductor ecosystem, with US export controls

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[49] *Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study*, ISSN 1831-9424 (European Commission, n.d.), https://single-market-economy.ec.europa.eu/system/files/2023-03/Raw%20Materials%20Foresight%20Study%202023.pdf.

[50] *Rise of the "Big 4" The Semiconductor Industry in Asia Pacific* (Deloitte, n.d.), https://roar-assets-auto.rbl.ms/files/66476/cn-tmt-rise-of-the-big-4-en-082820.pdf.

[51] Ardi Janjeva et al., *Semiconductor Supply Chains, AI and Economic Statecraft*, n.d., accessed June 1, 2025, https://cetas.turing.ac.uk/publications/semiconductor-supply-chains-ai-and-economic-statecraft.

[52] "Taiwan's Semiconductor Export Conundrum," accessed June 1, 2025, https://thediplomat.com/2024/10/taiwans-semiconductor-export-conundrum/.

[53] "Localizing the Global Semiconductor Value Chain," Arthur D. Little, June 4, 2024, https://www.adlittle.com/at-en/insights/report/localizing-global-semiconductor-value-chain.

[54] Benson et al., "Securing Semiconductor Supply Chains in the Indo-Pacific Economic Framework for Prosperity."

[55] "Remarks by Secretary of the Treasury Janet L. Yellen on Way Forward for the Global Economy," U.S. Department of the Treasury, February 8, 2025, https://home.treasury.gov/news/press-releases/jy0714.

significantly impacting Chinese manufacturers like SMIC and Yangtze Memory Technologies.[56] The situation has escalated through multilateral actions, as evidenced by Japan and the Netherlands joining US efforts to restrict advanced chip manufacturing equipment exports to China in 2023.[57] China's retaliatory measures, including export restrictions on critical materials like gallium and germanium through a government-controlled licensing system, have further complicated global supply chains and driven price increases.

This global reordering, driven by a desire for supply chain resilience and strategic diversification away from concentrated hubs and geopolitical flashpoints, presents a profound opportunity for India. With its significant pool of skilled engineers and growing domestic market, India is well-positioned to become a vital partner in the "friend-shoring" initiatives. While building an end-to-end semiconductor ecosystem is an immense and likely unfeasible undertaking given the specialized nature and high barriers to entry in each segment of the value chain, India can strategically focus its efforts on areas like R&D and design. By leveraging its existing talent base and aligning with the broader international push for diversified and secure supply chains, India can solidify its place as a critical node in the global semiconductor ecosystem, moving beyond simply being a consumer to becoming a key contributor and a reliable partner in the new, geopolitically reshaped landscape.

Emerging use of export controls

Another important imperative for India to begin work on increasing their sovereign capacity of semiconductor R&D is due to the ongoing policy uncertainty around the export of semiconductors and advanced chips. As geopolitical rivalries intensify, U.S. export controls on semiconductors and AI technologies have become strategic weapons that extend far beyond trade policy. The unprecedented volatility in these controls, which can be seen though the drastic changes in the US export controls policy over the course of 6 months, makes a compelling case for India to accelerate its sovereign R&D capabilities to insulate itself from some of the shocks in the international trade system.

U.S. export controls are creating significant friction for India, primarily due to a growing divergence in their underlying philosophies. While India aligns its export control regime (SCOMET) with country-agnostic multilateral agreements like the Wassenaar Arrangement, the U.S. has increasingly adopted unilateral, country-specific measures driven by concerns such as maintaining technological superiority over rivals, human rights, and resilient supply chains. This shift by the U.S. makes it difficult for India to fully comply, as it prioritizes strategic autonomy, bilateral engagements over large blocs, and its domestic development needs, including access to a wider range of markets like Russia and Iran. The ongoing policy whiplash creates fundamental vulnerabilities that India cannot ignore. This tension is particularly evident in the muted high-tech trade between the two nations; U.S. export licensing data for India is low, suggesting that American companies may be deterred from even applying due to perceived difficulties in securing approval. Furthermore, India's burgeoning defense exports and domestic manufacturing initiatives mean it's increasingly producing dual-use items, and while India maintains it adheres to international regimes, U.S. concerns persist about potential transshipment of sensitive goods, particularly to Russia. This puts Indian customs authorities in a more challenging position, requiring heightened scrutiny and raising questions about how to reconcile India's adherence to multilateral norms with the U.S.'s expanding unilateral controls.[58]

There is a reversal in the US strategy of protecting US technology and trying to guard it from falling into Chinese hands. The new policy appears to be a push to create technological dominance for US based companies- Commerce Secretary Lutnick's described the US strategy as - "you want to sell the Chinese enough that their developers get addicted to the American technology stack." The conversation around export controls is no longer limited to security, and rather it now looks at to create technological dependency.

[56] Arthur D. Little, "Localizing the Global Semiconductor Value Chain."
[57] "Japan, Netherlands to Join U.S. in Restricting Chip Equipment Exports to China, Bloomberg Reports," Technology, *Reuters*, January 27, 2023, https://www.reuters.com/technology/japan-netherlands-join-us-china-chip-controls-bloomberg-2023-01-27/.
[58] Konark Bhandari, "Export Controls: Balancing the Tensions Between U.S. and Indian Priorities |," Council on Foreign Relations, accessed July 23, 2025, https://www.cfr.org/article/export-controls-balancing-tensions-between-us-and-indian-priorities.

India is currently placed in a vulnerable situation- on the one hand, it has strong ties at the leadership level, as is evident from the Joint leader statement, which was released in February 2025, which announced the TRUST initiative. However, at the same time it is difficult to ignore that India was the only Quad member state to be positioned outside the inner circle of trusted allies during the diffusion rules and is currently grappling with the negotiations on a trade treaty which is delayed. With political conditions changing too quickly to allow the policy environment to adapt to it – it becomes difficult for countries to create long term partnership or investment plans. Export thresholds and licensing requirements appear, disappear, and reappear based on electoral cycles in Washington rather than technical considerations. India's semiconductor projects requiring high-performance computing face sudden license requirements that can change within months. International collaborations become hostage to geopolitical alignments rather than technical merit. The rapid reversal of EDA software restrictions, critical design tools that became bargaining chips overnight, demonstrates how even strategic controls can vanish when convenient for trade negotiations.

India's semiconductor market is projected to reach USD$100.2 billion by 2032, but this growth remains vulnerable to foreign policy volatility that treats technology partnerships as instruments of control rather than collaboration. The export control chaos creates opportunities for India. Policy instability is driving global companies to seek stable R&D environments outside the U.S.-China rivalry. India can position itself as the reliable third pole in the global semiconductor ecosystem, offering both stability and talent that electoral cycles cannot disrupt. India has successfully navigated similar challenges before, overcoming export controls in space and nuclear technology to achieve indigenous capabilities that no foreign restriction can touch.

Global best practices

The semiconductor industry's strategic importance has surged in the wake of recent global disruptions. In recent years, semiconductor supply chains have experienced dramatic changes due to COVID-19 and geopolitical tensions.[59] These shocks exposed critical vulnerabilities and have led policymakers worldwide to seek more resilient, localized supply chains. Research reviews emphasize that such disruptions underscore the need for innovative supply chain management practices and decentralized networks for necessary redundancy.[60] Since the pandemic, semiconductor policy has become highly nationalistic, with many governments launching grand R&D and investment programs. Central to these resilience strategies is robust R&D, since semiconductor R&D is the driving force behind the entire semiconductor supply chain and a key driver of innovation and competitiveness. In short, countries recognize that securing future chip supplies requires onshoring cutting-edge R&D as well as manufacturing.

Case Studies of Successful Semiconductor Nations

Taiwan's Ecosystem Integration Approach

Taiwan's approach has long centered on a world-class R&D manufacturing cluster. For decades, the Taiwan government fostered integrated circuit parks and supported Taiwan Semiconductor Manufacturing Company (TSMC) to achieve global leadership.[61] TSMC was founded in 1987 as a public–private consortium (government plus Philips) specifically to build dedicated foundries for chip fabrication.[62] This foundry model meant that capital-intensive wafer fabrication was concentrated in TSMC and similar fabs, while fabless firms could focus on design and R&D. Taiwan also invested heavily in R&D centers and training. In fact, Taiwan today produces almost 100% of the world's most advanced chips via TSMC's fabs, underpinned by sustained government investment and a model of concentrated R&D investment on wafer design.[63]

[59] Wei Xiong et al., "Semiconductor Supply Chain Resilience and Disruption: Insights, Mitigation, and Future Directions," *International Journal of Production Research*, August 2024, https://www.researchgate.net/publication/383096847_Semiconductor_supply_chain_resilience_and_disruption_insights_mitigation_and_future_directions.

[60] Xiong et al., "(PDF) Semiconductor Supply Chain Resilience and Disruption."

[61] *U.S., Taiwan, and Semiconductors: A Critical Supply Chain Partnership* (US - Taiwan Buissness Council, 2023), https://www.us-taiwan.org/wp-content/uploads/2023/06/2023.06.21-Final-Semiconductor-Report.pdf.

[62] *U.S., Taiwan, and Semiconductors: A Critical Supply Chain Partnership*.

[63] Damien Chang, "The Return of Japan's Semiconductor Industry: Rapidus and the Pivot Towards an Ecosystem of Innovation," *Harvard Technology Review*, April 7, 2025, https://harvardtechnologyreview.com/2025/04/07/the-return-of-japans-semiconductor-industry-rapidus-and-the-pivot-towards-an-ecosystem-of-innovation/.

Such coordination of state support, industrial clustering, and continual R&D enabled Taiwan to win major clients (e.g. Apple) and out-compete rivals on process technology.[64]

Taiwan's transformation into a global semiconductor powerhouse presents particularly valuable insights for emerging players in the industry. The Industrial Technology Research Institute (ITRI) has played a pivotal role in Taiwan's success by serving as a bridge between fundamental research and commercial applications.[65] ITRI's systematic approach to technology transfer and commercialization, coupled with substantial government investment in R&D infrastructure, has created a robust foundation for innovation. The institute's close collaboration with academic institutions has facilitated rapid knowledge transfer and talent development, while its strategic partnerships with industry leaders have enabled the commercialization of cutting-edge technologies.

This commitment to R&D excellence extends across Taiwan's entire semiconductor ecosystem.[66] The country maintains its leadership not only in mature process technologies (28nm and older) but also in advanced manufacturing processes, including 16/14 nm and more sophisticated technologies. Taiwan has particularly distinguished itself in extreme ultraviolet lithography (EUV) processes, a cutting-edge technology crucial for manufacturing advanced integrated circuits. The government's forward-looking approach is exemplified by its new 10-year chip program, launching in 2024 with an initial USD$375 million budget, aimed at supporting advanced IC process development and fostering global semiconductor collaboration. This commitment is further reinforced through substantial fiscal incentives, including a 25% tax deduction for R&D expenditures and an additional 5% for advanced machinery investments.[67] The private sector's response to these initiatives is evident in major investments like TSMC's USD$2.9 billion chip-packaging plant and Fujifilm's USD$110 million chip-polishing expansion,[68] demonstrating a coordinated push to maintain Taiwan's technological edge in semiconductor manufacturing through continued R&D investment and infrastructure development.[69]

South Korea's Strategic Focus and National Champions

South Korea, long dominant in memory chips, has adopted a comprehensive R&D and cluster strategy to broaden its chip base.[70] Seoul's K-semiconductor strategy (2022) earmarks roughly USD$451 billion by 2030 for the entire supply chain.[71] This includes approximately USD$260 billion in tax incentives and grants for facilities and R&D. The plan envisions a "K-Semiconductor Belt" – a high-tech cluster uniting foundries, packaging, fabless start-ups, and research institutes for seamless chip development. The Korean government explicitly targets strategically important sectors (AI, automotive, power semis) in its R&D roadmap. To boost innovation, Seoul sponsors cooperative R&D: national programs fund university labs to commercialize semiconductor research and subsidize fabless start-ups to adopt leading-edge design tools.[72]

South Korea provides a robust model for a focused education strategy in high-tech industries. Recognizing a projected need for 270,000 chip specialists, the Korean government aims to train 150,000 new semiconductor experts (from colleges to PhD programs) over 10 years, part of a broader plan to nurture one million digital industry workers within five years.[73]

[64] *U.S., Taiwan, and Semiconductors: A Critical Supply Chain Partnership*.
[65] Fareeha Yasmin Iqbal, "The Role of Large-Scale Government-Supported Research Institutions in Development : Lessons from Taiwan's Industrial Technology Research Institute (ITRI) for Developing Countries" (Thesis, Massachusetts Institute of Technology, 2003), https://dspace.mit.edu/handle/1721.1/30025.
[66] *Rise of the "Big 4" The Semiconductor Industry in Asia Pacific*.
[67] "Taiwan 'Chips Act' Sets R&D Spending at NT$6 Billion - Taipei Times," May 2, 2023, https://www.taipeitimes.com/News/front/archives/2023/05/02/2003798964.
[68] "Fujifilm to Invest $110m in Taiwan Chip Material Production - Nikkei Asia," accessed June 1, 2025, https://asia.nikkei.com/Business/Tech/Semiconductors/Fujifilm-to-invest-110m-in-Taiwan-chip-material-production.
[69] Sheila Chiang, "TSMC to Invest $2.9 Billion in Advanced Chip Packaging Plant in Taiwan," CNBC, July 25, 2023, https://www.cnbc.com/2023/07/25/tsmc-to-invest-2point9-billion-in-advanced-chip-packaging-plant-in-taiwan.html.
[70] *South Korea's Nationwide Effort for AI Semiconductor Industry – Communications of the ACM*, July 1, 2023, https://cacm.acm.org/research/south-koreas-nationwide-effort-for-ai-semiconductor-industry/.
[71] Kim Jaewon, "South Korea Plans to Invest $450bn to Become Chip 'Powerhouse,'" Nikkei Asia, accessed July 24, 2025, https://asia.nikkei.com/Business/Tech/Semiconductors/South-Korea-plans-to-invest-450bn-to-become-chip-powerhouse.
[72] *South Korea's Nationwide Effort for AI Semiconductor Industry – Communications of the ACM*.
[73] Im Eun-byel, "Korea to Lift School Limits in Chip Expert Push," The Korea Herald, July 19, 2022, https://www.koreaherald.com/article/2916323.

To achieve this, South Korea is implementing comprehensive policy measures: universities are allowed to ease student quotas for semiconductor and other digital-related departments, even in densely populated areas, by reallocating existing capacity or potentially revising regulations. Financial aid is provided to regional universities to ensure equitable development. The government is also designating "Graduate Schools of Semiconductors" with special grants, relaxing qualification standards for adjunct and visiting professors to attract industry experts and foreign talent and providing research funds to lure more academics. Furthermore, the interuniversity Semiconductor Research Center at Seoul National University is meant to act as a central hub, establishing a national network with regional centers.

Beyond higher education, the Ministry of Education plans to double information technology curriculum hours in elementary and middle schools by 2025, making computer coding mandatory. Boot camp programs are being introduced at universities, offering "micro degrees" for students from various majors to gain digital and chip-related skills, signifying a systemic and national commitment to building a skilled workforce from the ground up.[74]

South Korea's emergence as a dominant force in the memory chip market demonstrates the effectiveness of focused R&D efforts supported by strategic government initiatives. The country's success has been built on a foundation of targeted tax incentives and substantial R&D funding, which have enabled companies like Samsung and SK Hynix to achieve technological leadership in specific market segments.[75] The Korean government's systematic approach to industry development, including the creation of specialized research institutes and the implementation of comprehensive talent development programs, has created a self-reinforcing ecosystem of innovation and commercial success.[76]

South Korea's commitment to semiconductor leadership continues to evolve, with the government announcing a substantial investment of over USD$450 billion in chips by 2030, primarily funded by private sector participants. Major players like Samsung Electronics are expected to invest USD$230 billion over the next 20 years to create the world's largest chip manufacturing base, aligned with the South Korean government's strategic objectives.[77] The country has also developed an AI semiconductor development strategy aimed at achieving a 20% global market share, fostering 20 innovative companies, and developing 3,000 top-level engineers by 2030.[78]

The recently approved K-Chips Act raises tax credits to 15% for major companies and 25% for smaller firms,[79] but the high technical barriers for qualification (requiring 15nm or lower DRAM technology, 170+ layer NAND capabilities, and 7nm or less foundry technology) effectively concentrate benefits among the chaebols, Samsung and SK Hynix, who possess these advanced capabilities. This reflects a broader political reality where conservative governments tend to support national champions while liberal administrations attempt, with limited success, to diversify benefits beyond the Seoul-centered chaebol ecosystem.[80]

United States' Innovation Ecosystem

The United States maintains its leadership position in the semiconductor value chain through a robust, multi-layered approach to research and development that combines substantial private sector investment with strategic government support. In the United States, the 2022 CHIPS and Science Act authorized approximately USD$53 billion in subsidies and tax credits to strengthen US chip R&D and production.[81] According to legislators, CHIPS represents the largest single investment that has been seen in US R&D for semiconductors, and explicitly funds the entire semiconductor supply chain, from research

[74] Im Eun-byel, "Education Ministry to Nurture 1m Skilled Workers for Digital Industry," The Korea Herald, August 22, 2022, https://www.koreaherald.com/article/2940912.

[75] "The Future of K-Power: What South Korea Must Do After Peaking," Carnegie Endowment for International Peace, accessed June 1, 2025, https://carnegieendowment.org/research/2024/08/the-future-of-k-power-what-south-korea-must-do-after-peaking?lang=en.

[76] *Rise of the "Big 4" The Semiconductor Industry in Asia Pacific*.

[77] Heekyong Yang and Joyce Lee, "Samsung Electronics to Invest $230 Bln through 2042 in South Korea Chipmaking Base," Technology, *Reuters*, March 15, 2023, https://www.reuters.com/technology/samsung-electronics-invest-230-bln-through-2042-south-korea-chipmaking-base-2023-03-15/.

[78] Kim Eun-jin, "South Korea Aiming to Become AI Semiconductor Industry Powerhouse," Businesskorea, October 13, 2020, https://www.businesskorea.co.kr/news/articleView.html?idxno=53036.

[79] Arthur D. Little, "Localizing the Global Semiconductor Value Chain."

[80] "South Korea's Semiconductor Funds Highlight a Partisan Battle," accessed July 11, 2025, https://thediplomat.com/2023/09/south-koreas-semiconductor-funds-highlight-a-partisan-battle/.

[81] Judy Meiksin, "US 'CHIPS and Science Act' Gives Semiconductor R&D and Industry a Multibillion Dollar Boost," *MRS Bulletin* 47, no. 9 (2022): 890–92, https://doi.org/10.1557/s43577-022-00409-z.

and development to key inputs.[82] This bipartisan Act channels hundreds of millions to domestic microelectronics research centers, national labs, and universities (NSF, NIST, DOE, etc.) to drive long-term innovation.[83]

At the federal level, a network of key research institutions including the National Science Foundation, National Institute of Standards and Technology, Defense Advanced Research Projects Agency, and the Department of Energy's Office of Science provide crucial funding and infrastructure for basic scientific research that drives semiconductor innovation.[84]

This public investment is complemented by remarkable private sector commitment, with the US semiconductor industry reinvesting approximately 20% of its annual revenue into R&D, the highest percentage of any industry sector. This synergistic relationship between government-funded basic research and aggressive private sector R&D investment has created a powerful innovation engine that continually advances America's technological capabilities and helps maintain its global competitiveness in critical areas like chip design and intellectual property development.[85]

China: State-Led Strategic Investment

China's government has pursued an aggressive R&D strategy in recent decades. Beginning in the early 2010s, China launched national programs (notably the National IC Plan and Made in China 2025) that coordinate massive state funding for chip R&D, fabrication, and IP development.[86] Analyses note that China's attempts since 2014 to support and grow its domestic semiconductor industry have drawn considerable international attention. Under these plans, China has created multi-billion-dollar chip funds, subsidized domestic foundries, and required foreign firms to transfer technology locally (to boost indigenous R&D). The goal is technological self-sufficiency – for example, the Made-in-China initiative explicitly aimed to raise domestic chip output to 70% of demand by 2025. Despite trade restrictions and technical challenges, China's R&D push has already made it the world's largest filer of semiconductor research papers and patents.[87]

China's motivations have been attributed to the pursuit of technological self-reliance, being spurred by U.S. export controls, and the desire to 'design out' American components. However, China's semiconductor market is perceived as more 'inward looking,' perhaps driven by the quest to accelerate self-reliance as opposed to working with the best semiconductor firms in the market, many of which are based in the United States and Europe.[88]

China's approach represents the most ambitious state-directed technology investment in history, with over $150 billion invested in semiconductors since 2014. The National IC Industry Investment Fund exemplifies this approach across three phases:[89]

- Big Fund I (2014-2019): USD$21-23 billion with 69.7% allocated to manufacturing
- Big Fund II (2019-2024): USD$29-35 billion with conservative focus on equipment and materials
- Big Fund III (2024-present): USD$47.5 billion, exceeding the first two phases combined

This is complemented by extensive provincial and local funding, with at least 15 local government IC funds totaling USD$25+ billion.[90] Shanghai alone has committed USD$45 billion in integrated circuit industry investment, while Shenzhen has established 38 IC funds collectively worth over USD$13.8 billion.[91] The success of their policies can be seen through the metrics - China's share of global semiconductor manufacturing rising from 12% (2014)

[82] Meiksin, "US 'CHIPS and Science Act' Gives Semiconductor R&D and Industry a Multibillion Dollar Boost."

[83] Meiksin, "US 'CHIPS and Science Act' Gives Semiconductor R&D and Industry a Multibillion Dollar Boost."

[84] Sarah Ravi, "Semiconductor Industry Sets Out Research Needed to Advance Emerging Technologies, Unleash Next-Generation Semiconductors," *Semiconductor Industry Association*, March 30, 2017, https://www.semiconductors.org/semiconductor-industry-sets-out-research-needed-to-advance-emerging-technologies-unleash-next-generation-semiconductors/.

[85] Ravi, "Semiconductor Industry Sets Out Research Needed to Advance Emerging Technologies, Unleash Next-Generation Semiconductors."

[86] John VerWey, "Chinese Semiconductor Industrial Policy: Past and Present," *Journal of International Commerce and Economics*, July 2019.

[87] VerWey, "Chinese Semiconductor Industrial Policy: Past and Present."

[88] Konark Bhandari, "India's Semiconductor Mission: The Story So Far," Carnegie Endowment for International Peace, accessed September 7, 2025, https://carnegieendowment.org/research/2025/08/indias-semiconductor-mission-the-story-so-far?lang=en.

[89] Sarah Ravi, "Taking Stock of China's Semiconductor Industry," *Semiconductor Industry Association*, July 13, 2021, https://www.semiconductors.org/taking-stock-of-chinas-semiconductor-industry/.

[90] Ravi, "Taking Stock of China's Semiconductor Industry."

[91] "Shenzhen Steps up Semiconductor Investments with City-Backed Fund Worth US$692 Million | South China Morning Post," accessed July 11, 2025, https://www.scmp.com/tech/tech-war/article/3310215/shenzhen-steps-semiconductor-investments-city-backed-fund-worth-us692-million.

to 23% (2024), with monthly wafer production reaching 8.85 million wafers and 18 new fabs constructed in 2024.

China has devoted considerably more funds toward its semiconductor journey, although with mixed results, when considering the overall scale of funds deployed. Despite massive investments, China is still looking to undertake the ambitious task of building its own version of technologies that currently serve as chokepoints in the semiconductor supply chain. This can in part be attributed to the fact that Chian's semiconductor strategy differs markedly from other countries' approaches. While nations like India have adopted strategies that solicit interest from key anchor firms, often American, to move domestically along with their supplier ecosystems, China's approach has been more focused on building indigenous capabilities. This inward-looking strategy reflects China's broader goal of technological independence rather than integration with existing global supply chains.[92]

Japan's Reshoring imperatives

Japan, a once-leading chip exporter, has recently re-entered the semiconductor policy race with an emphasis on R&D and international partnerships. By 2021 Japan's Ministry of Economy, Trade, and Industry (METI) "framed its grand strategy for semiconductors … as a high priority for public and private support," driven by "a concern for strategic independence amid the conflict for technological hegemony between the US and China".[93] In late 2022 and 2023 Japan passed new incentives and co-funding projects for chip fabs and next-generation R&D. The language is explicitly about national security: METI now treats semiconductors as a national security interest and aims to reverse decades of offshoring advanced chip production.[94] Recent Japanese initiatives include the startup Rapidus (a government-backed new foundry) and funding for joint industrial research projects. Japan has also signed bilateral agreements to secure its supply chain: for example, a 2023 Japan-India Semiconductor Partnership Dialogue was established to "enhance supply chain resilience" and "explore areas of mutually beneficial R&D collaboration".[95] These moves signal that Japan, like other democracies, now views domestic R&D and international R&D linkages as key to chip sovereignty.

Other regions are following suit. In the European Union, the 2023 Chips Act aims to double Europe's share of global chip production (to 20%) by 2030 through coordinated R&D and manufacturing projects.[96] The EU explicitly frames chip policy in terms of "technological sovereignty" and strategic autonomy, like Japan's rhetoric. In short, across the globe governments are layering massive R&D spending on top of manufacturing incentives to shore up supply chains in an era of geopolitical uncertainty.

Key Success Factors and Strategic Insights

An analysis of the semiconductor strategies employed by leading nations - Taiwan, South Korea, the United States, and China, reveals several shared foundational elements that underpin their approaches to fostering domestic semiconductor industries.

- Substantial Government Investment and Subsidies: A prominent commonality across these nations is the commitment of significant government capital to bolster their domestic semiconductor sectors. This financial backing is recognized as critical for an industry characterized by immense capital expenditure and the need for long-term research and development. Examples include Taiwan's enduring support for TSMC, South Korea's K-semiconductor strategy, the provisions within the US CHIPS and Science Act, and China's multi-phase "Big Fund." These investments typically encompass direct grants, tax incentives for R&D and capital projects, and the formation of public-private consortiums.
- Prioritization of Research and Development: Each nation underscores the central role of R&D and innovation as the primary driver of the semiconductor industry. There is a concerted effort to cultivate cutting-edge research, spanning from fundamental scientific inquiry to commercial applications.

[92] Bhandari, "India's Semiconductor Mission."
[93] Chang, "The Return of Japan's Semiconductor Industry."
[94] Chang, "The Return of Japan's Semiconductor Industry."
[95] *Outline of Semiconductor Revitalization Strategy in Japan* (Commerce and Information Policy Bureau, Ministry of Economy, Trade and Industry, 2024), https://www.meti.go.jp/english/policy/0704_001.pdf#:~:text=%E2%9C%93%20Establish%20the%20Japan,IT.
[96] Xiong et al., "(PDF) Semiconductor Supply Chain Resilience and Disruption."

Long-term commitment to R&D investment is fundamental to success, with nations maintaining consistent funding across economic cycles.[97] This is exemplified by Taiwan's Industrial Technology Research Institute (ITRI), South Korea's national programs supporting university laboratories and fabless startups, the US funding of key research institutions (such as the National Science Foundation, National Institute of Standards and Technology, and Department of Energy), and China's aggressive R&D initiatives, which have resulted in a notable increase in semiconductor-related patents and research publications. The objective extends beyond mere manufacturing capacity to encompass the development of intellectual property and technological leadership essential for advancing future generations of chips.

- Strategic Workforce Development: A critical and widely acknowledged bottleneck across all national strategies is the imperative for a highly skilled workforce.[98] Consequently, nations are proactively investing in comprehensive education and training programs, ranging from early-stage coding instruction in primary schools to specialized university and doctoral-level programs. South Korea's ambitious plan to train 150,000 new semiconductor experts and the US emphasis on STEM graduates and attracting global talent serve as prime illustrations. This demonstrates that a robust semiconductor industry necessitates a continuous supply of highly trained engineers, scientists, and technicians in addition to fabrication facilities and financial resources.
- Promotion of Strategic Clustering and Ecosystem Development: Nations are actively encouraging the formation of integrated industrial clusters to foster synergy within their semiconductor sectors. Taiwan's successful integrated circuit parks, South Korea's conceptualized "K-Semiconductor Belt," and the US CHIPS Act's focus on domestic microelectronics research centers and national laboratories all aim to cultivate cohesive ecosystems where R&D, design, fabrication, packaging, and related industries can operate in close proximity. This strategic co-location facilitates collaboration, accelerates knowledge transfer, and enhances operational efficiency throughout the value chain.
- Targeted Focus on Key Strategic Sectors and Technologies: While striving for broad industry strength, each nation also identifies and targets specific areas for technological leadership or strategic importance. For instance, South Korea explicitly targets artificial intelligence (AI), automotive, and power semiconductors, leveraging its existing dominance in memory chips. Taiwan prioritizes advanced manufacturing processes and extreme ultraviolet (EUV) lithography. China's "Made in China 2025" initiative aimed for self-sufficiency across the entire value chain, with particular emphasis on key inputs and advanced manufacturing. The United States maintains a focus on preserving leadership in chip design and intellectual property development.
- Multi-Level Governance Framework: A notable emerging trend in semiconductor policy is the rise of sophisticated multi-level governance frameworks that balance national coordination with regional specialization. Unlike traditional top-down industrial policy, these models recognize that semiconductor development requires alignment of federal objectives with local competitive advantages. The European Union exemplifies this through its Chips for Europe Initiative, which harmonizes Union- and national-level funding while enabling member states to specialize. The United States adopts a reverse-sequencing model under the CHIPS and Science Act, requiring companies to first secure state or local incentives before qualifying for federal support—thereby ensuring local buy-in and risk-sharing. India offers yet another variation through its federal–state coordination model: projects must first be approved by the India Semiconductor Mission, after which states compete to offer additional incentives. This two-tier structure

[97] KPMG, "India's Semiconductor Ambitions."

[98] Nile Hatch and Dyer, "Human Capital and Learning as a Source of Sustainable Competitive Advantage | Request PDF," *ResearchGate*, n.d., https://doi.org/10.1002/smj.421.

uniquely combines national strategic coherence with dynamic state-level competition, positioning India as an important test case for how multi-level governance can drive both alignment and innovation in semiconductor policy.

A Comprehensive R&D and Ecosystem Development Strategy

India's strategic imperative to restructure its semiconductor R&D ecosystem is driven by a confluence of internal capabilities and external geopolitical realities. While India possesses a significant human capital advantage in chip design, its contribution has largely been in design services rather than the creation of proprietary intellectual property (IP). A successful restructuring must explicitly aim to shift this dynamic, fostering indigenous IP creation and moving beyond a service-centric model to secure greater long-term strategic and economic value. This shift is crucial for India to fully leverage its large and rapidly growing domestic electronics market, which can serve as a crucial and potentially guaranteed customer base for locally produced semiconductors, thereby de-risking domestic R&D and manufacturing investments.

Based on the discussions above and after analyzing the R&D models used by other countries- these are the policy recommendations which can be adapted to India. This section analyzes the fundamental components required for a successful semiconductor R&D ecosystem, drawing heavily on lessons from leading global nations. It specifically addresses the user's requirements for a semiconductor roadmap, a triple helix cluster, and strategic specialization.

Developing a National Semiconductor Technology Roadmap: A Strategic Tool

India's semiconductor industry requires a comprehensive research and development strategy to strengthen supply chain security and reduce import dependence. The framework for an effective R&D policy must be predicated on several fundamental principles.[99] Consequently, India should develop a detailed technology roadmap with clear milestones for advancing semiconductor capabilities across the value chain. The policy roadmap idea is not new- there is an AI infrastructure roadmap envisioned under the TRUST framework between India and the US.[100] Conversations with stakeholders have revealed that use of specific instruments such as road maps with pre-determined timelines have proven to be effective policy tools for development in critical and emerging technologies.

This roadmap should align R&D priorities with strategic national objectives while identifying specific technologies and capabilities for focused development. The roadmap can be a dynamic tool, which is regularly updated to reflect changing industry dynamics and technological developments. This can help to frame the R&D policy for India and can also be used to develop collaborations with other states through technology partnerships.

The key to framing and implementing an appropriate R&D policy for India to establish itself in the semiconductor value chain lies in building a long-term vision. It is essential to have a strategic focus that aligns R&D efforts with national priorities, particularly in achieving technological sovereignty and ensuring supply chain security.[101] This recognition of the importance of R&D into semiconductors and its effects on the overall security and technological sovereignty of India are key components of building a framework for semiconductor policy. Consequently, the framework necessitates a long-term vision, acknowledging that building a robust semiconductor industry requires sustained investment and commitment over multiple years.[102]

The development of India's semiconductor industry requires an integrated approach that combines targeted research and development with systematic ecosystem building. This section presents a comprehensive framework for advancing India's

[99] Nidhi Singh, "An Indian Semiconductor Story," *The CCG Blog*, December 23, 2024, https://ccgnludelhi.wordpress.com/2024/12/23/an-indian-semiconductor-story/.

[100] "The India-U.S. TRUST Initiative: A Policy Roadmap for Accelerating AI Infrastructure," Carnegie Endowment for International Peace, accessed June 1, 2025, https://carnegieendowment.org/posts/2025/04/the-india-us-trust-initiative-the-us-india-roadmap-on-accelerating-ai-infrastructure-a-policy-agenda?lang=en.

[101] Nidhi Singh, "India's Semiconductor Story Needs A Focused Strategy," *The Secretariat*, n.d., accessed June 1, 2025, https://thesecretariat.in/article/india-s-semiconductor-story-needs-a-focused-strategy.

[102] Nidhi Singh, "In Global Semiconductor Race, India Playing Catch-Up," *The Secretariat*, n.d., accessed June 1, 2025, https://thesecretariat.in/article/in-global-semiconductor-race-india-playing-catch-up.

semiconductor capabilities through strategic R&D investments and ecosystem development initiatives.[103]

The attraction of global semiconductor companies requires a sophisticated incentive framework, which focuses on building up the overall semiconductor ecosystem in the country. A comprehensive R&D framework would have to look at not just the areas of research priority but also factors to improve the overall semiconductor ecosystem in India.

The Semicon India Program's offering of substantial financial incentives, including project cost reimbursement and production-linked incentives, provides a foundation for industry development.[104] These financial incentives must be complemented by capital expenditure subsidies and targeted tax benefits that encourage both manufacturing operations and research activities.[105]

For India, a national semiconductor roadmap must be more than a mere list of technologies; it needs to function as a strategic tool for resource allocation, for de-risking investments, and for signaling national intent to both domestic and international stakeholders. In an industry characterized by immense capital expenditure and long lead times, a clear roadmap significantly reduces uncertainty for investors, both public and private. It provides a clear indication of which technologies the government will prioritize and support, thereby de-risking private investment in those specific areas.

This clarity is crucial for attracting both domestic and foreign capital. The roadmap thus serves as a guiding principle for the entire ecosystem. It helps prevent fragmented efforts, ensures optimal allocation of limited resources, and provides a common vision for industry, academia, and government. For international partners, a well-defined roadmap clearly articulates India's strategic focus, making it easier to identify areas for mutually beneficial collaboration. The dynamic nature of such a roadmap is particularly important in a fast-evolving sector, implying a need for regular review and adaptation mechanisms to remain relevant and effective.

Fostering a Triple Helix Model for Talent and Innovation Workflow: Deepening Collaboration

A recurring lesson that has emerged is that successful chip ecosystems require the so-called triple helix of coordinated R&D among government, industry, and universities. Historical examples include the U.S. SEMATECH consortium (1987–1990s), a DARPA-industry R&D joint venture credited with helping the U.S. regain leadership. Japan’s postwar VLSI projects similarly pooled government subsidies across companies and research institutions, spurring patenting and collaboration. Today’s policies echo this model: South Korea’s government directly funds university-startup tech transfer programs; European Chips Act creates innovation hubs linking firms and labs; and India’s ISM is signing academic R&D MOUs (IISc–Lam, Purdue–ISM, etc.) to train talent and co-develop technology.

While India has initiated collaborations within the triple helix framework, their effectiveness depends on moving beyond general agreements to deeply integrated, outcome-oriented programs that directly address the "industry-readiness" gap in talent. The existing talent landscape highlights a significant gap between theoretical knowledge and practical industry requirements, emphasizing the need for making graduates industry-ready.[1] The mere existence of Memoranda of Understanding (MoUs) or general partnerships does not automatically translate into industry-ready talent or direct commercialization of research. True triple helix success, as seen in Taiwan's Industrial Technology Research Institute (ITRI) or South Korea's focused programs, involves deep, structured integration, such as industry experts teaching in academic settings, joint laboratories, extensive internships, shared equipment, and direct funding for commercialization-focused university research.[1] India needs to evaluate if its current collaborations are sufficiently deep and outcome-oriented. The focus should shift from simply increasing the number of trained individuals to ensuring the quality and relevance of the training, directly linking academic output to industry needs and integrating industry professionals into curriculum development and

[103] Singh, “India’s Semiconductor Story Needs A Focused Strategy.”

[104] “Government of India Taking Steps to Encourage Domestic Manufacturing of Semiconductors & Promote Country’s Digital Transformation and Self-Reliance,” Press Information Bureau, accessed June 1, 2025, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=2039638.

[105] “R&D Tax Incentives,” OECD, accessed June 1, 2025, https://www.oecd.org/en/topics/r&d-tax-incentives.html.

delivery. This will be crucial for bridging the skills gap and fostering a seamless talent workflow.

The establishment of an India Semiconductor Research Centre provides crucial coordination for R&D activities. [106] Modeled on successful international institutions like IMEC and MIT Micro-Electronic Labs, the ISRC should focus on semiconductor processes, advanced silicon solutions, packaging R&D, compound semiconductors, and chip design. [107] The center should serve as the cornerstone institution in driving semiconductor R&D and innovation. As a central hub, the ISRC would coordinate research activities across various institutions and organizations, facilitate industry-academia collaboration through joint research projects and knowledge sharing initiatives, and develop specialized training programs to attract and cultivate skilled talent.[108] The center would also play a crucial role in promoting international collaboration by engaging with global research institutions and organizations.

Furthermore, the success of the triple helix model in talent development is intrinsically linked to creating attractive career pathways and addressing the perceived return on investment for semiconductor engineering students. South Korea's comprehensive model, which includes easing student quotas, providing financial aid, designating "Graduate Schools of Semiconductors," and attracting industry experts as professors, is part of a broader plan to nurture a large digital workforce.1 These measures aim to both increase the supply of talent and make semiconductor careers more appealing. By easing quotas, they increase access; by providing financial aid and specialized schools, they reduce financial burden and enhance the perceived quality of education; and by bringing in industry experts, they bridge the theory-practice gap, making graduates more employable. For India, simply increasing training programs, such as the "Chips to Startup" scheme, might not be enough if students continue to perceive better opportunities elsewhere, like in AI or data science.1 The triple helix must actively work to create a compelling value proposition for semiconductor careers, demonstrating clear pathways to employment, competitive salaries, and opportunities for advanced research and innovation within India. This requires active participation from industry in defining curricula and offering early career opportunities.

Strategic Specialization in R&D and Talent within the Semiconductor Value Chain: A Pragmatic Pathway

India's specialization in R&D and talent is not a compromise but a strategic imperative driven by global market realities and India's comparative advantages, offering a more efficient path to technological sovereignty than a "full-stack" approach. Given the prohibitive capital costs and decades-long lead times for advanced manufacturing, attempting to compete across the entire value chain would dilute India's limited resources and likely prove unsustainable. Focusing on R&D and talent leverages India's existing human capital strength and allows it to enter the high-value, less capital-intensive segments. This approach aligns with the global trend of specialization, where nations like the United States lead in design, Taiwan in advanced manufacturing, and the Netherlands in critical equipment. This specialization allows India to achieve technological sovereignty not by doing everything, but by controlling critical intellectual property and human capital, which are foundational to the entire value chain. It also positions India as an indispensable partner in the new geopolitically driven supply chain diversification efforts, rather than a direct competitor to established manufacturing giants. This represents a pragmatic and strategic pathway to global competitiveness.

International collaboration offers significant opportunities for advancing India's semiconductor R&D capabilities. Strategic alliances through mechanisms like the Quad, Indo-Pacific Economic Framework, and India-EU Trade and Technology Council can facilitate access to advanced technologies and expertise. [109] Collaboration with countries like Japan and the Netherlands, which possess specialized expertise in specific segments of the

[106] Aashish Aryan, "Centre Eyes Dedicated R&D Wing under Semicon Research Centre," *The Economic Times*, May 9, 2024, https://economictimes.indiatimes.com/tech/technology/centre-eyes-dedicated-rd-wing-under-semicon-research-centre/articleshow/109958069.cms?from=mdr.

[107] Bhupendra Paintola, "Govt Mulls Separate Semiconductor R&D Unit With Short Project Timelines," *Inc42 Media*, May 9, 2024, https://inc42.com/buzz/govt-mulls-separate-semiconductor-rd-unit-with-short-project-timelines/.

[108] ITIF, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains |."

[109] "Securing Semiconductor Supply Chains," Hinrich Foundation, accessed June 1, 2025, https://www.hinrichfoundation.com/research/how-to-use-it/securing-semiconductor-supply-chains/.

semiconductor value chain, can accelerate technological development.[110]

The establishment and promotion of global standards represents another crucial policy objective. Active participation in international standards development ensures compatibility with global systems while protecting India's technological interests.[111]

Building an implementation framework

Government funding for semiconductor development must increase substantially through grants, subsidies, and tax incentives.[112] Public-private partnerships can leverage private sector expertise while sharing investment risks. Venture capital and private equity participation should be encouraged through appropriate policy frameworks and incentive structures.[113] These partnerships should facilitate joint research initiatives between universities and industry, establish centers of excellence in key technical areas, and promote knowledge transfer between research institutions and commercial enterprises.

Additionally, the government must look to create a more stable and transparent regulatory environment must support both R&D activities and ecosystem development. Single-window clearance systems can minimize administrative burdens, while robust intellectual property protection encourages innovation. India's National Single Window System (NSWS), launched in September 2021 by the Department for Promotion of Industry and Internal Trade, aims to streamline business operations by providing a unified platform for regulatory approvals.[114]

While the system's goal is to simplify the process for investors and entrepreneurs by eliminating redundant paperwork, reducing compliance burdens, and accelerating project timelines, its early performance indicates room for improvement. As of January 2023, the NSWS had processed just 75,000 approvals out of 1.23 million applications, representing a modest 6% approval rate.[115] This suggests that while the platform represents a step toward reducing bureaucratic complexity in India's business environment, significant efficiency gains are still needed to achieve its intended purpose of facilitating ease of doing business.

A crucial element of this is also creating advanced analytics capabilities, including artificial intelligence and machine learning, offer significant potential for managing development risks. These tools can help predict and mitigate supply chain disruptions while providing metrics for assessing program effectiveness.[116] Regular performance assessment enables timely policy adjustments and resource reallocation.

Conclusion

India's aspiration to become a semiconductor powerhouse emerges at a pivotal moment in the global semiconductor landscape. The industry's ongoing transformation toward "multi-markets" and the push for supply chain diversification, accelerated by geopolitical tensions, creates a unique window of opportunity for India to establish itself as a new manufacturing hub. India's position as a democratic nation with strong ties to Western countries that control critical segments of the semiconductor value chain provides a strategic advantage in this evolving landscape.

The analysis presented in this paper reveals that India's path to semiconductor prominence lies not in attempting to replicate the comprehensive value chains of established players, but in leveraging its distinctive strengths to carve out an indispensable role in the global ecosystem. India's comparative advantage in human capital, its large and growing domestic market, and its position as a stable democratic partner in an increasingly fragmented world create a unique strategic foundation.

[110] Benson et al., "Securing Semiconductor Supply Chains in the Indo-Pacific Economic Framework for Prosperity."

[111] Carnegie Endowment for International Peace, "Is India 'Ready' for Semiconductor Manufacturing?"

[112] Paintola, "Govt Mulls Separate Semiconductor R&D Unit With Short Project Timelines."

[113] Manik Sadashiv Sonawane et al., "The Development of the Semiconductor Supply Chain in India: Challenges and Opportunities," in *ICT: Smart Systems and Technologies*, ed. M. Shamim Kaiser et al. (Springer Nature, 2024), https://doi.org/10.1007/978-981-99-9489-2_4.

[114] "National Single Window System," accessed June 1, 2025, https://www.nsws.gov.in/about-us.

[115] ITIF, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains |."

[116] Mei Yang et al., "Supply Chain Risk Management with Machine Learning Technology: A Literature Review and Future Research Directions," *Computers & Industrial Engineering* 175 (January 2023): 108859, https://doi.org/10.1016/j.cie.2022.108859.

The proposed R&D-centered strategy addresses India's most pressing challenges while building on its inherent strengths. The National Semiconductor Technology Roadmap provides the strategic clarity necessary to align government, industry, and academic efforts while de-risking private investment. The Triple Helix Innovation Ecosystem ensures that India's impressive talent pipeline translates into industry-ready skills and indigenous innovation. Strategic specialization in R&D and intellectual property creation offers a more efficient path to technological sovereignty than capital-intensive manufacturing competition. The enhanced legal framework removes critical barriers to innovation and IP protection that currently hinder ecosystem development.

India's semiconductor journey, while promising, must learn from global experiences. For a country that started from scratch four years ago, in an industry as complex as semiconductor supply chains, the current effort has been implemented well. However, the focus must remain on leveraging India's collaborative approach with global partners rather than pursuing complete self-sufficiency, which has proven challenging even for nations with far greater resources.

India's semiconductor future depends not only on the policies it adopts but also on the speed and effectiveness of their implementation. The window of opportunity created by current global dynamics may not remain open indefinitely, making urgent and coordinated action essential for securing India's position in the global semiconductor ecosystem. The path ahead is challenging but achievable. With appropriate policies, sustained investment, and strategic focus, India can transform from a semiconductor-dependent nation into a global semiconductor powerhouse, contributing to both national prosperity and global technological advancement. The time for action is now, and the opportunity for transformation has never been greater.

Glossary of Terms

AI (Artificial Intelligence): The simulation of human intelligence processes by machines, especially computer systems. These processes include learning, reasoning, and self-correction.

Chip: A common term for an integrated circuit (IC) or microchip, a set of electronic circuits on one small flat piece of semiconductor material, usually silicon.

Design (Semiconductor): The process of creating the blueprints and specifications for integrated circuits, often involving highly specialized software and intellectual property.

Fab (Fabrication Plant): Short for "fabrication plant," a factory where semiconductor devices are manufactured. These facilities are highly complex, require massive investment, and operate under extremely controlled conditions.

Friend-shoring: The strategy of relocating supply chains to countries considered political and economic allies, aiming to reduce risks associated with geopolitical tensions and ensure supply chain resilience.

Generative Artificial Intelligence (Generative AI): A type of artificial intelligence that can create new content, such as text, images, or other media, rather than just analyzing existing data.

Integrated Circuit (IC): An electronic circuit fabricated on a small, flat piece of semiconductor material, typically silicon. It integrates many miniature electronic components into a single, compact device.

Intellectual Property (IP): Creations of the mind, such as inventions, literary and artistic works, designs, and symbols, names, and images used in commerce. In semiconductors, this often refers to chip designs, manufacturing processes, and

Onshoring: The process of bringing manufacturing or production operations back to a company's home country.

Process Node: A reference to the feature size of transistors on a chip, typically measured in nanometers (nm). Smaller process nodes generally indicate more advanced and powerful chips.

R&D (Research and Development): Systematic work undertaken to increase the stock of knowledge, including knowledge of humankind, culture, and society, and the use of this stock of knowledge to devise new applications. In this context, it refers to efforts in semiconductor technology.

Semiconductor: A material, such as silicon, that has electrical conductivity properties between those of a conductor and an insulator, making it fundamental for electronic devices.

Semiconductor Ecosystem: The entire network of entities involved in the semiconductor industry, including design companies, foundries (fabs), equipment manufacturers, material suppliers, research institutions, and workforce development programs.

Semiconductor Value Chain: The sequence of activities involved in the production of semiconductors, from raw material extraction and wafer manufacturing to chip design, fabrication, packaging, testing, and distribution.

Supply Chain Resilience: The ability of a supply chain to withstand and recover from disruptions, maintaining its functions and operations.

Technological Sovereignty: A nation's capacity to develop, control, and secure its own core technologies, reducing dependence on foreign entities and protecting national interests.

ABOUT THE AUTHOR

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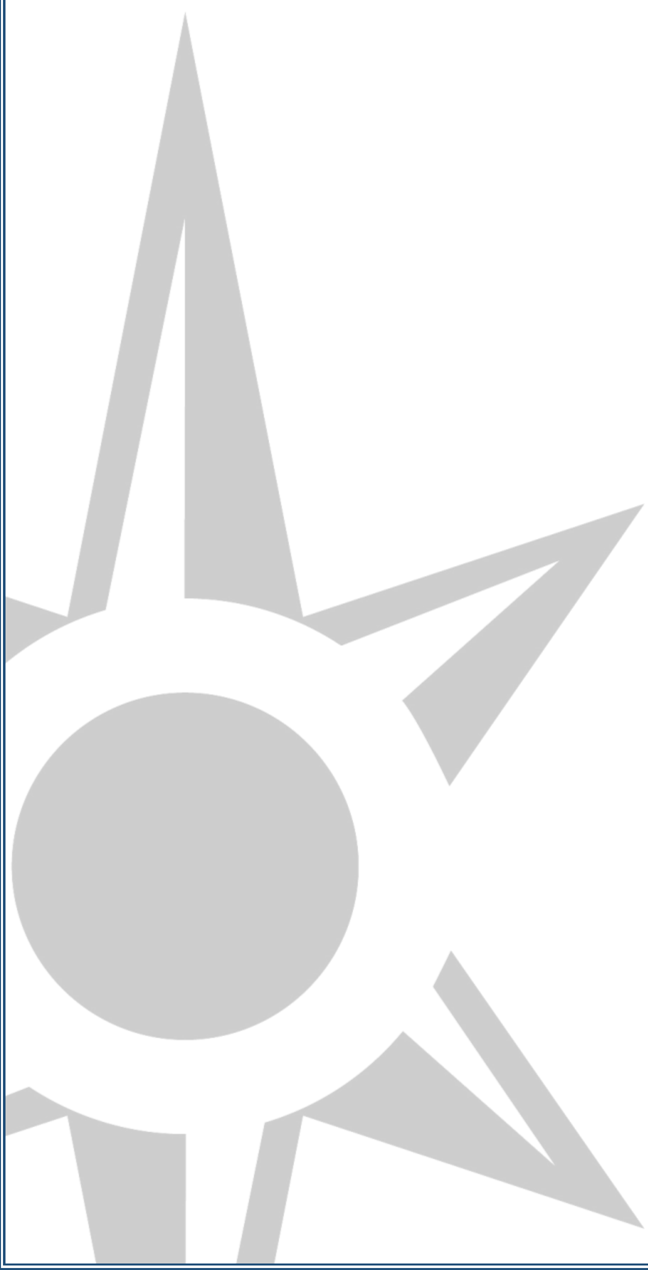
Towards a Just Chips Partnership: Embedding Trade Justice in Global Semiconductor Policy

By
Pranusha Kulkarni



Executive Summary

Pranusha Kulkarni

As the global semiconductor economy reorganises around resilience, security, and industrial competitiveness, a critical governance gap has emerged. The emerging trade architecture driven by strategic export controls, capital-intensive reshoring subsidies, and informal techno-industrial alliances has largely excluded emerging and developing economies (EDEs) from both supply chain participation and rule-making. Yet these same economies account for a growing share of global demand for chips powering energy transitions, digital infrastructure, and public service delivery.

This paper argues that semiconductors must be treated as normative global public goods when used in climate and development applications. It proposes the creation of a Just Chips Partnership (JCP) – a plurilateral, development-aligned governance mechanism designed to rebalance participation, access, and innovation in the global semiconductor economy.

Why a Just Chips Partnership?

Despite growing policy interest in "trusted" supply chains and "friend-shoring," current efforts remain narrowly defined and exclusive. Forums like Chip 4, export control coalitions, and plurilateral trade deals reinforce dependency hierarchies by controlling access to upstream technologies (like EDA software, IP cores, advanced nodes) and maintaining tight restrictions on fabrication inputs. Meanwhile, subsidy regimes in the Global North, such as the US CHIPS Act and the EU Chips Act, favour domestic firms without offering institutional space for development-led collaboration.

In contrast, the JCP proposes a rules-based, equity-oriented alternative. It enables EDEs to:

- Coordinate diplomatic positions on export controls, IP reform, and trade equity;
- Build shared design and fabrication capacity for climate-relevant chip innovation;
- Access public-good licensing models and pooled IP repositories; and
- Mobilize capital for inclusive semiconductor ecosystems through blended finance instruments.

Why the JCP Also Benefits the Global North and Semiconductor Industry

The JCP is not a zero-sum shift in semiconductor governance, but is a mutually reinforcing platform for resilience and legitimacy across the global trade ecosystem. For governments and companies in the Global North, the JCP creates:

- **Expanded and diversified markets** for semiconductor firms seeking scale in emerging climate-tech sectors (e.g., mobility, energy, public infrastructure);
- **Stability in supply chains** by reducing geopolitical bottlenecks and expanding fabless design ecosystems in politically stable allied economies;
- **Innovation partnerships** with public research institutions, startups, and governments in new geographies, many of which offer specialized use-case development;
- **Geopolitical legitimacy** by rebalancing the normative optics of semiconductor diplomacy, transitioning from exclusion to co-development;
- Opportunities to shape **open licensing standards and norms** aligned with climate and SDG goals, especially in multilateral forums such as WTO, WIPO, and UNFCCC.

Private capital also benefits by the proposed JCP, as global VC and private equity can co-invest with sovereign vehicles through "JCP-Invest", enabling de-risked, SDG-aligned returns across geographies. As advanced semiconductor nodes saturate in industrial economies, the next growth opportunity lies in mission-driven chips for public goods, precisely what the JCP unlocks.

Structure of the Just Chips Partnership

The JCP should be designed as a multi-node institutional platform with the following components:

1. **Steering Committee:** A deliberative and coordination body with rotating representation from EDEs, observers from WTO/UNCTAD/WIPO, and technical advisors from academia and industry.
2. **Regional R&D Clusters:** Publicly funded fabless design hubs in South Asia, Africa, Latin America, focused on low-energy chips, climate-tech, and public infrastructure.
3. **Shared Prototyping Infrastructure:** Mid-range fabrication, packaging, and test facilities with time-sharing models for countries lacking fabs, funded via development banks and public–private consortia.
4. **Common IP Pools:** Non-exclusive, climate-aligned licensing regimes modelled after WIPO's development agenda and the Medicines Patent Pool, to prevent fragmentation and duplication.
5. **JCP-Invest:** A coordinated investment vehicle that blends sovereign, private, and philanthropic capital to de-risk chip ventures serving public-interest domains.
6. **Plurilateral Platform:** A legal-policy coordination node that aligns JCP countries' positions on WTO TRIPS reform, ITA reinterpretation, and Paris Agreement Article 10 climate-tech provisions.

Strategic Recommendations for Emerging and Developing Economies (EDEs)

To operationalise the JCP vision, the paper proposes interlinked policy shifts across trade diplomacy, domestic industrial policy, IP governance, and finance:

- **Multilateral Diplomacy:** EDEs should push for a reinterpretation of WTO TRIPS Article 66.2 (tech transfer obligations), expansion of Special and Differential Treatment (SDT), and proactive inclusion in any ITA-3 deliberations. Export control rules must be subjected to transparency and developmental scrutiny.
- **Domestic Policy Reform:** Governments must reorient from subsidy-led strategies (e.g., PLI-style incentives) to building regional R&D ecosystems, shared fab access, and licensing commons aligned with climate and public goods needs.
- **Climate-Tech Integration:** Semiconductor access should be embedded into NDCs and climate finance mechanisms, making chips a formal part of technology transfer under Article 10 of the Paris Agreement.
- **Finance and IP Ecosystems:** Sovereign innovation funds should co-invest in open-standards chip ventures, support EDA software commons, and offer fiscal support for firms contributing to IP pools and regional skilling networks.
- **South-South and Triangular Cooperation:** Peer learning, pooled infrastructure, and harmonised regulation via ASEAN, AU, BRICS+, or MERCOSUR should be institutionalised, with agile partnerships with Singapore, South Korea, and Israel facilitating transitions.

Implications for US-India Engagement

For the US, the JCP offers a framework for engaging with EDEs beyond extractive partnerships. Integrating development-friendly terms into the semiconductor supply chain resilience agenda especially in Asia and Africa can enhance geopolitical legitimacy and climate credibility. For India, the JCP aligns with existing digital public infrastructure strategies, advances south–south industrial diplomacy, and provides a plurilateral counterweight to polarised chip geopolitics.

Introduction: The Weaponization of Hi-Tech Trade and the Case for a Global Public Goods Approach

As semiconductors become central to climate adaptation, digital governance, and civilian innovation, their governance architecture must evolve from exclusionary strategic control to an inclusive, development-oriented framework. This section argues that knowledge systems underpinning advanced semiconductor technologies ought to be treated as normative global public goods, particularly for the developmental needs of technology-constrained economies.

The global semiconductor ecosystem is no longer simply a commercial domain. It has evolved into a geopolitical terrain, shaped by growing techno-nationalism, export restrictions, and strategic reshoring[1]. The post-pandemic decade has witnessed intensified securitization of semiconductor trade, most visibly in the form of US-led export controls on high-end AI chips and China's countermeasures involving rare earth minerals[2]. While these measures are framed as national security imperatives, they risk institutionalizing exclusionary practices in one of the most crucial general-purpose technologies of our time.

This is a cause for concern, especially for countries like India, which sit at the intersection of high developmental ambitions, digital innovation capacity, and a persistent dependency on foreign-controlled chip technologies. India's attempts to build a semiconductor ecosystem through initiatives like the Semicon India Programme, PLI schemes, and recent announcements of collaborative fabs indicate policy momentum – but the structural limitations of the current global trade architecture [3] remain unaddressed.

Chips, Vaccines, and Fertilizer Inputs: The case for using normative public goods approach for policy innovation

The COVID-19 pandemic demonstrated how concentrated control over critical technologies can produce global externalities. Just as the intellectual property and production capacity for mRNA vaccines were monopolized during the pandemic[4], leading to profound inequalities in access and recovery trajectories, the concentration of chip design and fabrication capabilities similarly threatens the ability of developing countries to respond to 21st-century challenges - from climate adaptation to digital governance to AI applications in public service delivery.

Similarly, the disruption of fertilizer supply chains following the Russia-Ukraine war had a cascading effect on food security across EDEs[5]. Here again, a "strategic" resource became globally consequential, affecting domestic planning in countries that had no stake in the originating conflict. Chips, much like fertilizer, are not end-consumer goods. But their upstream position in multiple critical value chains gives them systemic importance in carving out effective domestic Science, Technology, and Innovation (STI) policies, especially in EDEs.

Rethinking Semiconductor Trade: From Strategic Control to Normative Equity

Because of the reasons mentioned above, the question is not whether semiconductors can be made available to every country in equal measure. The question is whether the *knowledge and institutional conditions* that enable chip access should be hoarded as instruments of strategic competition[6], or shared as enablers of global resilience and economic development.

While semiconductors are, by conventional economic definition, *excludable and rivalrous*, the knowledge systems, R&D capabilities, and foundational IP regimes surrounding them are, in many cases, non-

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[1] Raymond Robertson and Hyung-gon Jeong, "Beyond the Battle for Supremacy: Reshaping the Global Semiconductor Supply Chain," *Mosbacher Institute for Trade, Economics, and Public Policy*, Mosbacher Institute White Paper Series, vol. 3, no. 1 (2023).

[2] Gregory D Wischer, "The U.S. Military Risks Mineral Shortages in a U.S.-China War: Lessons from World War I, World War II, and the Korean War," *MILITARY REVIEW*, 2025.

[3] "Evolution of India's Electronics Policy and Its Semiconductor Pursuit: A Journey That Has Just Begun," in *Technology Rivalry between the USA and China*, ed. Mordechai Chaziza, with Prashant Kumar Singh (Springer Nature Switzerland, 2024), https://doi.org/10.1007/978-3-031-76169-0_12.

[4] Matthew M. Kavanagh and Renu Singh, "Vaccine Politics: Law and Inequality in the Pandemic Response to COVID-19," *Global Policy* 14, no. 2 (2023): 229–46, https://doi.org/10.1111/1758-5899.13203.

[5] Zhengyang Zhang et al., "Countries' Vulnerability to Food Supply Disruptions Caused by the Russia–Ukraine War from a Trade Dependency Perspective," *Scientific Reports* 13, no. 1 (2023), https://doi.org/10.1038/s41598-023-43883-4.

[6] Chad P. Bown, "How the United States Marched the Semiconductor Industry into Its Trade War with China," *East Asian Economic Review* 24, no. 4 (2020): 349–88, https://doi.org/10.11644/kiep.eaer.2020.24.4.384.

rival in nature[7]. Drawing from Stiglitz[8], who emphasized the non-excludable benefits of knowledge as a global public good, we can argue that cooperative knowledge sharing in semiconductor innovation generates positive global spillovers, particularly for climate and development goals.

Moreover, the United Nations Sustainable Development Goals (SDGs) explicitly recognize the role of technology facilitation mechanisms and capacity-building in STI (Science, Technology and Innovation) as core components of sustainable development (SDG 17.6-17.8). From this lens, denial of *access* to upstream technologies that enable climate adaptation, AI for governance, and digital infrastructure amounts to structural exclusion.

Trade Law Considerations: WTO Limitations and the Risk of Interpretive Bias

The World Trade Organization (WTO), historically tasked with enabling non-discriminatory trade, has struggled to adapt to the specificities of knowledge-intensive sectors like semiconductors. Under the Information Technology Agreements (ITA and ITA-2), tariffs on a wide range of ICT products were eliminated. However, these agreements do not mandate technology transfer, nor do they address non-tariff barriers such as export controls, IP hoarding, or standards-setting exclusions[9].

Furthermore, as Gathii[10] notes, the WTO regime exhibits a pattern of "interpretive monopoly", whereby powerful economies shape trade norms in a way that perpetuates historical advantage. The WTO's Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement, for instance, codified stringent IP protections for industrial and pharmaceutical goods while offering little in terms of equitable access mechanisms for critical inputs[11]. In the context of semiconductors, this legal asymmetry leaves developing countries with limited avenues to demand Special and Differential Treatment (SDT) or assert development-oriented claims.

As a result, developing economies face a situation where:

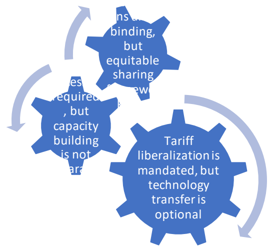

Figure 1 Challenges faced by EDEs in the current global Semicon economy (Source: Author)

This imbalance makes it difficult for countries like India to move beyond downstream assembly roles in the global value chain toward sovereign design capacity, materials innovation, or green fab development.

Toward a Just Semiconductor Regime

The structural imbalance in global chip trade is not accidental. It reflects a deeper institutional design flaw, where the current multilateral system treats technology as a proprietary asset rather than as an enabling infrastructure for development. By contrast, a *just semiconductor regime* would:

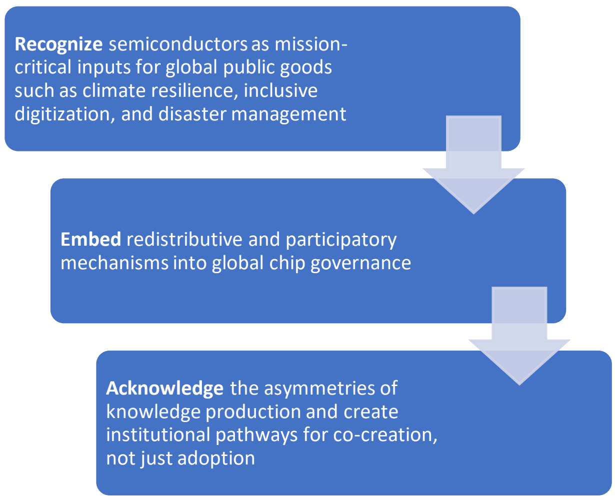

Figure 2 Normative goals of a just semiconductor regime (Source: Author)

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[7] Séverine Deneulin and Nicholas Townsend, "Public Goods, Global Public Goods and the Common Good," *International Journal of Social Economics* 34, no. 1/2 (2007): 19–36, https://doi.org/10.1108/03068290710723345.

[8] "Knowledge as a Public Good," in *Global Public Goods: International Cooperation in the 21st Century*, ed. Inge Kaul et al., with Joseph E. Stiglitz (Oxford Scholarship Online, 2003).

[9] Han-Wei Liu and Ching-Fu Lin, "Techno-Geopolitics and Semi-Conductor Chokepoints: Beyond the US-China WTO Dispute," *The Journal of World Investment & Trade*, Walter de Gruyter GmbH, June 25, 2025, 749–91, https://doi.org/10.1163/22119000-12340372.

[10] James T Gathii, "International Justice and the Trading Regime," *Emory International Law Review* 19 (2005): 1407–28.

[11] Bayu Krisnamurti and Dinda Ayu Hapsari, "Global Economic Inequality: A Review of International Law on the Mechanism and Fairness of Free Trade Regulation," *RESPONSIVE LAW JOURNAL* 1, no. 2 (2024): 15–20, https://doi.org/10.59923/rlj.v1i2.267.

In this sense, this paper argues that semiconductors must be treated, at least normatively, as global public goods – not in the strict economic sense of non-excludability, but in their developmental function and catalytic role for wider public goods[12].

India, by virtue of its geopolitical location, development priorities, and diplomatic history, is well-positioned to propose an alternative framework – Just Chips Partnership. This paper outlines how such a framework could be institutionalized through inclusive governance mechanisms, pooled IP arrangements, shared regional fabs, and green technology knowledge hubs. It also proposes how India and like-minded economies can collectively advocate for these changes across forums like the World Trade Organization (WTO), G20, BRICS, and Indo-Pacific Economic Framework for Prosperity (IPEF).

Theoretical Framework: What Trade Justice Demands in a Hi-Tech World

This section outlines how core theories of trade justice, particularly those by de Bres, Garcia, and Gathii, inform the normative case for equitable semiconductor access. Drawing from development studies and science policy, it argues that procedural and structural justice must guide India's engagement with the global chip ecosystem.

Trade Is Not Neutral: The Problem of Asymmetry

While trade regimes are often justified as neutral mechanisms for facilitating comparative advantage, in practice, they are shaped by institutional asymmetries, power differentials, and historical exclusions[13]. This is especially true in technology-intensive sectors, where entry barriers are not merely about tariffs but about knowledge access, IP constraints, and participatory exclusion.

As Helena de Bres[14] notes, trade is a "rule-governed social practice" where justice demands more than voluntary mutual exchange. When a select group of countries controls both the rules and the rents of trade, the outcome is structurally unjust, even if the transactions themselves appear legal.

In the context of semiconductors, this trade injustice manifests as:

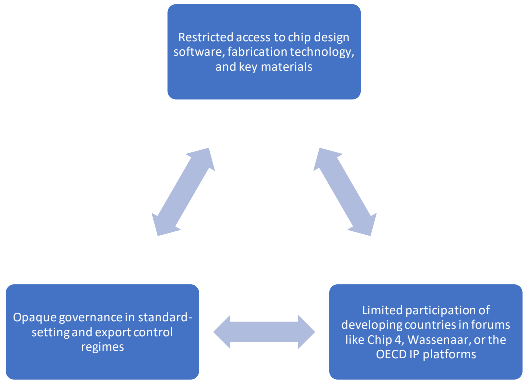


Figure 3 How trade injustice manifests in the global semicon economy (Source: Author)

This calls for an approach to semiconductor governance that explicitly integrates principles of trade justice.

Structural and Procedural Dimensions of Trade Justice

Frank Garcia[15] offers a useful distinction between the structural and procedural dimensions of trade justice as follows:

- **Structural justice** addresses the material inequalities embedded in trade outcomes, i.e., who benefits, who is excluded, and why.
- **Procedural justice** relates to who gets to shape the rules – a concern particularly relevant in the design of plurilateral tech alliances and IP regimes.

According to Garcia, formal market access alone is not sufficient. Special and Differential Treatment (SDT) mechanisms[16] – long underutilized in WTO negotiations – must be reactivated to address unequal starting points. In high-tech sectors, SDT could translate into:

[12] Ernesto Zedillo et al., eds., *Meeting Global Challenges: International Cooperation in the National Interest ; Report of the International Task Force on Global Public Goods* (Stockholm, 2006).
[13] Helena De Bres, "Justice and International Trade," *Philosophy Compass* 11, no. 10 (2016): 570–79, https://doi.org/10.1111/phc3.12346.
[14] De Bres, "Justice and International Trade."
[15] Frank J. Garcia, "Trade and Inequality: Economic Justice and the Developing World," *Michigan Journal of International Law* 21, no. 4 (2000): 975–1049, https://doi.org/10.2139/ssrn.240611.
[16] *The Unmaking of Special Rights*, with Klaus Dingwerth et al. (Edward Elgar Publishing, 2024), https://doi.org/10.4337/9781035325986.00008.

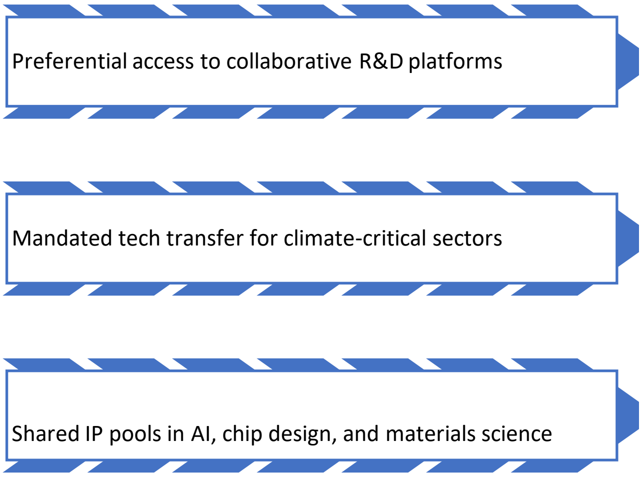


Figure 4 Examples of policy instruments operationalising WTO's SDT in global Semicon economy (Source: Author)

India's current industrial policy, while proactive, risks replicating structural dependencies if it does not also push for procedural inclusion at the multilateral level.

Trade Justice and the Right to Technological Self-Determination

As already discussed in the previous section, James Gathii [17] strengthens this normative position by arguing that historical and colonial legacies continue to shape the global trading regime. His concept of "interpretive monopoly" highlights how dominant states not only benefit from trade rules but also control their interpretation and application.

This is particularly true in WTO dispute resolution, where precedent is often set by wealthier states with greater legal capacity. In the context of semiconductor trade, such interpretive power also plays out in:

- **Export control justifications**, which often invoke security language without transparent metrics
- **IP enforcement**, where the burden of compliance falls on less-resourced states
- **Standard-setting**, where epistemic authority is concentrated in OECD and industry-led platforms

Gathii's argument is that procedural justice cannot be separated from power – a point highly relevant for India's position in global technology diplomacy. Without access to norm-setting spaces, countries like India remain rule-takers, even when they are major market participants.

When Is Trade Injustice a Moral Concern?

From a more minimalist standpoint, Mathias Risse[18] asks whether all structural inequalities in trade are morally objectionable, or only those that result in direct harm. While this lens can downplay systemic disparities, it is useful in identifying zones of moral urgency, for instance, when trade rules exacerbate:

- Climate vulnerability (Climate mitigation and Access to Climate tech are normative global public goods)
- Food insecurity (Agricultural inputs like fertilizers and pesticides that contribute to food security are normative global public goods)
- Loss of health or educational opportunity (Right to Health and Education are fundamental human rights. Hence, access to knowledge and medicines are global public goods)

In this light, restricted access to semiconductors, which directly limits a country's ability to build climate forecasting tools, electrify transport, or digitize governance, can be read as a violation of developmental rights, particularly in climate-vulnerable and technology-constrained economies.

Implications for Semiconductor Governance

Bringing these frameworks together, the theoretical case for a Just Chips Partnership rests on four justice-oriented principles:

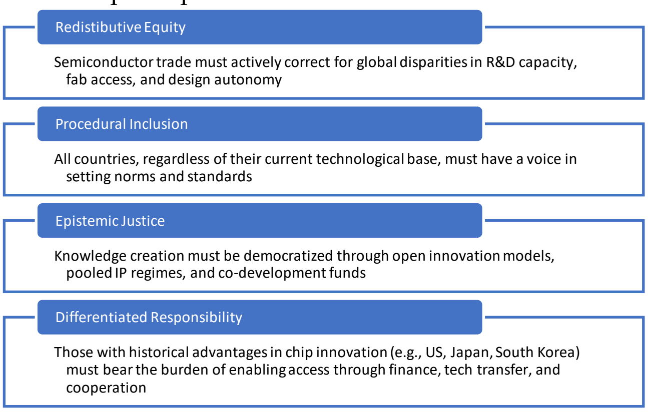


Figure 5 Principles of Trade Justice underpinning the Just Chips Partnership framework

[17] Gathii, "International Justice and the Trading Regime."

[18] Helena De Bres, "Risse on Justice in Trade," *Ethics & International Affairs* 28, no. 4 (2014): 489–99, https://doi.org/10.1017/s0892679414000628.

These normative global trade policy goals are consistent with existing provisions in:

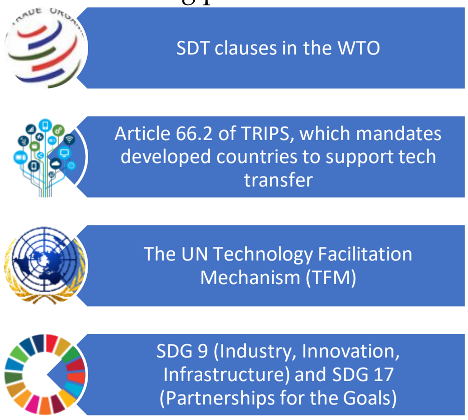


Figure 6 Existing international trade policy provisions that support trade justice argument in Semicon supply chains (Source: Author)

Thus, India's future in the global semiconductor ecosystem will depend not just on domestic capacity-building, but on its ability to reshape multilateral norms around access, equity, and co-creation. (See **Appendix II** for a summary on theories of trade justice applied to global semiconductor policy in this paper.

Global Hi-Tech Trade: The Chasm between EDEs and incumbent states

This section examines the structural shifts in global semiconductor trade since the 1990s, with a focus on how developing countries are responding to techno-nationalist reconfigurations. While many have adopted investment-led policy mixes to build domestic capacity, this approach, without redistributive safeguards, risks reinforcing asymmetries in the global trading system.

Historical evolution: The Transition from Trade Liberalism to Strategic Bifurcation

Global semiconductor trade, once a beneficiary of post-WTO trade liberalization and just-in-time global value chains (GVCs), is increasingly shaped by techno-nationalism and strategic decoupling[19]. The US-China chip rivalry, with its tariffs, export controls, and supply chain "friendshoring," marks a decisive shift away from the efficiency-driven globalization of the 1990s and 2000s toward a more bifurcated and security-oriented economic order[20].

This reorientation has downstream effects, especially on EDEs. Countries historically excluded from upstream chip design and fabrication, particularly in South and Southeast Asia, Latin America, and parts of Africa, are now positioning themselves as alternate hubs for semiconductor manufacturing, testing, and assembly. Yet this race to attract investment is unfolding under highly uneven starting conditions, and without structural corrections to the underlying asymmetries in knowledge, capital, and governance.

India's Policy Mix: High Aspirations, Limited Redistribution

India has emerged as a key aspirant in the global semiconductor supply chain. With over USD 10 billion committed under the Semicon India Programme and PLI schemes, India is offering financial subsidies to attract fab and OSAT (outsourced semiconductor assembly and testing) investors. The recent announcement of joint ventures with global players like Micron and ISMC reflects momentum.

However, the policy architecture is narrowly investment-led[21]. It emphasizes capital subsidies for plant setup, single-window clearances, and infrastructure guarantees, but lacks redistributive components that build long-term ecosystem capacity, like:

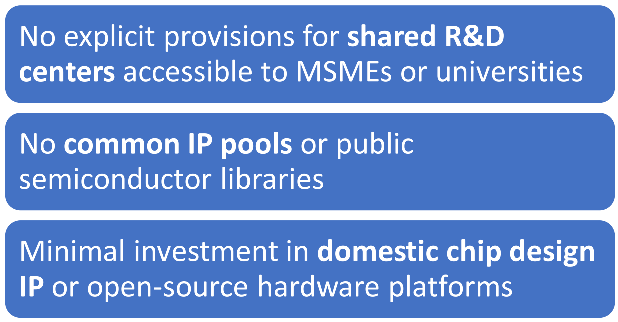


Figure 7 Trade Justice Issues in India's Semicon Policy (Source: Author)

From a trade justice perspective, India's current model risks reproducing the dependency cycle: attracting capital but remaining a downstream assembler, with little bargaining power in IP governance or standard-setting.

[19] Chad P Bown and Dan Wang, *Semiconductors and Modern Industrial Policy*, 24–3 (Peterson Institute for International Economics, 2024).
[20] Bown, "How the United States Marched the Semiconductor Industry into Its Trade War with China."
[21] Stephen Ezell, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains," *INFORMATION TECHNOLOGY*, 2024.

Vietnam and Malaysia: Agile Integration, But IP-Dependent

Vietnam and Malaysia have attracted major OSAT and backend semiconductor operations by leveraging low labour costs, political stability, and FTAs with both China and the US.

They offer a case of agile integration into global value chains, but largely through assembly-centric roles[22]. This model, while successful in job creation and export earnings, leaves these economies vulnerable to external IP licensing costs, excluded from fabless design networks, and dependent on foreign standard-setting and tooling technologies.

Vietnam's recent attempts to promote domestic chip design education and collaborate with Japan for workforce development are promising but limited in scale.

These countries highlight the structural tension of giving market access without epistemic inclusion. That is, these countries are being included in value chains, but not in value creation.

Brazil: Strategic Autonomy Meets Legal Bottlenecks

Brazil offers a contrasting example. Historically more protectionist, Brazil has tried to integrate semiconductor policy within its broader industrial and science policy frameworks. Initiatives like the state-owned CEITEC fab in Porto Alegre, public R&D support via FINEP and BNDES – key Brazilian institutions working towards economic and technological development, and participation in Mercosur-led standards initiatives, show an emphasis on strategic autonomy rather than low-cost integration[23]. However, Brazil faces:

- WTO constraints on domestic content requirements,
- Limited international IP pooling, and
- Judicial and regulatory fragmentation

Brazil's case raises a key point – while state-led development is necessary for tech sovereignty, current WTO rules, and lack of SDT enforcement, severely limit the domestic policy space available to pursue structural equity in the global trade space.

Middle Powers and South-South Pathways: Missed Normative Opportunities

Countries like South Africa, Egypt, and Indonesia have signalled interest in joining semiconductor supply chains, but are primarily engaging through digital economy initiatives or public–private partnerships in AI and electronics. The absence of a coordinated EDE-wide strategy on semiconductor equity is hence notable, unlike in climate negotiations where EDEs have been relatively successful in integrating equity concerns in the global policy narratives.

This lack of EDE-wise semiconductor trade policy is evident in the form of following examples:

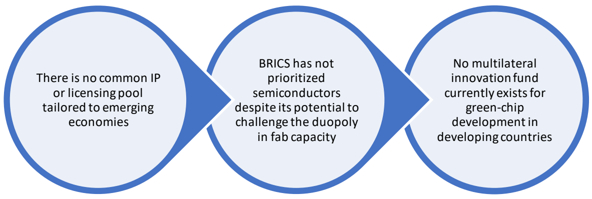


Figure 8 Lack of EDE-wide global semiconductor trade policy

This signals a gap not in technical ambition, but in normative coordination among resource-constrained states. While WTO rhetoric emphasizes "inclusive trade," the lack of collective bargaining frameworks from EDEs weakens their ability to shape the new tech order.

Trade Justice implications: Not All Global Trade Integration Is Empowering

For these reasons, the proliferation of investment-led semiconductor strategies in the developing world may seem like trade convergence, but it risks deepening dependence if structural injustices[24] are not addressed. From a trade justice standpoint, three key injustice patterns emerge in the current global

[22] Chia-Nan Wang et al., "Assessing Southeast Asia Countries' Potential in the Semiconductor Supply Chain: An Objectively Weighting Multi-Criteria Decision-Making Approach," *Humanities and Social Sciences Communications* 11, no. 1 (2024), https://doi.org/10.1057/s41599-024-03768-x.
[23] Xênia L'amour Campos Oliveira et al., "Open Innovation in the Semiconductor Industry: Analysis of Brazilian Design Houses," *Innovation & Management Review* 17, no. 2 (2020): 133–56, https://doi.org/10.1108/inmr-02-2019-0014.
[24] Christine Arriola et al., *Towards Demystifying Trade Dependencies: At What Point Do Trade Linkages Become a Concern?*, OECD Trade Policy Papers (Organisation for Economic Co-Operation and Development (OECD), 2024), https://doi.org/10.1787/2a1a2bb9-en.

semiconductor policy landscape that the Just Chips Partnership can ameliorate:

Table 1 Patterns of Trade Injustice in the current global semicon economy (Source: Author)

Patterns of injustice	**Description**	**Justice Concern**
Investment without IP	Countries offer land, labor, and capital—but IP and standards remain foreign-controlled	Epistemic exclusion, dependency on external licensing
Participation without rule-setting	Backend assembly roles do not translate into seats at governance tables (e.g., WIPO, Chip 4)	Procedural injustice
Access without affordability	Tools like EDA software and chip design kits remain cost-prohibitive for smaller economies	Structural inequity in capability building

Toward a More Equitable Model

These EDE policies and their justice externalities indicate that developing countries do not lack ambition, but the policy space and institutional backing to build equitable positions in semiconductor value chains. Hence, a redistributive, justice-oriented policy strategy would focus on:

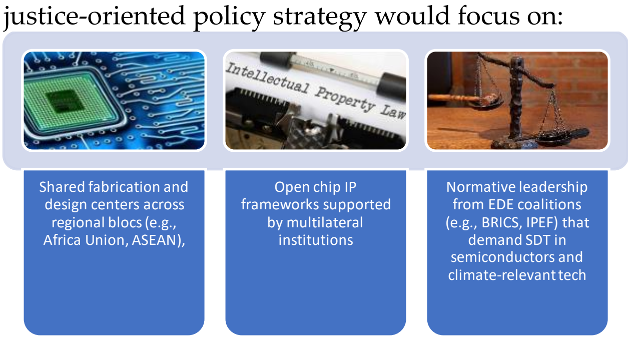


Figure 9 Some examples of justice-oriented semicon policy strategy (Source: Author)

In the absence of such strategies, the developing world may replicate old industrial models of exporting labor and land, while importing the core knowledge that drives innovation and resilience[25].

Structural Exclusion in the Global Trade Architecture: The WTO, Export Controls, and the Public Good Paradox

This section analyzes how the existing multilateral trade architecture, including the WTO, export control regimes, and non-tariff barriers, systemically limits the ability of developing countries to shape their technological futures. It argues that treating semiconductor access as a global public good is not only ethically necessary but also functionally urgent for climate and development outcomes.

The WTO's Unfinished Agenda: Formal Access, Structural Denial

The World Trade Organization (WTO) was founded on the principle of non-discrimination and the liberalization of global trade. For decades, it played a key role in integrating developing economies into global markets. But in sectors like semiconductors, where strategic knowledge, not just goods, governs value creation, the WTO's legal architecture shows clear limitations.

While tariff liberalization through the Information Technology Agreements (ITA and ITA-2) eliminated duties on a broad range of electronics and ICT goods, these agreements:

- Do not mandate technology transfer in critical sectors
- Do not address export controls
- Do not correct for IP asymmetries
- And most critically, do not acknowledge development asymmetries in technological readiness

In effect, developing countries are bound by obligations that open their markets, but receive no reciprocal obligation from developed economies to share capacity, data, or know-how.

This is what James Gathii[26] refers to as "interpretive exclusion" – a condition where rules appear neutral but operate to consolidate power among incumbent technology holders.

[25] WIPO, *World Intellectual Property Report 2024: Making Innovation Work for Development*, 1st ed (World Intellectual Property Organization, 2024).

[26] Gathii, "International Justice and the Trading Regime."

Export Controls as Development Barriers: The Hidden Face of Non-Tariff Barriers (NTBs)

The recent proliferation of export controls on advanced chips, chip-making equipment, and design software by countries like the US, Japan, and the Netherlands is reshaping the very notion of what constitutes a non-tariff barrier (NTB).

Unlike traditional NTBs like quotas or local content requirements (which the WTO disciplines), export controls are framed as security instruments, giving them a kind of immunity from multilateral challenge[27]. But their effects are not neutral, as they:

- **Constrain** STI policy autonomy in developing countries by cutting off access to frontier technologies.
- **Fragment** value chains, forcing countries to choose sides in geopolitically driven alliances, and
- **Prevent** downstream innovation in AI, green mobility, and digital governance by restricting upstream inputs.

This form of strategic denialism undermines not only trade justice, but also the right to development, which has long been recognized in international law through instruments like the UN Declaration on the Right to Development (1986).

From a development policy perspective, export controls constitute a hard ceiling on technological sovereignty. They don't just limit market access, but also the very imagination of STI futures in EDEs.

The Climate Justice Link: Denial of Chips, Delay of Action

The exclusion of developing countries from access to advanced semiconductors also has direct consequences for climate justice, that encompasses the triumvirate tenets of procedural justice, distributive justice, and restorative justice[28]. This is because semiconductors are the enabling infrastructure for most climate mitigation tech including but not limited to:

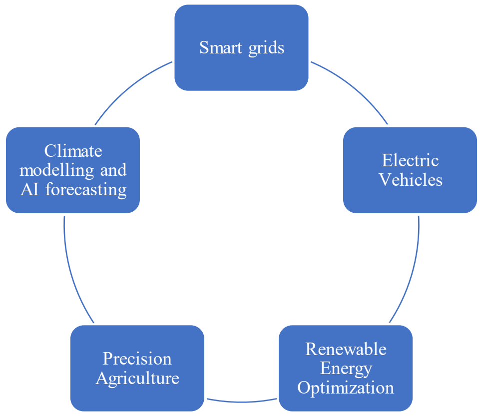


Figure 10 Climate Tech sectors that make use of high-end semiconductors (Source: Author)

By restricting access to the very inputs needed to build low-carbon infrastructure, export controls create a perverse condition where the countries most vulnerable to climate change are the least equipped to adapt or mitigate, not due to domestic inertia, but due to global governance asymmetries pertaining to sourcing of climate tech.

This aligns with Frank Garcia's[29] critique of trade regimes that fail the Rawlsian "difference principle", as they perpetuate rules that do not benefit the least advantaged, despite formal inclusion. Furthermore, Garcian critique of trade regimes reframes export controls as not only trade distortions but as developmental and ecological injustices for EDEs.

A Governance Vacuum: Who Sets the Rules for Critical Tech?

The current global trade system lacks a coherent governance framework for emerging and critical technologies, as the WTO is procedurally stalled and substantively ill-equipped to handle dual-use technologies[30]; forums like Wassenaar Arrangement and Chip 4 Alliance are exclusive and strategically aligned, not development-oriented; and TRIPS enforces strict IP protections, but has no obligation for technology-sharing in sectors beyond pharmaceuticals[31].

This global trade governance vacuum in which trade, security, IP, and development policy are handled in

[27] Dai Tamada and Philippe Achilleas, eds., *Theory and Practice of Export Control: Balancing International Security and International Economic Relations*, SpringerBriefs in Economics (Springer Singapore, 2017), https://doi.org/10.1007/978-981-10-5960-5.

[28] Darren McCauley and Raphael Heffron, "Just Transition: Integrating Climate, Energy and Environmental Justice," *Energy Policy* 119 (August 2018): 1–7, https://doi.org/10.1016/j.enpol.2018.04.014.

[29] Garcia, "Trade and Inequality."

[30] Rodrigo Polanco and Sean Stacy, "Process Failure: What Does the Lack of Appellate Review Mean for Due Process of Law in WTO Disputes?," *Zeitschrift Für Europarechtliche Studien* 27, no. 4 (2024): 539–67, https://doi.org/10.5771/1435-439x-2024-4-539.

[31] Jayashree Watal and Leticia Caminero, *Least-Developed Countries, Transfer of Technology and the TRIPS Agreement*, n.d.

silos, while strategic nations rewire supply chains to their own advantage creates a global economy ill-suited for furthering collective technological advancement.

For emerging economies, this means navigating an international regime where liberalization is mandatory, but cooperation is optional; where compliance is policed, but inclusion is not guaranteed.

The Public Good Paradox: Chips as Excludable but Essential

Semiconductors are classically private goods: they are excludable, priced, and patent-protected. But functionally, they behave like enablers of public goods, especially when they support climate mitigation, digital governance, and public health.

The result is a public good paradox. Chips are treated as proprietary commodities by exporting nations, yet they are essential to delivering public goods (climate mitigation, for example) within importing countries. This contradiction creates a governance dilemma. If we accept the Stiglitzian premise that knowledge is a global public good, then the institutional conditions to access and co-create chip-related knowledge must also be treated as public goods. That means a diverse range of policy innovations need to be integrated into the current semiconductor governance architecture, like:

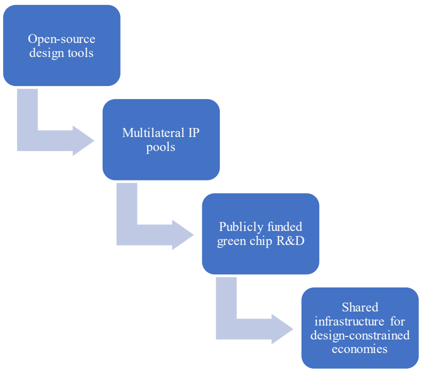


Figure 11 Trade justice policy innovations for an equitable Semicon trade (Source: Author)

Without deploying such innovative policy instruments, we risk reproducing the very condition the WTO was created to prevent, that of preventing trade without fairness, openness without reciprocity, and supply chain integration without justice.

Strategic Implication: India Must Lead the Normative Turn

India has both the geopolitical standing and the institutional capacity to lead a normative realignment of global tech governance. This requires:

- Reframing export controls as developmental barriers, not just security tools
- Advocating for an SDT-like carve-out for climate-relevant technologies in WTO reform negotiations
- Mobilizing BRICS, IPEF, and G20 to recognize semiconductors as development-critical infrastructure, not merely strategic commodities, and
- Proposing a new plurilateral framework - a Just Chips Partnership - grounded in knowledge equity and development-oriented trade policy

In summary, the current rules-based order for semiconductor trade is not rules-based at all. It is power-based and selectively enforceable. To restore legitimacy and inclusivity in the international semiconductor economy, global governance must make room for the normative goal of technology access as a right, and tech co-creation as a shared responsibility.

The Future of Semiconductor Trade Justice and Global STI Policy

Thus, to create an equitable and efficient global STI architecture, the future must be guided by the following shifts:

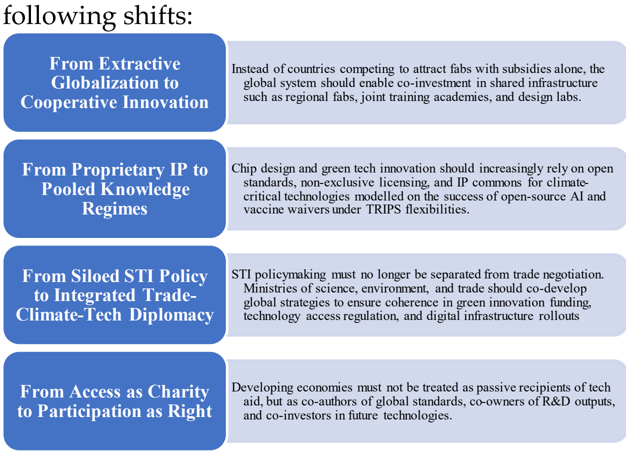


Figure 12 Integrating global STI policy with semiconductor trade policy (Source: Author)

In conclusion, the future of trade justice in semiconductors depends not on abstract fairness, but on a reimagined global STI compact. India, positioned between the advanced economies and the emerging world, can lead this shift, not just by scaling fabs, but by shaping the future ethics of global tech governance.

Climate Justice and Chips: Enabling Green Transitions through Fair Technology Access

This section outlines the material link between semiconductor trade policy and global climate outcomes. It argues that restricted chip access through export controls, IP regimes, and techno-alignment blocs undermines the ability of emerging economies to meet climate goals. It calls for a recalibrated global trading system where green technology is treated as a climate necessity, not a strategic asset.

Semiconductors Are Climate Infrastructure

As briefly discussed in the last section, semiconductors power the technologies that underpin modern climate responses like:

- EVs and battery systems
- Smart grid controllers
- Precision agriculture
- Green industrial automation
- AI for climate modeling and disaster response, to name a few.

As is common knowledge, these are not fringe sectors, but are core infrastructure for countries attempting to decarbonize, adapt to extreme weather, and build resilient livelihoods, in the pursuit of reaching national net zero goals. A chip shortage or denial in these areas has the risk of translating directly into:

- Delayed EV rollout plans
- Higher emissions from inefficient grids, and/or
- Increased climate vulnerability for agriculture-based economies

Semiconductors, hence, require an integrated policymaking approach at the global level, as they are strategic levers of climate mitigation policies.

Climate Tech and Trade: A Growing Tension in the Global Regime

Despite this dependence, global trade rules currently treat semiconductors as strategic, security-sensitive goods, not climate-critical inputs. This creates two major tensions:

1. Export Controls vs. Climate Goals

- The US, Japanese, and Dutch export controls on advanced lithography and AI-enabling chips aim to limit dual-use technologies reaching adversaries.
- However, these same restrictions also constrain access for non-aligned, climate-vulnerable countries that rely on advanced computing to roll out green transitions.

Currently, no international legal instrument obliges chip-exporting nations to consider the climate consequences of export controls. Under the Paris regime, this is a serious governance gap that needs redressal.

2. Green Tariffs vs. Developmental Parity

- Instruments like the EU's Carbon Border Adjustment Mechanism (CBAM) introduce tariffs on carbon-intensive imports without proportionate support for technology access or green capacity-building in the exporting countries.
- This approach reinforces what many developing countries view as eco-protectionism where climate goals are pursued at the cost of development equity.

Legal Precedents for Technology Equity in International Climate Instruments

While climate technology access is not new to global discussions, implementation has been weak[32].

Relevant existing legal and policy instruments include, but are not limited to:

Figure 13 International Climate Law provisions that can be harnessed for semiconductor trade justice (Source: Author)

[32] Samuel Pienknagura, "Trade in Low Carbon Technologies: The Role of Climate and Trade Policies," *IMF Working Papers* 2024, no. 075 (2024): 1, https://doi.org/10.5089/9798400271083.001.

However, none of these mechanisms have been operationalized in the context of semiconductors, despite their pivotal role in green transitions[33]. There is no binding multilateral requirement to ensure equitable access to climate-enabling chips, nor a reporting mechanism on whether export controls violate climate equity principles.

Multilateral Instruments That Can Be Leveraged

To address this gap, India and like-minded countries can pursue reforms and initiatives through several policy channels:

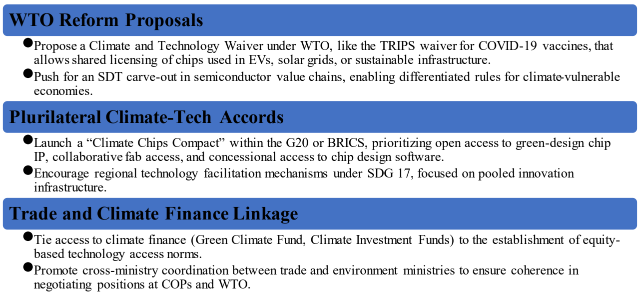


Figure 14 Roadmap for India's tech/trade diplomacy (Source: Author)

India's Strategic Role: From Recipient to Agenda-Setter

India is one of the few large economies with the capacity to link climate diplomacy and technology trade diplomacy in a credible, forward-looking framework. Its positions at the G20 presidency (2023), BRICS, and as a partner in the IPEF Clean Economy Pillar give it the multilateral legitimacy to propose:

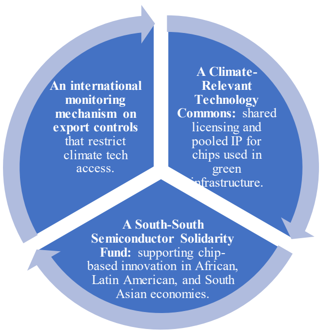


Figure 15 India's potential role in semiconductor trade justice narrative building (Source: Author)

This would allow India to speak from its dual position as a technology-seeking economy and a representative of climate-vulnerable nations[34], and shape a future regime where access to semiconductors is seen as part of global climate equity, not just economic strategy[35].

The Case for a Just Chips Partnership: Designing Institutional Alternatives for an Inclusive Semiconductor Order

The prevailing international semiconductor trade regime is characterised by fragmentation, asymmetry, and strategic securitisation. In particular, it privileges a handful of incumbent economies largely from the OECD bloc, who dominate upstream value chain segments such as chip design, EDA software, materials science, and advanced fabrication[36]. While the language of "resilience" and "diversification" is increasingly deployed by these actors, the institutional mechanisms through which supply chains are being reconfigured remain exclusive, ad hoc, and heavily securitised[37].

Emerging and Developing Economies (EDEs), despite being deeply impacted by the downstream implications of such trade restructuring, ranging from delayed electric vehicle production to reduced access to AI compute infrastructure, continue to operate at the periphery of decision-making in global chip governance. This exclusion is not merely material, but is also normative and epistemic[38], reinforcing a hierarchy of participation that runs counter to the stated principles of the WTO and the SDGs.

In this context, the idea of a Just Chips Partnership (JCP) is proposed as a plurilateral coordination mechanism that articulates an equity-based

[33] Yuhao Zhang et al., "Wide-Bandgap Semiconductors and Power Electronics as Pathways to Carbon Neutrality," *Nature Reviews Electrical Engineering* 2, no. 3 (2025): 155–72, https://doi.org/10.1038/s44287-024-00135-5.

[34] Aditya Anand Singh, "Local Actions to Global Conversations: India's Climate Justice Movement and the Expansion of Human Rights Framework," *Journal of Human Rights and Social Work*, ahead of print, February 19, 2025, https://doi.org/10.1007/s41134-025-00373-z.

[35] Adrian Friday et al., "The Belief in Moore's Law Is Undermining ICT Climate Action," arXiv:2411.17391, preprint, arXiv, November 27, 2024, https://doi.org/10.48550/arXiv.2411.17391.

[36] Robert Huggins and Andrew Johnston, "Conflict and Cooperation in the Semiconductor Industry: The Global Evolution of Chip Production," *Eurasian Geography and Economics* 66, no. 1 (2025): 153–58, https://doi.org/10.1080/15387216.2022.2149586.

[37] Shree Kumar, "Semiconductor Geopolitics - Past, Present, and Future: Book Review of 'When the Chips Are Down: A Deep Dive into a Global Crisis' by Pranay Kotasthane and Abhiram Manchi," *Indian Public Policy Review* 5, no. 1 (Jan-Feb) (2024): 171–74, https://doi.org/10.55763/ippr.2024.05.01.005.

[38] James McCollum, "Hermeneutical Injustice and the Social Sciences: Development Policy and Positional Objectivity," *Social Epistemology* 26, no. 2 (2012): 189–200, https://doi.org/10.1080/02691728.2011.652212.

alternative to the current trajectory of semiconductor globalisation.

Why an Equity-Oriented Framework Is Needed

The current structure of the global semiconductor economy is neither market-driven in the classical sense, nor public in function. It is shaped by:

- Export controls and investment screening regimes, often imposed unilaterally on vaguely defined security grounds;
- Trade facilitation instruments (like ITA-2) that liberalise tariff barriers without mandating commensurate tech transfer or capacity-building;
- Private IP regimes, which consolidate control over critical tools and know-how—such as design software and process nodes—without transparency or accountability.

For most EDEs, this constellation of governance mechanisms operates as a de facto exclusionary order, restricting their ability to use chip technologies for domestic development priorities, including climate adaptation, digital infrastructure, and innovation in public service delivery.

Treating semiconductor access as a developmental enabler, and the upstream knowledge systems that underpin it as normative global public goods, is not a theoretical proposition—it is an institutional imperative. The governance of chips must move beyond the binary of "strategic commodity" vs. "commercial good" and be reframed as infrastructure for shared global futures.

Institutional Design Principles of a Just Chips Partnership

The JCP would function as a voluntary, plurilateral coordination platform aimed at reducing entry barriers to the semiconductor ecosystem for capacity-constrained economies, while preserving space for differentiated industrial strategies across jurisdictions.

Key institutional features of the JCP should include:

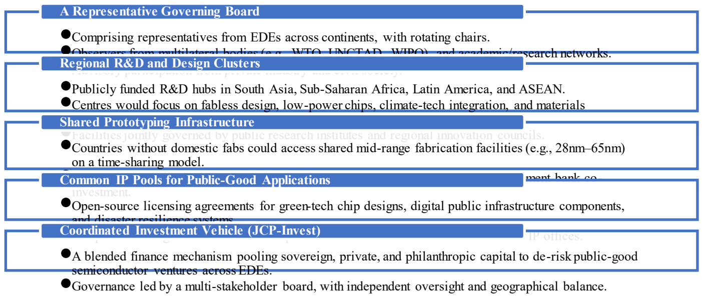


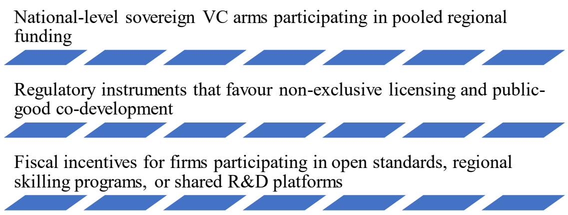
Figure 16 Institutional Design on the proposed Just Chips Partnership (Source: Author)

The Role of the Private Sector: Between Opportunism and Institutional Alignment

While the bulk of global semiconductor R&D remains privately held[39], the role of private capital and industry consortia in building inclusive tech ecosystems cannot be discounted. In India, for example, venture and private equity investment in chip design, embedded systems, and electronics supply chains, especially in the upstream segment, has not gathered much momentum, that is negatively impacting the domestic design ecosystem that the semicon policies want to build.

The JCP offers a structural opportunity to redirect private capital toward mission-oriented innovation and offer an investment opportunity in long tail R&D projects. By de-risking investment in shared infrastructure, offering IP commons in critical sectors, and fostering regional ecosystems, it can be used as a model of public-private engagement that is governed by developmental logic.

Such alignment can be institutionalised through:



[39] Pinelopi Goldberg et al., *Industrial Policy in the Global Semiconductor Sector*, NBER Working Paper No. W32651 (National Bureau of Economic Research, 2024).

Figure 17 How can JCP help India attract PE/VC investments to build a domestic semicon innovation hub (Source: Author)

What Distinguishes the JCP from Status Quo Frameworks

Unlike the security-led "friend-shoring" model advocated by the US and its allies, or the subsidy-heavy techno-industrialism of East Asia, the Just Chips Partnership uses a collaborative governance framework built on nurturing partnerships and co-creating innovations (See **Appendix I** for a tabular explanation of the JCP Framework). The following table lays down how the JCP governance model is different from the existing governance model regulating the global semiconductor trade:

Table 2 How is JCP different from the current regulatory framework governing international semicon trade (Source: Author)

	Current Model	**Just Chips Model**
Governance	Bilateral alliances and industrial policy clubs	Plurilateral coordination with broad geographical representation
Access	Fragmented, IP-intensive, and security-restricted	Cooperative, demand-responsive, and mission-aligned
Equity Mechanism	Absent or secondary	Built into design: SDT, shared fabs, pooled IP
Development Role	Peripheral	Central; Chips as enablers of inclusive digital and climate transitions

Strategic Implications for EDEs

As is evident from the above discussion, the Just Chips Partnership is not an alternative supply chain per se. Rather, it is an institutional scaffolding that enables a more just, participatory, and climate-aligned chip economy by addressing the normative gaps in the existing regime. For EDEs, the key value of the JCP lies not in fab construction or subsidy competition, but in:

- Reclaiming agency in rule-making, particularly around export controls, IP enforcement, and tech transfer conditionalities;
- Aligning technology development with public priorities, especially climate adaptation, health, and democratic infrastructure; and
- Reducing structural dependencies on strategic blocs that offer inclusion only on asymmetrical or conditional terms.

In a context where geopolitical realignments are accelerating and climate deadlines are non-negotiable, the JCP represents a rare policy lever to both stabilise and democratise a sector that is otherwise drifting toward a geopolitical cold war.

Strategic Actions for JCP Implementation by Emerging and Developing Economies: A 14-Point Action Plan

This section identifies a set of 14 concrete, feasible actions that governments of emerging and developing economies (EDEs) can undertake individually, regionally, and plurilaterally, to build the institutional, legal, and material scaffolding of the Just Chips Partnership (JCP). These actions are designed to operationalise the components proposed in the preceding section, and are grounded in existing international trade norms, STI policy frameworks, and climate finance channels.

The strategic entry points below reflect a shift from rhetorical commitments to policy mechanisms capable of sustaining inclusive and climate-relevant semiconductor innovation ecosystems.

Coordinate Plurilateral Diplomacy on Chip Access and Trade Norms

Action 1: Establish a JCP Coordinating Forum, ideally within an existing regional bloc (e.g., G20 developing members, BRICS+, AU, ASEAN, or CELAC), to align positions on:

- Export control challenges;
- Representation in multilateral standards and security forums;
- Reforms to ITA-2 and TRIPS interpretations that affect semiconductor policy space.

Action 2: Initiate a joint proposal at the WTO Trade and Development Committee or General Council calling for:

- A review of technology trade measures impacting the SDGs;

- Inclusion of climate-aligned chips in the scope of WTO discussions on technology transfer and green goods.

These diplomatic efforts would be anchored by the Representative Steering Committee of the JCP, as proposed in the previous section.

Invest in Regional R&D and Shared Infrastructure

Action 3: Create publicly funded or development bank-supported Regional R&D and Design Clusters, focusing on:

- Climate-relevant fabless chip design;
- Context-specific chip architecture (e.g., low-energy, IoT-enabled, edge-compute compatible);
- Digital public infrastructure (e.g., chips for identity, payments, and public health systems).

Action 4: Jointly establish Shared Prototyping and Packaging Facilities, through South-South and triangular cooperation, particularly for countries that lack capital-intensive fabs.

Participating countries may co-finance these through pooled innovation funds, such as JCP-Invest, and should ensure open access to universities, MSMEs, and public research labs.

Institutionalise IP Commons[40] for Climate and Public-Good Applications

Action 5: Collaborate with WIPO and national IP offices to:

- Launch a Climate Chips IP Commons, granting non-exclusive, affordable access to design libraries for energy systems, sustainable mobility, water management, and rural electrification.

Action 6: Encourage public research institutions to:

- Adopt open licensing models for semiconductor research funded by national or regional innovation grants;
- Participate in a shared repository of designs and toolchains governed by JCP norms.

This directly supports the JCP's goal of normative deconcentration of IP ownership.

Link Semiconductor Strategy to Climate Diplomacy and Finance

Action 7: Integrate semiconductor access into Nationally Determined Contributions (NDCs) by:

- Identifying climate-relevant use cases for chips;
- Requesting technical and financial support under Article 10.6 of the Paris Agreement.

Action 8: Advocate for a dedicated semiconductor technology window within:

- The Green Climate Fund (GCF);
- Global Environment Facility (GEF);
- Multilateral development banks' climate innovation financing tools.

These efforts will enable countries to position semiconductors as a core enabler of climate resilience, not merely a high-tech luxury.

Advance Legal Reform within WTO and Regional Trade Platforms

Action 9: Call for reinterpretation and expansion of:

- TRIPS Article 66.2, to include fabless semiconductor technologies as development-relevant for technology transfer purposes;
- Special and Differential Treatment (SDT) clauses within any future ITA-3 negotiations, with allowances for domestic content requirements, joint R&D, and licensing flexibility.

Action 10: Establish a Plurilateral Working Group on Technology Equity under UNCTAD or the WTO's Trade and Development Committee to:

- Regularly assess asymmetries in export control implementation;
- Monitor progress on technology access commitments under SDG 9 and 17.

This work would complement and strengthen the Plurilateral Coordination Platform of the JCP.

Mobilise and Align Private Sector Capital with Public Missions

Action 11: Create sovereign-backed venture and innovation funds that:

[40] Nathan Goodman and Otto Lehto, "Intellectual Property, Complex Externalities, and the Knowledge Commons," *Public Choice* 201, nos. 3–4 (2024): 511–31, https://doi.org/10.1007/s11127-023-01110-8.

- Co-invest with international VC/PE players in chip startups oriented toward climate-tech and digital inclusion;
- Offer performance-linked incentives for companies engaging in open licensing and standards-based design.

Action 12: Support start-up consortia, EDA commons, and training networks linked to JCP infrastructure, particularly for women-led, rural, or minority-founded ventures.

By aligning private capital with mission-driven, de-risked innovation, EDEs can expand meaningful participation in chip ecosystems beyond elite clusters. Scale South-South and Triangular Cooperation for Semiconductor Governance

Action 13: Leverage existing regional initiatives (e.g., Digital Cooperation Organization, India-Africa Partnership, ASEAN Digital Masterplan) to:

- Harmonise regulatory approaches to chip certification and testing;
- Facilitate regional design competitions and skilling exchanges.

Action 14: Build triangular cooperation pathways with diplomatically agile, tech-capable partners (e.g., Singapore, Israel, South Korea) to access mid-tier fabrication, shared IP toolchains, and climate-relevant R&D partnerships.

These cooperative structures serve to institutionalise peer learning and knowledge circulation, mitigating over-dependence on incumbent blocs.

Strategic Priorities for JCP Implementation

The table below distils the 14 actions into five core implementation priorities, directly mapped to the JCP institutional structure:

Table 3 Mapping EDE Action Plan to Implementation Priority Areas and the JCP Institutional structure (Source: Author)

Implementation Priority	**Key Actions**	**Linked JCP Institutional structure**
Rule-Making Power	Joint diplomacy at WTO, Chip 4+, ITA forums	Representative Steering Committee
Infrastructure	Regional R&D, shared prototyping facilities	Regional Clusters, Shared Infrastructure
IP Access	Licensing commons, pooled IP regimes	Common IP Pools
Climate-Tech Linkages	NDC alignment, GCF engagement	Plurilateral Coordination Platform
Finance and Private Sector	Sovereign VC, open innovation incentives	JCP Invest

Conclusion: Embedding Justice in the Global Semiconductor Order

The global semiconductor economy is undergoing a foundational transformation geopolitically, institutionally, and industrially[41]. What began as a response to pandemic-era supply disruptions has rapidly evolved into a multipolar realignment of value chains, driven by state-backed industrial policy, strategic export controls, and narrow securitised interpretations of global technological interdependence. This reconfiguration, however, is unfolding along lines that reproduce familiar exclusions in international trade like, limited voice for developing economies, restricted access to upstream knowledge systems, and minimal institutional accountability for distributive outcomes. In this context, the case for a Just Chips Partnership (JCP) as outlined in this paper is a policy and legal imperative grounded in the logic of international cooperation, and in the principle that semiconductor technologies, when deployed as enablers of climate action and inclusive innovation, function as normative global public goods[42].

This concluding section synthesises the major proposals made throughout the paper, maps their

[41] Robertson and Hyung-gon Jeong, "Beyond the Battle for Supremacy: Reshaping the Global Semiconductor Supply Chain."

[42] "Knowledge as a Public Good."

legal grounding, and restates their relevance to the evolving global trade regime.

Representation and Rule-Making: Beyond Strategic Clubs

As the semiconductor economy becomes increasingly governed by informal security alliances such as Chip 4, the Wassenaar Arrangement, and the US-led export control coalitions, developing countries face the risk of institutional marginalisation. Yet global trade law, under both WTO principles and UN mandates, recognises the right of all states to participate in the formation of trade norms that affect their development priorities. For example,

- Article 12.1 of the WTO Agreement affirms the inclusive nature of membership and decision-making.
- The UN Charter and the Right to Development Declaration (1986) support equitable participation in rule-making processes that affect sovereign development capacities.

Thus, developing economies must pursue coordinated diplomacy to demand entry into semiconductor governance platforms, while simultaneously building their own plurilateral frameworks like the proposed JCP, to articulate collective interests.

Industrial Policy: From Subsidy Competition to Ecosystem Building

While subsidy-based competition has become the dominant logic of national semiconductor strategies (e.g., the US CHIPS Act's USD 52 billion outlay; India's PLI scheme of ₹76,000 crore), these policies often entrench dependency and do not yield meaningful upstream capability in EDEs. The JCP framework proposes a shift towards regional R&D consortia, shared fab infrastructure, and open innovation platforms, particularly for applications linked to climate and digital inclusion. The following two legal provisions in international trade and climate laws can be utilised to promote the interests of EDEs in the global semiconductor trade:

- WTO jurisprudence, while generally cautious on subsidies, permits development-enhancing subsidies under Article 27 of the Agreement on Subsidies and Countervailing Measures, particularly for technology transfer and environmental goods.
- SDG Target 9.b explicitly encourages support for domestic technology development and research infrastructure in developing economies.

Thus, EDEs should move beyond isolated subsidy regimes and coordinate industrial policy across borders, prioritising institutions over incentives, and regional/global ecosystems over low-value entry points.

Trade-Climate-Tech Integration: Chips as Infrastructure for Just Transitions[43]

The climate implications of semiconductor access remain under-theorised in mainstream trade discourse, despite their centrality to EVs, solar grids, smart agriculture, and energy-efficient infrastructure. Denial of chip access through export controls and/or unregulated IP restrictions undermines the "common but differentiated responsibilities" (CBDR) principle enshrined in the UNFCCC and Paris Agreement (Article 10).

Therefore, chip-climate nexus must be institutionally recognised, and JCP-type initiatives must be situated within multilateral climate finance and technology transfer frameworks.

Trade Law Reform: Correcting Asymmetries in Access and Ownership

Semiconductors are governed by trade regimes that prioritise market liberalisation (e.g., ITA-2, signed by 82 WTO members, accounting for 97% of the world trade in covered IT products) but offer limited recourse for knowledge transfer or policy flexibility. The following international law provisions can be utilised by EDEs for streamlining tech transfer relevant to the semiconductor industry:

- TRIPS Article 66.2 provides legal precedent for mandating tech transfer from developed to developing countries, though enforcement mechanisms remain weak.
- Proposals for SDT expansion under WTO tech agreements have precedent in ongoing discussions around digital trade and e-commerce.

[43] Alaize Dall-Orsoletta et al., "Low-Carbon Technologies and Just Energy Transition: Prospects for Electric Vehicles," *Energy Conversion and Management: X* 16 (December 2022): 100271, https://doi.org/10.1016/j.ecmx.2022.100271.

This is an entry point for action for EDEs to reinterpret TRIPS flexibilities for semiconductors, advocate for enforceable tech transfer obligations, and construct new SDT regimes for upstream chip access tied to development indicators.

Capital and IP: De-risking Innovation for Public Purpose

Private capital investment in semiconductor design and manufacturing in EDEs has not been promising, due to unfavourable legal and regulatory environment. De-risking private capital by using innovative blended finance models to build chip design ecosystem in countries like India will help EDEs build strategic autonomy using local talent.
Also, IP restructuring by way of pooled IP commons (which is supported by WIPO's Development Agenda) recognises the right of states to adopt IP regimes aligned with public interest, and helps in economic development.

Thus, JCP-style sovereign and regional VC fund, combined with commons-based IP licensing, can provide the enabling environment for mission-oriented, climate-compatible semiconductor innovation in EDEs.

South-South and Triangular Cooperation: Leveraging Collective Strength

South-South cooperation remains underutilised in semiconductor governance, despite complementarities in skills, raw materials, and research agendas. While China, South Korea, and Singapore have successfully scaled elements of the value chain, few mechanisms exist to translate these experiences into joint capacity-building for other EDEs.

- SDG 17.6 and 17.7 explicitly promote cooperation on science, tech, and innovation through regional and interregional initiatives.
- Triangular cooperation models, as endorsed by the UN Office for South-South Cooperation, have already proven effective in health, education, and digital domains.

Along these lines, the JCP framework provides the institutional scaffolding to organise knowledge-sharing, regional investments, and diplomatic leverage through an EDE-led technology bloc grounded in equity and co-creation.

Conclusion

The semiconductor economy is not neutral. It reflects and reinforces global hierarchies of knowledge, capital, and participation. As the next wave of industrial policy unfolds, the risk is not only that EDEs are left behind—but that their developmental trajectories are shaped in ways they did not choose, and cannot contest. The proposals outlined in this paper grounded in existing international law, emerging diplomatic alignments, and practical policy instruments offer a way forward.

The Just Chips Partnership is not a parallel architecture, but a corrective one. It builds on the idea that technology can serve as a platform for shared sovereignty rather than exclusive advantage, and that the global governance of semiconductors must reflect the world as it is—not just the world as the incumbents define it.

Appendix I: The JCP Governance Framework

Just Chips Partnership	Representative Steering Committee	Members from Developing/Emerging Economies, Industry, and Multi-lateral Bodies
	Regional R&D and Design Clusters	South Asia: Fabless design
		Sub-Saharan Africa: Low-power chips
		Latin America: Climate-Tech integration
	Common IP Pools and Public Good applications	Open source green tech chip designs
		Licensing agreement developed with WIPO
	Coordinated investment vehicle-JCP Invest	Pooling of sovereign, philanthropic, and private capital
		De-risking of publicgood semiconductor ventures
	Plurilateral Coordination Platform	Addressing entry barriers for capacity constraints
		Tech-aligned development priorities
	Shared Prototyping Infrastructure	Time sharing access to mid-range fabs
		Blended finance and Multilateral development banks' co-investment

Appendix II: Theories of Trade Justice applied to Global Semiconductor Policy

Theorist	**Key Concept**	**Policy Relevance for Semiconductors**
de Bres (2016)	Trade as a rule-governed practice	Need for fair distribution of access, not just voluntary exchange
Garcia (2000)	Structural vs. Procedural Justice	SDT, capacity-building, fair rule-setting
Gathii (2005)	Interpretive monopoly	Power asymmetries in export control, IP, WTO rulings
Risse (2007)	Minimalist trade ethics	Moral concern when exclusions harm development rights of sovereign nation states

ABOUT THE AUTHOR

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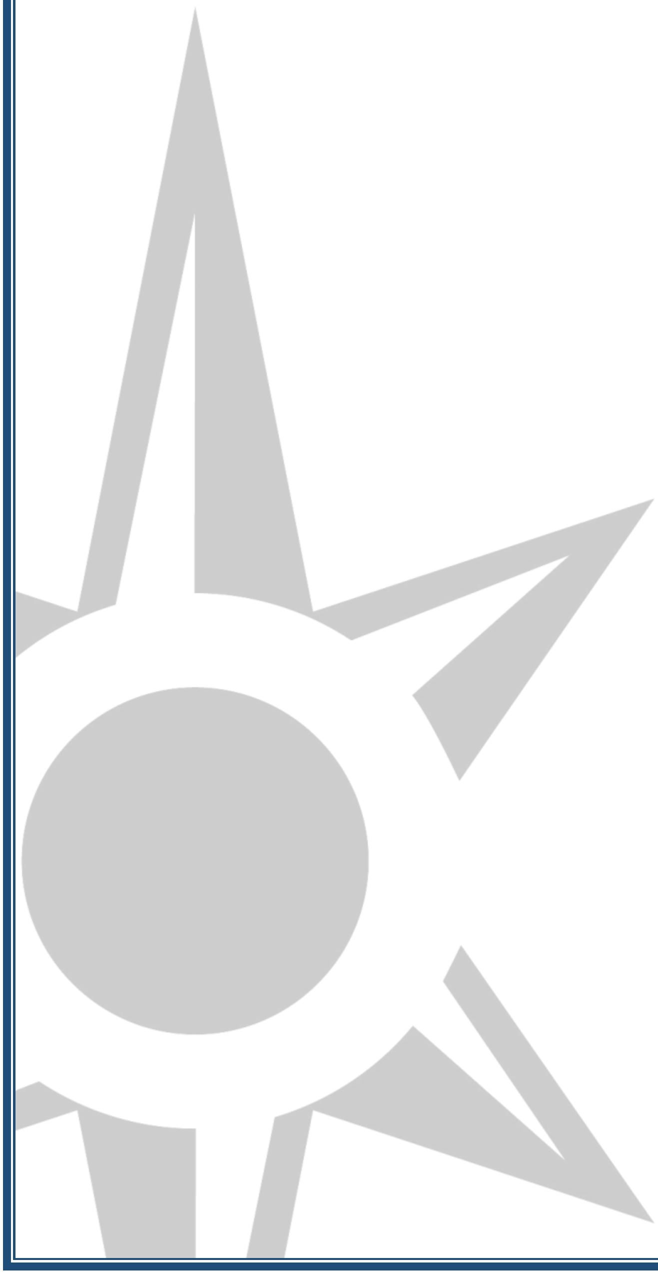
PACIFIC FORUM INTERNATIONAL

Protecting Innovation in the Indian Semiconductor Industry: Key Gaps, Challenges, and IP Strategies

By
Aparna Sharma



Executive Summary

Aparna Sharma

India has emerged as a crucial node in the global semiconductor value chain, with multinational corporations (MNCs) establishing large research and development (R&D) centres in the country. However, this integration has not translated into robust domestic intellectual property (IP) generation or innovation-led entrepreneurship. This paper investigates the structural limitations that prevent India from evolving from a service provider to an IP originator in the semiconductor space.

Through qualitative expert interviews and empirical review, the paper identifies key barriers: centralized global IP strategies of MNCs, minimal local patent filings, limited monetization opportunities, and weak IP enforcement in India. These factors discourage both foreign firms and Indian startups from investing in domestic IP creation. Moreover, India lacks a dedicated legal framework for trade secret protection, making sensitive semiconductor innovations vulnerable to insider threats and cross-border leakage.

Using global case studies and grounded policy analysis, the paper underscores the vulnerabilities faced by Indian startups and the risks MNCs encounter while operating in India. It presents a set of actionable policy recommendations targeted at the Indian government, the US government, and industry stakeholders. These include enacting a standalone trade secrets law, creating fast-track IP courts, offering patent filing incentives to startups, and establishing cross-border IP safeguards under the US-India initiative on Critical and Emerging Technologies (iCET) framework. The paper ultimately argues for a dual strategy, supporting global collaboration while building indigenous innovation capability, to secure India's position in the future of semiconductors.

Introduction

The global semiconductor industry underpins modern economies, powering sectors like telecom, defense, automotive, and consumer electronics. However, its centralized manufacturing, largely in Taiwan and South Korea, poses supply chain risks, as exposed by the COVID-19 pandemic and geopolitical tensions like the Russia-Ukraine conflict. In this context, India's semiconductor sector holds strategic importance for supply chain resilience and economic growth.

India's semiconductor push gained momentum with the $10 billion India Semiconductor Mission launched in 2021 to build a domestic manufacturing ecosystem. While India lacks large-scale fabs, it has a strong foothold in chip design, with over 20,000 engineers designing nearly 3,000 chips annually,[1] positioning it as an emerging hub for Research and Development (R&D).[2] The domestic semiconductor market is projected to exceed $60 billion by 2026[3], but manufacturing remains a challenge due to its complexity and capital intensity.

The India-United States (US) strategic partnership is pivotal, especially through the initiative on Critical and Emerging Technologies (iCET) launched in 2023.[4] The US has supported India with investments, such as Micron's $2.75 billion facility in Gujarat, and by supplying critical manufacturing equipment, design tools, and talent collaboration.[5]

Innovation is key in semiconductors, with continuous advances in chip design and manufacturing. Intellectual Property (IP) protection through patents, trade secrets, and other tools is essential for safeguarding innovations, attracting investment, and maintaining competitiveness. Reverse engineering poses serious threats to revenues and innovation incentives, making a strong IP framework crucial.

India ranks 39th in the Global Innovation Index (GII) and leads Central and Southern Asia in innovation. It hosts about 20% of the world's semiconductor design engineers.[6] However, most engineers and startups work for Multinational Corporations (MNCs), leading to limited domestic IP creation. Key challenges include high design costs, limited funding, and lack of fab access for local firms.

To achieve self-reliance, India must prioritize R&D and core IP creation. Understanding global and domestic IP strategies is vital to building a resilient and innovative semiconductor ecosystem. This paper argues that while India is increasingly embedded in the global semiconductor value chain through MNC-driven R&D centers, the country lacks a robust innovation ecosystem that enables domestic startups to generate and commercialize semiconductor-related IP. Weak patenting incentives, absence of trade secret protection, and underdeveloped IP enforcement mechanisms create systemic barriers for both Indian startups and foreign firms operating in India.

The following sections explore the current landscape of IP creation in India, key gaps and challenges, and IP strategies of MNCs. Further, it examines the underlying reasons for India's limited core design capabilities and low IP creation. Lastly, it provides the specific policy recommendations that can help to enhance the semiconductor industry's competitive growth.

Methodology and Analytical Framework

This study employs a mixed-methods research design that integrates quantitative analysis of patent data with qualitative insights from expert engagement and secondary sources such as research articles, media articles, government websites and annual reports, and industry reports. The quantitative component involves examining patent applications filed with the Indian Patent Office (IPO),

[1] "Need Improvement in Semiconductor Design Incentive Scheme: ICEA," The Financial Express, April 26, 2024, https://www.financialexpress.com/business/industry-need-improvement-in-semiconductor-design-incentive-scheme-icea-3468867/.

[2] India Cellular and Electronics Association (ICEA), The Challenges & Opportunities in Indian Semiconductor Industry (New Delhi: ICEA, 2024), 13, https://www.icea.org.in.

[3] "India's Semiconductor Market to Touch $64 Bn by 2026: Counterpoint, IESA," Business Standard, May 10, 2023, https://www.business-standard.com/industry/news/india-s-semiconductor-market-to-touch-64-bn-by-2026-counterpoint-iesa-123051000216_1.html.

[4] Rudra Chaudhuri and Neelanjan Bhandari, the iCET Effect: Advancing the US–India Technology Partnership (Washington, D.C.: Carnegie Endowment for International Peace, 2024), https://carnegieendowment.org/2024/01/16/icet-effect-advancing-us-india-technology-partnership-pub-91788.

[5] "Micron Begins Construction of $2.75 Billion Semiconductor Plant in Gujarat," Hindustan Times, September 23, 2023, https://www.hindustantimes.com/business/micron-begins-construction-of-2-75-billion-semiconductor-plant-in-gujarat-101695478422567.html

[6] "Need Improvement in Semiconductor Design Incentive Scheme: ICEA," The Financial Express, April 26, 2024, https://www.financialexpress.com/business/industry-need-improvement-in-semiconductor-design-incentive-scheme-icea-3468867/.

focusing on semiconductor-related technologies. This dataset is used to identify trends in IP creation, assess technological focus areas, and evaluate the role of both global and Indian firms in the semiconductor value chain. Patent data is analyzed through descriptive statistics, trend analysis, and classification by technology domains to map innovation patterns and strategic positioning.

The qualitative component draws on semi-structured interviews with key stakeholders in India, including industry professionals, policymakers, and startup founders, as well as roundtable discussions with government officials, industry experts, industry associations, non-governmental organisations, and academia based in the United States. Additional inputs are obtained through content analysis of media articles and policy documents, and participant observation from events attended by the author, including expert talks and national conferences. Together, these methods provide a holistic understanding of how firms leverage innovation capabilities to secure IP, the motivations behind their IP strategies, and the systemic challenges faced in the Indian context.

India's Existing Innovation policies and Semiconductor IP creation

India's semiconductor industry, along with its Information and Communication Technology (ICT) industries, has witnessed rapid growth in recent years. However, the country still lags significantly in IP creation and design capabilities compared to nations like the US, China, and South Korea. In recent years, India has taken strides to enhance its IP creation and protection framework. The Indian government has introduced several initiatives, such as:

- **National Intellectual Property Rights (IPRs) Policy:** Launched in 2016, it aims to foster a holistic environment for IP creation and protection.
- **Startup India:** Launched in 2016 to promote entrepreneurship and innovation, with schemes like tax exemptions and fast-track patent examination.
- **Make in India:** Launched in 2014 to stimulate manufacturing and foreign investment, including measures to protect and promote IP.
- **Atal Innovation Mission (AIM):** Launched in 2016 to foster innovation among young students.
- **Intellectual Property Facilitation Centres (IPFCs):** Established across the country to aid innovators in protecting their IP rights.

These initiatives collectively strive to provide an enabling environment for IP creation and protection in India, promoting innovation and entrepreneurship. Nevertheless, significant challenges remain, including a backlog of patent applications, limited awareness of IP rights, and difficulties in enforcing IP regulations.[7]

India's ICT and electronics industry has been experiencing significant growth in terms, of global players setting up manufacturing and R&D centres within the country. However, these centres primarily focus on product customization rather than fundamental design innovations.

The past annual IP reports[8] published by the Office of the Controller General of Patents, Designs, Trademarks, and Geographical Indications, the government of India, revealed that the major share of foreign patent applicants includes chip giants like Qualcomm, Samsung, and Huawei. In 2022-2023, Qualcomm, Samsung, and Huawei were the top three foreign patent applicants in India, holding 3482, 979, and 936 patent applications, respectively, at the IPO (refer to Figure 1). It shows that thousands of patent applications come from the Indian affiliates of these companies to the IPO. This means that despite India's huge talent pool that has already contributed to chip-making in Indian territory, India still does not hold many semiconductor IP assets. These patents could be a way for large foreign companies to enhance their profits through licensing, especially once Indian companies start entering the semiconductor market.

[7] India Cellular and Electronics Association (ICEA), The Challenges & Opportunities in Indian Semiconductor Industry (New Delhi: ICEA, 2024), 13, https://www.icea.org.in.

[8] Office of the Controller General of Patents, Designs and Trade Marks, Annual Report 2022–2023 (New Delhi: Intellectual Property India, 2023), https://ipindia.gov.in/writereaddata/Portal/IPOAnnualReport/1_114_1_ANNUAL_REPORT_202223_English.pdf.

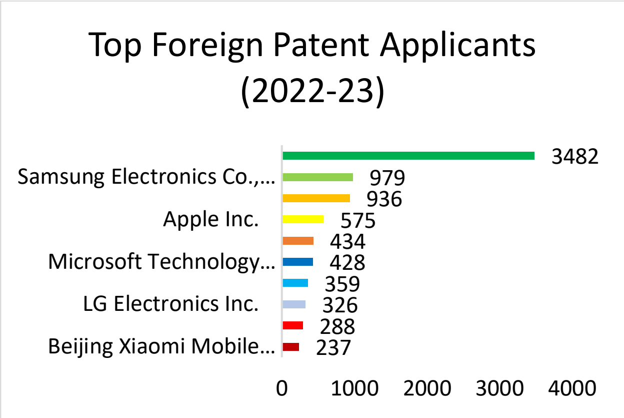


Figure 1: Top Foreign Patent Applicants at IPO

Key Forms of Semiconductor IP in India

The key forms of IP are particularly relevant to the semiconductor industry: layout designs, patents, trademarks, copyrights, trade secrets, and industrial design rights.

Layout Design Protection

The semiconductor industry benefits from the Semiconductor Integrated Circuits Layout Design (SICLD) Act, 2000, which protects the unique topographies or layout designs of integrated circuits. These 3D designs, which are crucial to a chip's performance and functionality, require significant investment in time and resources. By securing these designs, companies can protect their innovations from being copied, thereby safeguarding their competitive advantage.

The SICLD Act was enacted to protect the original layout designs of semiconductor integrated circuits (ICs), an essential component of modern electronics. ICs are devices with a single surface on which various components like transistors, resistors, capacitors, and diodes are mounted. These elements are connected to control electric current, modifying or amplifying it based on the circuit's intended function. Designing these elements within the IC requires meticulous order and management, referred to as the "layout design" or "topography" of the IC. This design, a 3-Dimensional (3D) arrangement of the circuits, is crucial for the circuit's performance and is the subject of protection under the Act.

For layout designs to be protected, they must meet two criteria: they must be original, resulting from the intellectual effort of the creator, and they must not be common knowledge among designers and manufacturers at the time of creation. Once a layout design meets these conditions, it qualifies for protection under the Act, granting the creator or company 10 years of exclusive rights to the design.

Patents

Patents are another key IP tool in the semiconductor sector, playing a critical role in protecting innovations and commercially exploiting R&D efforts. They cover a wide range of inventions, from new semiconductor processes and designs to novel materials used in chip production. For example, a company might patent a method for reducing energy consumption in chips or a breakthrough in chip design. Patents provide legal protection for inventions, ensuring that these innovations remain exclusive, giving companies the ability to recoup their investments without the threat of unauthorized use by competitors. Three major types of semiconductor innovations typically receive patent protection:

- Innovative methods for manufacturing semiconductors, such as novel production processes.
- Development of new semiconductor materials, enhancing product performance.
- Unique chip designs, optimizing performance and functionality to meet modern computing needs.

Patents in the semiconductor industry can be further categorized into three broad types:

- **Process Patents:** These cover specific manufacturing methods, essential for improving yield rates and cost-effectiveness in the highly competitive semiconductor market.
- **Product Patents:** Protecting the design and functionality of components like transistors or sensors, these patents drive innovations in performance and power efficiency.
- **System-Level Patents:** These patents cover integrated circuits that incorporate multiple components into a cohesive unit, vital for protecting complex chip designs used in everything from consumer electronics to automotive applications.

Examples of patented technologies in this field include thin-film transistors, which enhance performance while reducing power consumption, and Extreme Ultraviolet (EUV) lithography, a cutting-edge technology that enables the production of smaller, more powerful chips at the nanometer scale.

In India, patents are valid for 20 years from the filing date, provided the annuity fees are paid regularly. This ensures a balance between rewarding innovation and allowing public access to the invention after the patent expires.

Patent Landscape

As per the International Patent Classification (IPC)[11] established by the Strasbourg Agreement 1971 (World Intellectual Property Organization administered treaty), the semiconductor-related technologies fall in the following categories (refer to Table 1).

Table 1: International Patent Classification for Semiconductor Industry

S. No.	IPC Code	Description
1.	H01L	Semiconductor Devices not covered by class H10
2.	H10B	Electronic Memory Devices [2023.01]
3.	H10K	Organic Electric Solid-State Devices [2023.01]
4.	H10N	Electric Solid-State Devices not otherwise provided for [2023.01]

Source: WIPO[12]

As per IPO and PatSeer database total of 673 patent applications were filed in IPC code H01L till December 2024. Out of that, 475 are published. Table 2 highlights the top patent applicants with the number of patent applications published in semiconductor technologies (in a particular technology class) at the IPO between 2018 and 2024. Notably, Indian research and academic institutions rank among the top three filers, reflecting their strong contribution to innovation in specific technology classes in the semiconductor domain. However, the absence of private companies from these top ranks raises concerns about the limited participation of industry players in driving semiconductor-related R&D and innovation.

Trademarks

Trademarks help protect the brand identity of semiconductor companies, safeguarding logos and names associated with their products. In an industry where reputation and trust are vital, trademarks enable companies to differentiate their products from competitors. This form of IP protection is essential for maintaining customer loyalty and market recognition.

Table 2: Top Patent Applicants in the Semiconductor Industry at the IPO (2018-2024*)

IPC Code	Sub Classes	Description	Top Three Assignees in India	No. of Patent Applications
H01L	29-33	Devices adapted for rectifying, amplifying, oscillating, or switching Devices sensitive to, or emitting, radiation	Nichia Corporation	16
			Council of Scientific and Industrial Research (CSIR)	15
			Seoul Semiconductor Co Ltd	14
	35-51	Semiconductor Devices; Electric Solid-State Devices not Otherwise Provided for [2023.01]	Samsung Electronics Co Ltd	41
			Indian Institutes of Technology (IITs)	36
			LG Display Co Ltd	33
	21-27	Manufacturing process; Details; Assemblies of individual devices and Integrated circuits	Samsung Electronics Co Ltd	61
			Indian Institutes of Technology (IITs)	17
			Qualcomm Inc.	16

*Source: WIPO (IPC)[9] and Singh & Vaid (2024)[10] *2024 data is tentative*

Copyrights

Copyrights in the semiconductor industry primarily protect software embedded in chips, which is increasingly crucial for advanced tasks such as data processing, artificial intelligence, and power management. While patents protect the hardware, copyright covers the software that enables these chips to function. Copyright ensures that proprietary software cannot be copied or used without permission, which is critical in a sector that relies heavily on software-driven innovation.

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[9] Ibid.

[10] LexOrbis, The Semiconductor Industry in India – IP and Policy Updates (New Delhi: LexOrbis, 2024), https://www.lexorbis.com.

[11] IPC is used to classify patent documents in more than 100 countries. It divides technology fields into eight sections (A-H) with approximately 75,000 subdivisions, each represented by a language-independent symbol consisting of Latin alphabet characters and Arabic numerals.

[12] Guide to the International Patent Classification (2025). https://www.wipo.int/publications/en/series/index.jsp?id=183

In India, most software, including embedded firmware in semiconductor devices, is protected under copyright law. While software can sometimes be patented if it meets specific criteria, copyright protection primarily applies to the expression of the software code itself, rather than the underlying functional concepts or algorithms. Copyright protection often covers the embedded code within IC or system-on-chip (SOCs) that controls hardware operations. This protection prevents the unauthorized copying, distribution, or use of firmware, the software code essential for hardware functionality. Given its role as an intermediary between hardware and higher-level software, firmware controls vital aspects of semiconductor devices, such as communication protocols, system booting, and real-time operations.

In India, the duration of copyright protection for firmware is the lifetime of the author plus 60 years thereafter. While copyright protection is automatic upon creation, it is advisable for companies to formally register their copyright with the relevant authorities. Registration, though optional, offers additional legal advantages, providing prima facie evidence of ownership in the event of litigation or infringement claims.

Trade Secrets

In the fiercely competitive semiconductor industry, trade secrets are another critical form of IP protection, especially for highly specialized manufacturing techniques, processes, and technical know-how that companies choose not to patent or copyright to avoid public disclosure. Trade secrets protect confidential information, such as proprietary processes or material compositions, which gives companies a competitive edge. Unlike patents or copyrights, trade secrets do not require registration and can remain protected indefinitely, as long as confidentiality is maintained.

Trade secrets offer an advantage by safeguarding confidential information, allowing companies to maintain a competitive edge. For instance, specialized algorithms used in chip design, signal processing, and optimizing semiconductor performance are often protected as trade secrets. These proprietary methods remain unpublished, ensuring that competitors cannot replicate the technology. Similarly, advanced manufacturing techniques such as doping or lithography methods, key to fabricating semiconductor chips, are closely guarded to prevent imitation by rivals.

Another area where trade secrets play a role is in chip architecture. The intricate design structure of a semiconductor, including transistor configurations and electrical pathways, is critical to its performance. Companies developing custom architectures that increase efficiency, speed, or reduce power consumption, especially in high-demand markets like CPUs, often choose to protect this information as trade secrets.

Semiconductor companies like Intel and Taiwan Semiconductor Manufacturing Company (TSMC) heavily rely on trade secrets to safeguard proprietary manufacturing processes. TSMC's breakthroughs in five-nanometre and three-nanometre process technologies, for example, are closely guarded trade secrets. By keeping their core technologies confidential, these firms can achieve higher transistor densities, reduce power consumption, and offer superior chip performance.

Industrial Design Rights and Semiconductor Aesthetics

While much of the focus in semiconductor IP revolves around technical functionality, design rights play a crucial role in safeguarding the visual and aesthetic elements that define a product. Unlike patents, which protect the technical innovations of integrated circuits, design rights under industrial design law shield the physical appearance and aesthetic features of semiconductor devices.

This form of protection applies to the external design of microchips. For instance, the size, shape, or ornamentation of a microchip, as well as the outer packaging or casing of semiconductor components, can be protected under design rights. Even the design of chip packages featuring original and novel aesthetic elements can be subject to industrial design protection. Though design rights do not extend to the functional aspects of a semiconductor, they are essential for protecting the visual identity of a device and helping companies distinguish their products in a highly competitive market.

In India, the duration of industrial design protection is up to 15 years. Initially, the design is granted exclusive rights for 10 years, with the option to renew for an additional five years. This extended period allows semiconductor companies to maintain the exclusivity of their designs, ensuring that their products' visual appeal remains unique and safeguarded in the market.

Role of International Treaties

In the global landscape of IP for semiconductors, international treaties play a crucial role. Three key treaties facilitate the protection of IP across borders:

- **Patent Cooperation Treaty (PCT):** This treaty simplifies international patent filing, allowing applicants to submit a single application that can cover multiple countries. This streamlined process helps innovators protect their inventions more efficiently.
- **Madrid Protocol:** Similar to the PCT, the Madrid Protocol enables trademark applicants to seek registration in multiple jurisdictions with one application. This system is particularly advantageous for companies aiming to establish a global presence.
- **Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS):** The TRIPS agreement sets international standards for IP protection, ensuring compliance among member nations. This treaty is vital for harmonizing IP laws globally, thereby fostering innovation and protecting rights holders.

Together, these above forms of IP protection are essential for safeguarding innovation and securing the future of the semiconductor industry. By protecting their technological advances, companies can maintain their competitive advantage, attract investment, and ensure continued growth in a rapidly changing technological landscape.

Understanding the Gaps in Semiconductor IP Generation in India

Overall, India has approximately 2.2 million patent applications pending, compared to around 11 million combined from the US and China. Moreover, India's acceptance rate for research publications in IEEE stands at about 4.5%, significantly lower than the US's 36%. This disparity suggests that the lower quality of research may be a contributing factor to India's limited generation of IP.[13]

According to an expert, semiconductor fabrication and chip design are two distinct yet intertwined aspects of the semiconductor ecosystem. While semiconductor fabs, similar to high-tech chemical plants, remain scarce in India, the country has made notable progress in chip design and IP creation in recent years. He points out that India's progress in this arena is evidenced by the success of fabless semiconductor companies, which focus on designing chips while outsourcing their manufacturing to global foundries.

Companies like Selenium Circuits in Kochi and Netrasemi in Trivandrum exemplify this new wave of innovation. These startups are not just designing chips, they're developing unique IPs that could position India as one of the leaders in the semiconductor space. Although the actual fabrication of these chips occurs abroad, the intellectual capital remains firmly rooted in India.

A significant driver behind this evolution is the Design Linked Incentive (DLI) scheme, which encourages domestic companies to engage in product design and innovation. The scheme has spurred the growth of fabless semiconductor firms and supported the development of groundbreaking products in fields like MedTech, where companies have created devices such as neonatal blankets with embedded sensors (invented by research teams of Indian Institute of Science, and St John's Research Institute, Bangalore) and HD Steth (a digital stethoscopes with ECG functionality invented by HD Medical Services Pvt. Ltd., Chennai).

The other expert mentioned that India has long been celebrated for its prowess in design engineering, particularly in chip design, which forms the bedrock of semiconductor innovation. Global companies such as Intel, Qualcomm, and Advanced Micro Devices (AMD) have leveraged India's talent pool through their Global Engineering Centres (GECs). Global giants leverage India's brilliant talent pool, obtaining top-tier design engineering expertise at a fraction of the cost, typically 10-15 times less than in other markets like the US, Europe, Singapore, etc. Engineering and research are two distinct domains. Research involves in-depth, cutting-edge exploration, which can be termed the "brain" or "heart" of a product or service. Companies are generally

[13] India Cellular and Electronics Association (ICEA), The Challenges & Opportunities in Indian Semiconductor Industry (New Delhi: ICEA, 2024), 13, https://www.icea.org.in.

reluctant to outsource this critical component to India, as it constitutes their core IP. This hesitancy is understandable; if everyone had access to the same research and innovations, it could undermine a company's market position.

Instead, many companies outsource engineering tasks and manufacturing activities to India. They provide detailed instructions, including elaborate drawings and material specifications, for local teams to execute. While these tasks require skill and precision, they often do not demand high levels of creativity or innovation, as the focus is on following predefined guidelines. Therefore, for the last many years, India's potential as an innovation hub has been underutilized. Globally, Indians are recognized as some of the brightest minds, yet such operational frameworks have often constrained their ability to innovate and think freely. This is gradually changing due to efforts like those spearheaded by the present government, though it is a long-term process that may take decades to fully materialize.

Another expert supported the above argument saying that India's semiconductor design sector is robust. The country excels in areas like networking, microprocessors, analog chip design, and memory subsystems, with a thriving ecosystem of MNCs, design centers, service houses, and local companies. However, much of this talent serves multinational corporations, leaving limited visibility for indigenous work. Despite the presence of five to 10 small Indian fabless startups with products in production and 20-25 others in development, most startups focus on design testing and verification for larger firms. Acknowledging this, the Indian government has introduced supportive policies to address these challenges.[14]

He further said that the role of global development centers (GDCs) operated by multinational tech giants in India should not be overlooked. These centres, run by companies like Intel, Qualcomm, and Texas Instruments, are not merely support hubs, they are integral to the global product development process. However, patent filings by companies like Intel and Cisco are rare because they typically file patents at their headquarters in the US, even though much of the work is carried out at their Indian affiliates.

Indian engineers at these GDCs are heavily involved in R&D, contributing to cutting-edge innovation. However, while the work is done in India, the IP often resides with the parent companies abroad. Due to extremely high costs in chip design force many Indian companies to service large MNCs, using Indian expertise to create designs. An Indian Cellular and Electronics Association report published in April 2024 mentioned that while the 'brainpower' of Indians is used, it is the "money power" of MNCs that has led to most chip designs being designed in India (to a certain extent) and their IP resting outside India.

This dichotomy reflects both the challenges and opportunities for India's semiconductor industry. On the one hand, India's contribution to global IP is growing, driven by domestic innovation and the experience gained at GDCs. On the other hand, foreign companies' retention of IP rights underscores the need for a stronger domestic framework for IP creation and protection.

Securing IP is pivotal for safeguarding innovations and sustaining a competitive edge in the semiconductor value chain. However, in India, navigating the IP ecosystem can be daunting for startups and MSMEs (micro, small, and medium enterprises). The high costs of filing patents, legal complexities, and lack of streamlined processes deter smaller players from protecting their innovations. Entrepreneurs are increasingly securing funding from different government initiatives, but a significant challenge arises when a large portion of that funding is consumed by the legal formalities associated with their ideas. This leaves entrepreneurs with limited resources to invest in actual manufacturing or scaling their innovations.

For example, filing and maintaining a patent in India costs anywhere from $1,200 to $6,000, a prohibitive figure for budding entrepreneurs. Additionally, legal uncertainties can result in inadvertent violations, crippling businesses with penalties. These challenges often force innovators to shelve their ideas or seek foreign markets for better support.

Further, Indian IP experts criticize the SICLD Act, introduced in 2000 to protect the design of ICs. Despite India's growing presence in semiconductor

[14] India Cellular and Electronics Association (ICEA), The Challenges & Opportunities in Indian Semiconductor Industry (New Delhi: ICEA, 2024), 13, https://www.icea.org.in.

design, the act has seen limited use. IP experts criticize the act, describing it as fundamentally flawed, comparable to attempting to patent a process rather than the final product. The practical challenges and questionable return on investment have deterred many companies from utilizing this protection mechanism. Qualcomm, Samsung, Huawei, and other chip giants prefer patent protection over SICLD for their semiconductor products in India because patents offer broader, more valuable, and globally consistent protection. Patents also provide stronger enforcement mechanisms, longer protection durations, and greater strategic flexibility for licensing and business operations.

However, when it comes to IP, India cannot afford to wait that long. There is an urgent need to streamline processes and methodologies to foster IP creation. However, these centers largely handle engineering tasks and process optimization rather than core R&D.

Ground Level Struggles of the Indian Semiconductor Industry

India faces significant hurdles in semiconductor chip design, including the high costs of semiconductor chip design, driven by expensive Electronic Design Automation (EDA) tools and lengthy fab processes (12-18 months), making this industry dominated by major MNCs in India, leaving limited space for Indian companies and startups.

As per an expert, designing and developing chips is a costly endeavour for startups, with IP creation expenses ranging from $2 million (166 million rupee) to $20 million (1660 million rupee). With limited venture capital available for deep tech hardware startups, these companies often depend on grants, angel investors, and a handful of early-stage investors willing to take risks on unproven technologies.

The positive side of the MNCs' dominance

There is another side to having global chip giants in the Indian market. Engineers from companies such as Intel, Texas Instruments, and Qualcomm often gain invaluable experience and knowledge while working on global products. Many of these engineers eventually leave to start their own companies, using the expertise they've acquired. This trend has led to the emergence of successful ventures like FermionIC Design, Silizium Circuits Private Limited, Netrasemi, and Cientra, all founded by former employees of these tech giants. In this way, these companies serve as incubators for future entrepreneurs, fostering innovation and contributing to the growth of India's tech ecosystem.

Why Do Global Semiconductor Companies Not File Patents in India?

Despite India's emergence as a significant R&D destination in the global semiconductor value chain, MNCs with large operational bases in the country remain hesitant to file patents domestically. Several structural and strategic factors contribute to this trend.

(a) Centralized IP Strategy

MNCs typically operate under globally centralized IP strategies, where innovations created in subsidiaries, regardless of location, are legally assigned to headquarters. Indian R&D centers are often treated as contract research units, and the IP generated is attributed to the parent company. This leads to the patent filings being made in the home countries such as the United States, Taiwan, or European jurisdictions, rather than in India.

For example, firms such as Qualcomm, Intel, and Texas Instruments, which maintain substantial engineering and design operations in Bangalore and Hyderabad, rarely file for Indian patents, despite their technical contributions being significant. India hosts the second-largest number of Global Capability Centers (GCCs) in the world, with many of them contributing to patents filed overseas.[15]

(b) Limited IP Monetization Opportunity

The Indian semiconductor market has not yet developed a mature fabless ecosystem, nor an active licensing market for semiconductor IP. As a result, companies perceive minimal opportunity for monetizing patents filed in India. Consequently, firms prefer to register IP in jurisdictions that offer stronger licensing, enforcement, or market relevance.[16]

[15] NASSCOM and Zinnov, India GCC Trends Report 2021, accessed July 21, 2025, https://nasscom.in/knowledge-center/publications/india-gcc-landscape-report-5-year-journey.

[16] GIPC (Global Innovation Policy Center), International IP Index 2022, US Chamber of Commerce, accessed July 21, 2025,

Additionally, India remains a minor player in the global chip consumption market in value terms. India's share in global semiconductor sales remains below 1%, which limits the incentive for firms to seek protection in a low-revenue jurisdiction.[17]

(c) Weak Enforcement and Legal Uncertainty

A major limiting factor is India's historically weak IP enforcement ecosystem. Patent litigation in India is often marked by lengthy resolution timelines, low damages, and inconsistent judgments, reducing the effectiveness of patents as an enforceable right. This undermines the purpose of obtaining IP protection in the first place, especially for strategic technologies like chip design, layout architecture, or process innovations.

India's ranking in the US Chamber of Commerce's Global IP Index has remained low due to concerns around enforcement, judicial capacity, and trade secret protection. In the 2023 index, India scored 38.64 out of 100, ranking 42nd out of 55 economies.[18]

Patent Protection Challenges Faced by Indian Semiconductor Companies

Despite the importance of patents in fostering innovation, the semiconductor industry faces several challenges in securing and maintaining patent protection.

One of the key challenges is the rapidly evolving nature of semiconductor technology. Companies must act quickly to file patents and secure their IP before competitors develop similar innovations. This is particularly challenging for smaller players in the industry, who often face high costs in both protecting and maintaining patents.

Another major challenge is the issue of overlapping patents. Due to the complexity of semiconductor technologies, multiple parties may claim rights over similar innovations, leading to patent thickets and complicated litigation. This not only hinders the enforcement of patent rights but also slows down the development and commercialization of new technologies.

To maintain the validity of a patent, companies must pay the required renewal fees annually. Failing to do so results in the loss of the patent. Additionally, companies must actively enforce their patent rights, ensuring that third parties do not use their innovations without authorization. If patent rights are not properly enforced, the protection weakens, undermining the value of the patent. Challenges, including the fast-paced nature of technological advancements and complex patent litigation, underscore the importance of robust IP management strategies in the semiconductor space.

Advantages and Challenges of Trade Secrets in the Semiconductor Industry

One significant advantage of trade secrets is that, unlike patents, they do not require public disclosure and can remain protected indefinitely as long as confidentiality is maintained. This long-term protection allows companies to preserve valuable competitive advantages without setting a time limit on exclusivity. Trade secrets also avoid the risk of competitors reverse-engineering patented technologies or working around publicly disclosed designs.

However, protecting trade secrets comes with challenges. Employee mobility and inadvertent disclosures present substantial risks. Even with Non-Disclosure Agreements (NDAs) in place, there's always the possibility of employees unintentionally sharing confidential information. Additionally, trade secret theft is difficult to prove, especially when the information isn't formally documented. Global semiconductor companies also face complications due to varying laws in different countries, making the enforcement of trade secrets complex.

Moreover, the rapid pace of technological innovation in the semiconductor industry often makes it difficult to maintain trade secrets for extended periods. As new technologies emerge and older products become obsolete, the window for trade secret protection shrinks. Cybersecurity threats also pose significant risks, as semiconductor firms are prime targets for hackers seeking to steal valuable proprietary information.

https://www.uschamber.com/assets/documents/IPIndex-FullReport_2022.pdf.pdf

[17] Semiconductor Industry Association (SIA), State of the US Semiconductor Industry 2023, accessed July 21, 2025,https://www.semiconductors.org/wp-content/uploads/2023/07/SIA_State-of-Industry-Report_2023_Final_072723.pdf

[18] US Chamber of Commerce, Global Intellectual Property Index 2023, accessed July 21, 2025, https://www.uschamber.com/intellectual-property/2023-international-ip-index

Trade Secret Violations: India's Vulnerability

Trade secrets are a critical form of IP in the semiconductor industry, where proprietary processes and designs can determine global competitiveness. In India, however, the legal and institutional infrastructure to protect trade secrets remains underdeveloped, creating significant risks for both domestic startups and MNCs operating R&D centers in the country.

Key Legal Gaps

India does not currently have a standalone statute governing trade secrets. Instead, protection relies primarily on contract law, including Non-Disclosure Agreements (NDAs) and non-compete clauses governed by the Indian Contract Act, 1872. These mechanisms are insufficient in cases involving complex industrial espionage or cross-border IP theft.[19] Unlike jurisdictions such as the United States, India lacks:

- Specialized courts or judicial benches for trade secret litigation
- Consistent legal precedents on trade secret misappropriation
- Expedited legal remedies, with cases often delayed by long litigation timelines[20]

Moreover, India has not fully implemented its obligations under Article 39 of the WTO TRIPS Agreement, which mandates legal protection for undisclosed information against unfair commercial use.[21]

Case Study: Intel vs Former Employee

In a prominent 2021 case, Intel Corporation filed a lawsuit against Varun Gupta, a former employee, for allegedly stealing highly confidential technical documents related to Intel's Xeon processors, a critical line of chips used in cloud computing and enterprise servers. Gupta had worked at Intel as a product marketing engineer for nearly a decade before joining Microsoft's Azure division, where Intel feared the proprietary data could offer competitive insights.[22]

Before joining Microsoft's Azure division, Gupta was accused of downloading over 3,900 confidential files, including chip design specifications and performance data. The case highlighted the risks associated with insider threats and the need for robust legal protections for trade secrets, particularly as global R&D teams, including those in India, contribute to the development of sensitive chips.[23]

Key IP Strategies for the Semiconductor Industry in India

As the semiconductor industry in India evolves, the importance of robust IP strategies cannot be overstated. Companies are increasingly recognizing the need to protect their innovations to stay competitive in a rapidly changing technological landscape. Here are some key strategies for IP protection that semiconductor firms should consider.

Early Registration of Designs

Timely registration of unique design elements is crucial for semiconductor companies. By securing design rights early in key markets, firms can establish priority and prevent competitors from filing first. This proactive approach ensures that the novelty of a design is maintained and protects the aesthetic features that distinguish their products.

Vigilant Monitoring for Infringement

Keeping a close watch on competitors and market trends is essential for identifying potential infringements of protected designs. By actively monitoring the landscape, companies can swiftly address any unauthorized use of their IP and safeguard their market position.

[19] Aaliya Aleem, "A Critical Analysis of the Protection of Trade Secrets Bill, 2024," NLUJA Intellectual Property Law Review 3, no. 2 (2024): 119–134, accessed July 21, 2025, https://www.nluassam.ac.in/docs/Journals/IPR/vol3-issue-2/7.%20A%20CRITICAL%20ANALYSIS%20OF%20THE%20PROTECTION%20OF%20TRADE%20SECRETS%20BILL,%202024.pdf

[20] Ibid

[21] World Intellectual Property Organization. Agreement on Trade-Related Aspects of Intellectual Property Rights, ANNEX 1C, TRT/WTO01/001, Accessed July 23, 2025, https://www.wipo.int/wipolex/en/text/305736

[22] Anthony Spadafora, "Intel Accuses Ex-Employee of Stealing Trade Secrets Linked with Xeon Cloud Chips," TechRadar, February 9, 2021, https://www.techradar.com/news/intel-accuses-ex-employee-of-stealing-trade-secrets-linked-with-xeon-cloud-chips.

[23] Joel Hruska, "Intel Sues Former Employee for Alleged Theft of Xeon Data," ExtremeTech, February 9, 2021, https://www.extremetech.com/extreme/319877-intel-sues-former-employee-for-alleged-theft-of-xeon-data.

Leverage Government Support

The Indian government has introduced various initiatives to strengthen the semiconductor ecosystem, including the Production Linked Incentive (PLI) scheme, which offers financial incentives to companies engaged in semiconductor manufacturing and design. This support encourages domestic manufacturing and innovation, enabling companies to focus on robust IP strategies.

Prioritize Patent Filing

To remain competitive globally, semiconductor firms must prioritize patent filings in several areas:

- **New Chip Designs:** Companies should file patents for innovative chip architectures, circuit designs, and layouts. These patents protect the unique structure of chips, including advancements in efficiency, size, production methods, and performance.
- **Process and Manufacturing Innovations:** Patents can also cover innovative semiconductor fabrication processes, such as advancements in wave curve production and transistor placement. Protecting these innovations helps companies maintain a market advantage and contributes to India's competitiveness in semiconductor manufacturing.

As India's semiconductor industry continues to grow, the strategic filing of patents is becoming increasingly vital for protecting technical innovations and ensuring that domestic companies maintain a competitive edge in the global market.

Design Protection for Aesthetics

While patents safeguard functional innovations, design protection focuses on the visual and aesthetic elements of semiconductor devices. Given the growing importance of aesthetics in chip and packaging design, protecting non-functional innovations can yield significant commercial value.

Strategic Collaboration and Licensing

India's semiconductor sector is advancing through strategic collaborations and partnerships with global industry players. Licensing and IP-sharing agreements are key mechanisms for fostering innovation while protecting core IP.

- **Strategic IP Licensing:** Semiconductor companies can use strategic licensing agreements to grant global players access to their patented technologies, processes, or designs. This allows Indian firms to monetize their innovations while retaining ownership of their core IP. For instance, an Indian semiconductor company might license its proprietary chip design to a multinational firm, maintaining control over the patent rights.
- **Fostering Partnerships:** IP licensing also facilitates partnerships between domestic and international players. By collaborating with global leaders, Indian firms can access cutting-edge technologies while contributing to their own innovations. This environment promotes the sharing of knowledge, expertise, and IP, driving growth in India's semiconductor sector.
- **Protecting Core Innovations:** While licensing agreements encourage collaboration, companies must ensure that their core innovations remain protected. Licensing certain parts of technology should not compromise the safeguarding of the most valuable assets, preventing competitors from gaining full control over critical IP.

Maximizing Copyright Protection for Firmware

To strengthen copyright protection, semiconductor companies should adopt both technical and legal strategies. Advanced encryption methods can safeguard proprietary firmware from unauthorized access or tampering. Including explicit copyright notices within the firmware code and related documentation can deter potential infringement by making it clear that the software is protected.

Regular monitoring is another essential practice. Keeping a close eye on potential infringements, such as unauthorized distribution or reverse-engineered copies, enables companies to take swift legal action when needed. Additionally, licensing agreements with third parties should clearly define the permissible use of firmware, ensuring that companies retain control over their software while preventing unauthorized modifications or redistributions.

In a rapidly evolving industry like semiconductors, protecting embedded software through copyright is

critical. By employing robust strategies and legal safeguards, companies can ensure their IP remains secure in the competitive global marketplace.
In conclusion, as the semiconductor industry in India expands, implementing these key IP strategies will be vital for companies seeking to protect their innovations and thrive in a competitive landscape. Through early registration, vigilant monitoring, government support, strategic patent filing, design protection, and effective collaboration, semiconductor firms can secure their place in the global market.

Best Practices for Trade Secret Protection

To ensure the protection of trade secrets, semiconductor companies must implement strong security measures. Internal protocols are key, access to sensitive information should be limited based on employee roles, and strict documentation handling procedures must be in place. Confidential data, whether stored physically or digitally, must be labeled and securely stored.

Training employees is another critical component. Staff should be regularly educated on the importance of confidentiality and how to recognize potential threats to trade secrets. NDAs should be mandatory for all employees, contractors, and partners, with clear legal consequences for any violations.
Given the digital nature of semiconductor research, robust cybersecurity is essential. Companies should employ advanced measures like encryption, multi-factor authentication, and constant system monitoring to safeguard against cyberattacks. Regular audits of these systems, alongside close monitoring of access logs, can help detect and prevent unauthorized access.

In addition to digital safeguards, physical security measures are equally important. Secure labs, badge-based access control, and monitoring systems can help protect sensitive work environments where key semiconductor innovations take place.

In an industry driven by rapid innovation and intense competition, trade secrets remain a vital strategy for semiconductor companies to safeguard their most valuable technologies while navigating the challenges of maintaining confidentiality in a global market.

Global Challenges in Protecting Semiconductor Innovations

The semiconductor industry is at the forefront of technological advancement, yet it faces significant global challenges in protecting its innovations. These challenges are multifaceted, stemming from the complexity of the patent landscape, threats to trade secrets, enforcement issues, and the ongoing conflict between innovation and standardization.

Complexity of the Patent Landscape

One of the most daunting obstacles in the semiconductor sector is the intricate patent landscape. Each year, thousands of patents are filed across various jurisdictions, covering a wide array of components, processes, and technologies. A single semiconductor product can incorporate thousands of patented technologies, creating a complicated environment of overlapping IP claims, often referred to as "patent thickets". For instance, a company developing a new chip architecture may inadvertently infringe on existing patents related to materials, interconnects, or manufacturing methods, despite the novelty of its design.

Jurisdictional differences further complicate matters. Given the global nature of semiconductor manufacturing and distribution, companies must file patents in multiple jurisdictions to ensure comprehensive protection. However, varying standards for patentability among countries can lead to overlapping claims and disputes, requiring substantial legal resources to navigate. As a result, the cost and complexity of bringing products to market in competitive regions such as the US and Europe can be prohibitively high.

Case Study: Qualcomm vs. Apple

One of the most notable patent disputes in the semiconductor industry is the legal battle between Qualcomm and Apple. This long-standing conflict culminated in a settlement in 2019, highlighting the significance of IP in maintaining a competitive edge in high-tech markets. Qualcomm, a leader in wireless communication technologies, holds numerous patents related to chipsets, while Apple is one of its largest consumers. The dispute centred around royalty fees and licensing practices, with Apple accusing Qualcomm of unfair patent practices.

The case illustrates the complexities of standard essential patents (SEPs) in IP conflicts and underscores the importance of a well-managed patent portfolio, especially in lucrative markets like smartphones.

Trade Secret Theft

In addition to the challenges posed by patents, semiconductor companies heavily rely on trade secrets to protect key technologies that may not be easily patentable. However, the risk of trade secret theft looms large. Cyberattacks targeting semiconductor firms are on the rise, with hackers seeking to steal proprietary design algorithms and fabrication techniques. High-profile companies like Intel, TSMC, and Qualcomm have recently been victims of such attacks, underscoring the vulnerabilities in the industry.

To counter these threats, companies are implementing various strategies to safeguard sensitive information. Robust cybersecurity protocols are being established, and employees are educated about risks and required to adhere to strict confidentiality agreements. Additionally, access to critical information is being limited both physically and digitally to mitigate the risk of breaches.

Case Study: Qualcomm v. Former Engineer

In March 2022, Qualcomm Technologies Inc. filed a lawsuit in the US District Court for the Southern District of California against a former senior engineer, Gaurav Kathuria. The company alleged that Kathuria had violated a confidentiality agreement by downloading hundreds of files containing chip-related software architecture and design documents before resigning and accepting a position with a competing firm.[24] Qualcomm requested an injunction to prevent the use of its proprietary information and sought unspecified damages. This case highlights the risks semiconductor firms face from insider threats and underscores the necessity for strong trade secret protections, particularly important as global R&D operations become increasingly dispersed, including in countries like India.

Global Enforcement Issues

The enforcement of IPRs varies significantly across different jurisdictions, creating further challenges for semiconductor firms seeking global protection for their innovations. Differences in IP enforcement standards can complicate legal recourse. For instance, while China has made strides in strengthening its IP laws, enforcement remains inconsistent. In the US, although IP enforcement is generally robust, the high legal costs and complexity of patent litigation can be a barrier for smaller companies trying to defend their rights. India, while increasingly focused on IP enforcement, grapples with significant backlogs that slow the process.

Cross-border IP litigation presents additional hurdles, often proving to be both expensive and time-consuming, further complicating efforts to protect innovations on a global scale.

Conflict Between Innovation and Standardization

The semiconductor industry is also caught in a constant tug-of-war between the drive for innovation and the need to adhere to industry standards. While these standards ensure compatibility between devices and technologies, they can hinder companies' efforts to innovate. Semiconductor firms must continuously evolve to develop smaller, faster, and more efficient chips, but the prevalence of established standards can limit how far they can deviate from existing technologies without risking violation.

When developing new technologies, companies face a critical decision: should they standardize their innovations or keep them proprietary? Standardizing may require licensing technology on fair, reasonable, and non-discriminatory terms, which can restrict exclusive control over proprietary information. Additionally, patented technologies that become part of industry standards are classified as SEPs. Owners of SEPs are obligated to license their technologies to others, leading to potential disputes over licensing terms, royalty rates, and allegations of unfair practices.

As the semiconductor industry continues to innovate and expand, navigating these global challenges in protecting IP will be crucial. Companies must adopt

[24] Blake Brittain, "Qualcomm, Former Engineer Settle Trade-Secrets Lawsuit," Reuters, May 4, 2022, https://www.reuters.com/legal/litigation/qualcomm-former-engineer-settle-trade-secrets-lawsuit-2022-05-02/

proactive strategies to address the complexities of the patent landscape, safeguard trade secrets, tackle enforcement issues, and balance the imperatives of innovation and standardization. In doing so, they can better secure their innovations and maintain their competitive edge in a rapidly evolving technological landscape.

Technology Specific Challenges

As there are international treaties to support the international framework for IP protection, the semiconductor industry faces new challenges due to the emergence of innovative technologies. Here are three significant technological advancements and the associated IP challenges they present:

(a) 3D Integrated Circuits

3D integrated circuits (3D ICs) represent a groundbreaking shift from traditional 2D chip designs, allowing multiple layers of integrated circuits to be stacked vertically. This architecture enhances computational power while reducing power consumption and overall size, making it ideal for mobile devices, data centres, and high-performance computing.

The IP landscape surrounding 3D ICs is complex, with patents primarily focusing on the innovative manufacturing processes required for vertical stacking. This includes techniques like through-silicon vias, wafer bonding, and die stacking. Major players like Samsung and TSMC are heavily investing in this technology, emphasizing the need for robust IP protection to maintain competitive advantages.

However, challenges abound. The novelty of 3D IC technology means the patent landscape is still evolving, leading to potential disputes as companies rush to patent similar stacking techniques. Additionally, enforcing IP rights can be difficult, as many manufacturing processes are not readily observable in the final product, complicating the detection of potential infringements.

(b) Quantum Computing

Quantum computing signifies a radical shift in processing capabilities, leveraging qubits instead of classical bits to solve complex problems that traditional semiconductor systems cannot handle. The development of quantum semiconductors necessitates innovations across various disciplines, including quantum theory and material science.

Patents in this field typically focus on the architecture of qubits, quantum error correction methods, and the design of quantum gates. However, protecting these innovations poses significant challenges due to the interdisciplinary nature of quantum computing. Overlaps between fields create uncertainty in patent boundaries, leading to potential conflicts over IP rights.

Moreover, the lack of established legal precedents in quantum computing complicates the resolution of disputes. Companies pioneering in this domain, such as Google and Intel, are actively filing patents related to quantum hardware. As the technology matures, navigating the patent landscape may become more manageable, but challenges will persist.

(c) Artificial Intelligence (AI)

AI is transforming semiconductor design by automating complex tasks such as chip layout optimization and testing. Machine learning and deep learning algorithms are now integral to enhancing manufacturing processes and improving overall efficiency.

As AI-driven designs become more prevalent, the need to protect the associated IP grows. Companies can file patents for proprietary AI algorithms that automate chip design aspects, as well as for specific models and frameworks that optimize chip performance.

However, the challenge lies in the fact that AI algorithms and models are often considered abstract ideas under many patent systems. Ensuring that these innovations meet patentability requirements, namely, novelty, non-obviousness, and industrial applicability, can be a complex endeavour.

While international treaties provide a framework for IP protection, the semiconductor industry must navigate a rapidly evolving landscape of emerging technologies. The interplay between innovation and IP challenges will continue to shape the future of semiconductor development, requiring companies to adopt proactive strategies to safeguard their intellectual assets.

Strategies to Address Global Challenges in Semiconductor Innovation

As the semiconductor industry navigates a complex landscape filled with challenges, companies must adopt strategic measures to protect their IP and sustain innovation. From managing robust IP portfolios to fostering international collaboration, several strategies can help tackle the pressing issues facing the sector.

Robust IP Portfolio Management

First and foremost, semiconductor companies need to focus on building and maintaining a robust IP portfolio. Regular IP audits are essential for identifying strengths and gaps within the portfolio, allowing firms to patent their innovations early in key global markets. By prioritizing proactive patent filing, companies can ensure comprehensive protection for their products and technologies.

Collaboration and Joint Ventures

Collaboration and joint ventures present another vital strategy for addressing global challenges. These partnerships can facilitate shared resources and expertise while driving innovation. However, it is crucial that companies also pay close attention to trade secret protection, which often gets overlooked. In India, for instance, trade secrets remain underutilized but can be an effective tool in safeguarding proprietary information.

Strengthening Cybersecurity Measures

In an age where cyber threats are rampant, semiconductor firms must enhance their digital defences to guard against IP theft. Protecting proprietary designs and technologies is critical, and companies should implement robust cybersecurity protocols. This includes employee training, adherence to strict confidentiality agreements, and limiting access to sensitive information.

Opportunities in India

India presents a burgeoning landscape for semiconductor IP protection, bolstered by various government initiatives and policies aimed at enhancing research and development in the sector. Companies can capitalize on these opportunities to strengthen their IP strategies.

IP is fundamental to safeguarding innovation within the semiconductor industry. While India offers a growing environment for semiconductor IP protection, the global challenges require thoughtful strategies. Companies must prioritize strategic IP management, engage in international collaboration, and comply with global treaties to secure long-term success. As the semiconductor industry continues to evolve, robust IP strategies will be essential for staying ahead in this dynamic landscape.

Summary and Key Policy Recommendations

India's ambitions to emerge as a semiconductor powerhouse are hindered by a critical imbalance between global R&D service delivery and domestic IP creation. While MNCs leverage India's skilled labor for innovation, they rarely file patents in India due to centralized IP strategies, limited IP monetization opportunities, and weak enforcement mechanisms. At the same time, Indian semiconductor startups face significant hurdles in accessing capital, navigating complex IP regimes, and protecting their trade secrets. The absence of a standalone trade secrets law and the slow, unpredictable nature of IP litigation further aggravate these issues. Drawing on case studies and policy insights, this paper highlights the urgent need for institutional reforms that strengthen India's IP regime while enabling a more innovation-friendly environment for domestic players. Table 3 below summarizes key challenges followed by policy recommendations.

Table 3: Challenges for Semiconductor IP Creation

Challenges	Startups in India	MNCs in India
IP Creation & Ownership	Lack of awareness and resources for patent filing; limited IP strategy	Centralized R&D abroad - IP filed in headquarters countries (e.g., US, Taiwan); India used mostly for services/R&D
IP Enforcement	Costly and slow legal recourse; low discouragement for infringement	Weak judiciary discourages India-based filings
Ease of Doing IP Business	High costs and delays in Indian	Prefer to patent only in

	IP system; complex procedures	commercially relevant markets; poor patent quality enforcement
Patent Filing	Expensive and complex process; low ROI for early-stage firms	Prefer US/EU/China filings where markets and legal protections are stronger
Trade Secret Protection	Informal mechanisms; weak enforcement of NDAs; HR mobility risks	Concern over lack of enforceability in Indian courts; hesitancy to share critical IP locally
Collaboration Risk	Risk of IP leakage when working with academia or public labs	Internal policies restrict external core R&D sharing in India due to enforcement concerns
Access to Funding for Innovation	Limited VC/angel funding for deeptech hardware startups	Prefer investing in proven markets with IP enforcement (e.g., US, EU)
R&D Ecosystem	Nascent industry-academia collaboration; low public R&D grants for semicon startups	Lack of incentives to co-create IP with Indian units
Skilled Manpower for IP Development	Shortage of specialised design engineers and IP management experts	Trained workforce often moves abroad or works in captive design centres

To translate India's semiconductor aspirations into sustainable innovation outcomes, policy interventions must directly address the structural IP barriers faced by both domestic startups and global firms. The following targeted recommendations aim to strengthen IP creation, protection, and enforcement across the ecosystem.

Indian Government

- **Endorse a Standalone Trade Secrets Law**: Implement a dedicated law aligned with global standards (e.g., US DTSA) to enable civil and criminal remedies for trade secret theft.
- **Create Fast-Track IP Courts**: Establish specialized benches within commercial courts to hear IP cases, with a 12-month resolution target.
- **Patent Subsidy for Startups**: Expand patent cost reimbursement and fast-track examination services under India Semiconductor Mission specifically for chip/IP startups.
- **Mandate IP Disclosure for PLI Beneficiaries**: Make patent/IP generation a performance metric for companies availing of the PLI scheme.

US Government

- **Encourage Local IP Filings**: Encourage US semiconductor firms to co-own IP developed in India and file locally. Tie future US investment guarantees and export incentives to the condition that US MNCs file India-based R&D patents locally.
- **Support Cross-Border IP Safeguards**: Through the US-India iCET, facilitate bilateral protocols for protecting jointly developed IP. Assist India in building IP enforcement capacity through training and judicial exchanges.
- **Fund Indo-US Startup IP Accelerator**: Establish a public-private program with USPTO, US government, and Indian partners to help early-stage semiconductor startups navigate IP landscapes.

Industry (Both Indian & Global)

- **Internal Trade Secret Policies:** Adopt stronger internal protocols for confidential information, especially for Indian R&D centres with high attrition. Develop standard

NDA templates and internal audit systems for IP/data handling.
- **IP Licensing Consortium:** Establish a neutral platform to pool, license, and monetize semiconductor IP developed in India, improving ROI for startups.
- **Industry-Led Negotiation Mechanism:** Create an IP negotiation forum with retired judges/IP experts to provide time-bound resolution outside courts.
- **Local Filling Mechanism:** MNCs should be encouraged (via policy nudges) to file Indian patents when IP is developed domestically.

Conclusion

India's strategic entry into the global semiconductor value chain, while impressive in scale, remains constrained by limited domestic IP generation and inadequate legal and institutional support for protecting and commercializing innovation. The dominance of MNC-led R&D operations has resulted in India becoming a hub for engineering services rather than a source of high-value intellectual assets. This paper has highlighted the structural challenges faced by both Indian startups and global firms, particularly the absence of a robust IP ecosystem, weak trade secret protection, and minimal incentives for local patenting.

While technology commercialization and transfer are crucial elements of any innovation ecosystem, their relevance becomes more pronounced when a significant body of domestic IP remains unutilized or underleveraged, a condition not yet fully realized in the Indian semiconductor landscape. Therefore, although commercialization is acknowledged as a vital future step, it is intentionally not covered in-depth here to maintain focus on the foundational challenge of limited domestic IP creation. This presents a valuable opportunity for future research, particularly once India's indigenous innovation base continues to strengthen.

Strengthening India's semiconductor IP framework through targeted policy interventions, institutional reforms, and industry-government-academia collaboration will be critical to translating R&D capabilities into an enduring competitive advantage. Only then can India secure not just participation in but ownership over its role in the global semiconductor future.

Glossary of Terms

Term	Definition
3D (3-Dimensional)	Refers to objects or representations that have depth, height, and width, allowing them to be viewed from multiple angles for a realistic perception of space.
CPU (Central Processing Unit)	The core computing unit in an SoC is responsible for executing instructions and performing basic operations.
Cyber Attack	A deliberate attempt by individuals or organizations to breach the information systems of another individual or organization with malicious intent.
Cybersecurity	The practice of protecting computer systems, networks, programs, and data from digital attacks, unauthorized access, damage, or theft.
DLI (Designed Linked Scheme)	A government initiative launched in December 2021 under the India Semiconductor Mission (ISM) to support domestic companies, startups, and MSMEs in semiconductor design. It aims to nurture companies and enable them to achieve market-ready IPs.
EDA Tools (Electronic Design Automation)	Software tools used to design, simulate, and verify SoCs and other integrated circuits.
Fabless Firm	A semiconductor company that designs chips but outsources manufacturing to foundries (fabs).
Fabrication	The process of manufacturing an SoC

	on a semiconductor wafer using photolithography and other techniques.
Firmware	Low-level software that controls the hardware of an SoC, typically stored in non-volatile memory.
Foundry	A specialized manufacturing facility that fabricates SoCs and other chips based on designs provided by semiconductor companies.
GCC (Global Capability Centre, also known as Global In-house Centre or GIC)	These centres are broader and more evolved. They include functions like R&D, data analytics, business strategy, finance, HR, marketing, and more, all aligned to the global business.
GDC (Global Delivery Centre)	These centres primarily support global clients by delivering IT services, software development, customer support, and business processes.
GEC (Global Engineering Centre)	These centres focus on R&D, product engineering, and core technology innovation.
GPU (Graphics Processing Unit)	A specialized processor within the SoC designed to accelerate graphics rendering and parallel computing tasks.
iCET (Initiative on Critical and Emerging Technologies)	A US-India bilateral framework to enhance cooperation in technologies like semiconductors, AI, and quantum computing.
ICs (Integrated Circuits)	ICs are devices with a single surface on which various components like transistors, resistors, capacitors, and diodes are mounted.
3D IC (3D Integrated Circuit)	A type of semiconductor device where multiple

	layers of circuits are stacked vertically, improving performance and reducing space compared to traditional 2D chips.
IPR (Intellectual Property Rights)	The legal rights granted to inventors and creators to protect their innovations and creative work from unauthorized use.
India Semiconductor Mission	A flagship Indian government program launched in 2021 to build a domestic semiconductor and display manufacturing ecosystem.
NDA (Non-Disclosure Agreement)	A legally binding contract between two or more parties that outlines confidential information to be shared and restricts its disclosure to third parties.
Patent Thickets	A dense web of overlapping patents that a company must navigate to develop or commercialize new technology. This often occurs in high-tech sectors like semiconductors, telecom, and biotechnology.
PLI (Production Linked Incentive) Scheme	The Indian government initiative offering financial incentives to companies for increasing domestic production and innovation.
SoC (System-on-Chip)	An integrated circuit that combines all components of a computer or electronic system, such as CPU, GPU, memory, input/output ports, and

	other peripherals, onto a single chip.
SEP (Standard Essential Patents)	A patent that protects technology deemed essential to a technical standard. It must be used to comply with that standard, and no alternative is available without infringing the patent.
US DTSA (Defend Trade Secrets Act)	A US federal law enacted in 2016 that provides a private civil cause of action for trade secret misappropriation under federal jurisdiction. It allows trade secret owners to sue in federal court.
USPTO (United States Patent and Trademark Office)	The US agency responsible for examining and granting patents and registering trademarks.
WIPO (World Intellectual Property Organization)	A United Nations agency that develops global IP services, policy, and standards to protect intellectual property worldwide.

ABOUT THE AUTHOR

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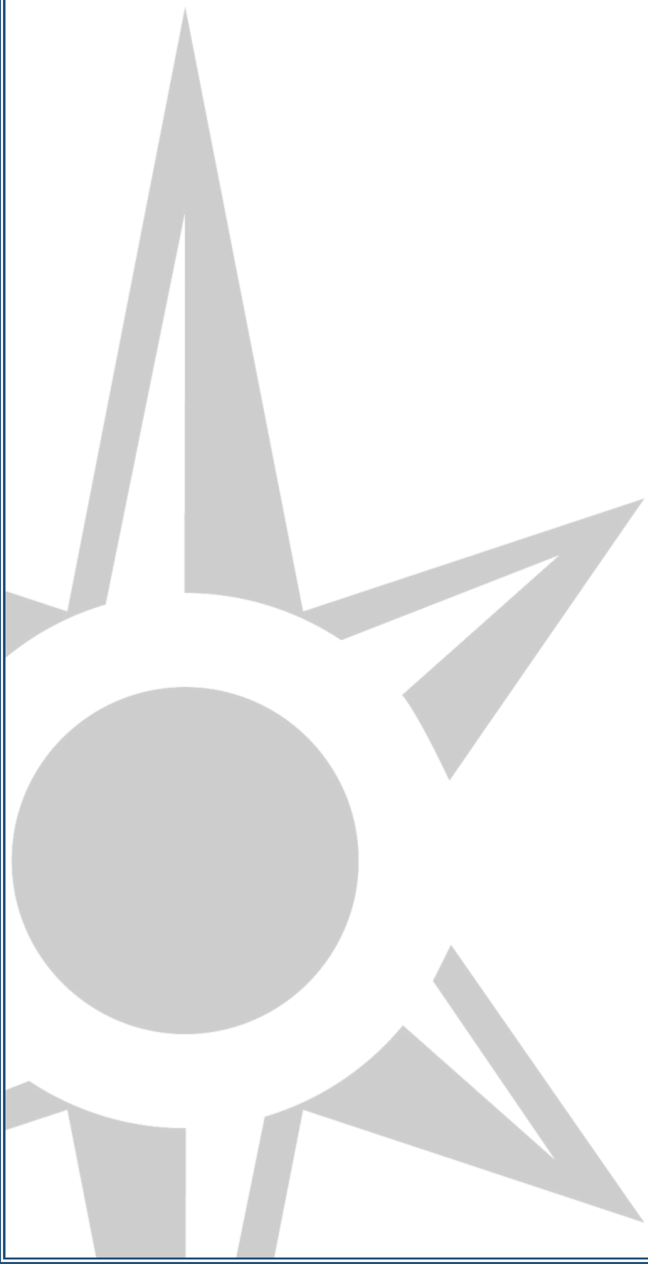
PACIFIC FORUM INTERNATIONAL

Policy Analysis and Framework Reform for Semiconductor Industry Competitiveness: A Comparative Study of India, China, the US, South Korea, and Taiwan

By
Harish Chowdhary



Executive Summary

Harish Chowdhary

India stands at a crossroads in its quest to become a significant player in the global semiconductor industry. This policy-focused analysis finds that while India has made strides – doubling patent filings in five years and launching a ₹76,000 crore ($10B) incentive program – it still lags in key competitiveness metrics compared to the U.S., China, South Korea, and Taiwan. The United States and its allies have leveraged robust IP protection, aggressive R&D investment, and tightly controlled export regimes to cultivate thriving semiconductor ecosystems. By contrast, India's IP enforcement is relatively weak and R&D spending is only ~0.7 % of GDP, far below peers. This gap presents both a challenge and an opportunity. Immediate policy reforms and strategic collaborations with the U.S. can position India as a reliable semiconductor alternative to China, especially amid global supply-chain reorganization and U.S.–China decoupling in advanced tech.

Key Findings:

i. Export Control Alignment**:** The U.S. maintains rigorous export controls (Export Administration Regulations, EAR) to restrict sensitive chip technologies from adversaries, complemented by allies like South Korea's Foreign Trade Act and Taiwan's National Security-focused export laws. China has responded with its own export restrictions (e.g. rare-earth metals). India's export-control list (SCOMET) is aligned with global regimes (Wassenaar, MTCR) but lacks scope and enforcement depth for cutting-edge semiconductors. Better alignment of India's controls with U.S. norms – through initiatives like the Quad and the Indo-Pacific Economic Framework – will ease tech transfers and build U.S. trust.

ii. Intellectual Property Competitiveness**:** Strong IP protection underpins innovation. India ranks only 42nd of 55 countries in the International IP Index (U.S. Chamber). Patent grants in India can take ~5 years on average – nearly 3 times longer than in China or the U.S. – undermining first-mover advantages. In contrast, Taiwan strictly enforces IP (a key to TSMC's success), and South Korea and the U.S. have efficient patent regimes and specialized IP courts. Without rapid IP reforms, India risks being the weak link in global semiconductor IP networks.

iii. Investment and R&D Gaps**:** India's R&D expenditure (~0.7 % of GDP) is dwarfed by South Korea (~4.8 %), the U.S. (~3 %), and Israel (>5 %). This investment gap has left India reliant on foreign technology. Meanwhile, China's state-backed "Big Fund" poured over $50 billion into domestic fabs (with a new $41B fund in 2023). South Korea and Taiwan each invest heavily in semiconductor R&D through tax credits (Taiwan offers 25 % R&D tax credit) and cluster development. Without raising R&D spending to at least 2 % of GDP, India will struggle to innovate in sub-10 nm process technologies and beyond.

iv. Case Studies – Successes and Failures: Industrial-policy outcomes vary widely. The U.S. CHIPS Act (2022) is channeling $52.7 B into domestic chip production and research, incentivizing dozens of new fab projects. This contrasts with the Solyndra episode, where a $535 M U.S. government loan to a solar startup failed disastrously – underscoring that throwing money at a sector without accountability can backfire. In China, SMIC has grown into a viable foundry (with extensive state aid), whereas the ambitious Wuhan Hongxin (HSMC) fab project collapsed after burning through $19 B, becoming a "zombie fab". Taiwan's TSMC illustrates the payoff of sustained strategy: early government investment, relentless focus on manufacturing excellence, and strict IP discipline made TSMC the world's leading chipmaker, producing 90 % of advanced (≤5 nm) chips globally. South Korea's history shows that success can breed complacency – its memory giants were fined hundreds of millions for cartel price-fixing in the 2000s – so pro-competition regulation remains vital.

Introduction: Semiconductor Industry in India

India's semiconductor industry holds significant potential to become a global player, contingent on strategic policy reforms and investments. A pivotal factor in India's advancement in this sector is the improvement of its business environment, which currently presents barriers such as complex customs, tariffs, taxation, and infrastructure issue[1]. The necessity for a conducive regulatory environment is further emphasized by the surge in global semiconductor value chains, where India could play a more critical role by avoiding unpredictable measures and upholding favorable investment policies in the future[2].

The technology export control measures implemented by the United States, particularly during the Trump administration and continued under Biden, have led to increased economic decoupling with China, underscoring the importance of self-sufficiency in the semiconductor industry. This scenario presents an opportunity for India to increase its semiconductor manufacturing capabilities[3].

India's readiness to expand its semiconductor facilities is supported by a report commissioned by the US and Indian governments that identifies industry opportunities and strategic development paths for complementary semiconductor ecosystems[4]. Despite currently comprising only 3% of the global market, India's burgeoning digital economy and substantial population present a ripe opportunity for growth in semiconductor demand across various sectors, such as electronics, automotive, telecommunications, and artificial intelligence (AI)[5]. The Indian government's vision of Aatmanirbhar Bharat (self-reliant India) aims to position India as a global hub for electronic system design and manufacturing (ESDM). To realize this vision, the government approved a comprehensive program with an outlay of 76,000 crores (over $10 billion) to develop a semiconductor and display manufacturing ecosystem in India. This program includes schemes offering fiscal support for 50% of the project costs for setting up semiconductor and display fabs, thus incentivizing investments in these fields[6]. In effect, India has joined the global race to subsidize and support domestic chip production on a scale comparable to major economies[7].

India's $10 Billion Semiconductor Program 2023

India's $10 billion semiconductor program, officially known as the "Programme for Development of Semiconductors and Display Manufacturing Ecosystem in India," is an ambitious initiative aimed at positioning the country as a significant player in the global semiconductor landscape. Approved by the Union Cabinet and chaired by Prime Minister Narendra Modi, the program was notified on Dec. 21, 2021, with an outlay of 76,000 crores (over $10 billion)[8] [9].

The program aims to build a robust semiconductor and display manufacturing ecosystem in India. It includes several measures to attract investment and encourage manufacturing in these critical sectors. A key component of the initiative is the establishment of three semiconductor units, including a semiconductor fabrication facility (fab) with 50,000 wafers per month (wfsm) capacity, set up by Tata Electronics Private Limited (TEPL) in partnership

[1] Stephen Ezell, "India Semiconductor Readiness Assessment Report: Initial Findings," Information Technology & Innovation Foundation, June 2023, https://itif.org/publications/2023/06/22/india-semiconductor-readiness-assessment/.

[2] Konark Bhandari, "The Geopolitics of the Semiconductor Industry and India's Place in It," Carnegie Endowment for International Peace, June 2023, https://carnegieendowment.org/research/2023/06/the-geopolitics-of-the-semiconductor-industry-and-indias-place-in-it?lang=en.

[3] Stephen Ezell, "Assessing India's Readiness to Assume a Greater Role in Global Semiconductor Value Chains," Information Technology & Innovation Foundation, February 2024, https://itif.org/publications/2024/02/14/india-semiconductor-readiness/.

[4] Information Technology & Innovation Stephen Ezell, "India Could Add Five or More Semiconductor Facilities in Five Years If It Makes the Right Policy Moves, New ITIF Report Concludes," Information Technology & Innovation Foundation, February 2024, https://itif.org/publications/2024/02/14/india-could-add-more-semiconductor-facilities/.

[5] India Brand Equity Foundation, "India's Semiconductor Push: Building a Robust Chip Manufacturing Ecosystem," India Brand Equity Foundation, May 2024, https://www.ibef.org/research/case-study/india-s-semiconductor-push-building-a-robust-chip-manufacturing-ecosystem.

[6] Ministry of Electronics & IT, "Semiconductors and Display Fab Ecosystem," Ministry of Electronics & IT, Government of India, December 2023, https://www.meity.gov.in/esdm/Semiconductors-and-Display-Fab-Ecosystem.

[7] I. N. Bureau, "Cabinet Okays Rs 76,000 Crore Package to Boost Electronic Chips Manufacturing in India," Indian Narrative, December 2021, https://www.indianarrative.com/india-news/cabinet-okays-rs-76000-crore-package-to-boost-electronic-chips-manufacturing-in-india-29186.html.

[8] pmindia.gov.in, "Giant Leap For India Semiconductor Mission Cabinet Approves Three More Semiconductor Units," www.pmindia.gov.in, January 2024, https://www.pmindia.gov.in/en/news_updates/giant-leap-for-india-semiconductor-mission-cabinet-approves-three-more-semiconductor-units/.

[9] Diksha Munjal, "Modified Incentive Scheme For Semiconductor Chip Making," www.drishtiias.com, January 2024, https://www.drishtiias.com/daily-updates/daily-news-analysis/modified-incentive-scheme-for-semiconductor-chip-making.

with Power Chip Semiconductor Manufacturing Corporation (PSMC), Taiwan[10].

In addition, the government has taken steps to make the initiative more attractive to investors by modifying the program to provide fiscal support covering 50% of the project cost for all technology nodes under the scheme of setting up semiconductors and display fabs[11]. To foster global collaboration and draw in foreign manufacturers, Invest India, the National Investment Promotion and Facilitation Agency, the India Semiconductor Mission (ISM), and Counterpoint Research have organized webinars to discuss opportunities for establishing semiconductor manufacturing bases in India. The topics covered include market sectors, government programs and incentives, talent availability, and infrastructural capabilities[12]. The program also includes a modified incentive scheme for semiconductor chip making, which was announced to provide additional incentives and support. This scheme falls under the broader Production-Linked Incentive (PLI) scheme launched by India in 2021 to boost semiconductor and display manufacturing[13]. Furthermore, in response to the unsuccessful initial round of applications 2022, the ISM reopened applications starting June 1, 2023, to invite both new and existing applicants to submit their proposals[14] [15].

Key components of this program include

*Fiscal Incentives for Fabs***:** The government offers to cover 50 % of the project cost for setting up semiconductor fabs and display fabs in India. Initially, incentives were tiered by technology node, but recognizing limited takers, the policy was later modified to a flat 50 % subsidy for all node sizes, including mature nodes (which are easier for new entrants). This generous subsidy mirrors global trends for instance, the U.S. CHIPS Act provides grants covering 20–40 % of fab costs along with tax credits.

*Anchor Projects with Foreign Collaboration***:** A marquee project under the program is a semiconductor fab by Tata Electronics in partnership with Taiwan's PSMC, planned with 50,000 wafers per month capacity. Bringing a Taiwanese foundry partner is a strategic move, tapping into Taiwan's process expertise and sending a positive signal to other global investors.
*Display Fabs and Packaging Units***:** The program isn't limited to silicon IC fabs; it also incentivizes display panel fabs (for AMOLED, LCD) and semiconductor ATMP/OSAT (assembly, testing, and packaging) units to create a holistic ecosystem.

*Project Re-bidding and Flexibility***:** After an initial round in 2022 that saw fewer qualified applicants (only a couple of proposals materialized, such as ISMC's plan for a GaN fab and Vedanta-Foxconn's fab proposal), the India Semiconductor Mission reopened applications in June 2023 to invite more bids. This indicates flexibility in approach – learning from the first attempt, the government adjusted criteria (e.g., allowing older-node fabs which might be more feasible) and extended deadlines.

*Investment Promotion***:** Agencies like Invest India and the India Semiconductor Mission have been actively conducting webinars and roadshows with industry (including events with global firms and Counterpoint Research) to showcase India's market demand (huge electronics consumption), talent availability, and infrastructure plans. Such outreach aims to overcome India's credibility gap by directly engaging with semiconductor executives.

Through these measures, India is actively courting foreign direct investment (FDI) in the semiconductor sector. The response so far includes the announced Vedanta–Foxconn joint venture to set up a fab in Gujarat (though technology partner and node are still uncertain) and interest from global chipmakers in packaging units. The program, however, also faces challenges: high upfront capital needs, India's limited existing supplier base, and competition from other countries' incentives. The government's

[10] pmindia.gov.in, "Giant Leap For India Semiconductor Mission Cabinet Approves Three More Semiconductor Units."
[11] Ministry of Electronics & IT, "Semiconductors and Display Fab Ecosystem," Ministry of Electronics & IT, Government of India, December 2023, https://www.meity.gov.in/esdm/Semiconductors-and-Display-Fab-Ecosystem.
[12] Rohan Thomas Abraham and Nupur Yadav, "India Semiconductor Manufacturing Trajectory," ed. Team Counterpoint, www.counterpointresearch.com, January 2024, https://www.counterpointresearch.com/insights/india-semiconductor-manufacturing-trajectory/.
[13] Diksha Munjal, "Modified Incentive Scheme For Semiconductor Chip Making," www.drishtiias.com, January 2024, https://www.drishtiias.com/daily-updates/daily-news-analysis/modified-incentive-scheme-for-semiconductor-chip-making.
[14] Gulveen Aulakh, "India Reopens Bids For 10 Bn Chip Plan," www.livemint.com, January 2024, https://www.livemint.com/economy/india-reopens-bids-for-10-bn-chip-plan-11685557153324.html.
[15] Dr Saroj Bishoyi, "India's Semiconductor Strategy," www.vifindia.org, January 2024, https://www.vifindia.org/article/2023/july/07/India-s-Semiconductor-Strategy.

decision to underwrite half the cost is a bold step that indicates its commitment, but it must ensure effective execution, selecting proposals with credible technology backing.

Successful implementation of the $10B program could significantly boost India's share in global semiconductor manufacturing. Even achieving 5–10 % of the global fab capacity in the next decade would be transformative for India's trade balance and tech self-reliance. The program also signals to allies (U.S., Japan, Taiwan, and EU) that India is serious about being part of the "friend-shoring" of chip supply chains, which can encourage more collaborative projects and perhaps financial support from those governments. Through these comprehensive measures, India is actively working to enhance its semiconductor manufacturing capabilities and meet the rising global demand for semiconductors across various fields such as electronics, the automotive industry, telecommunications, and artificial intelligence.

India's Workforce Development

To address the skill gaps and workforce development challenges in India's semiconductor industry, the government launched several strategic initiatives. One of the key efforts is the establishment of the India Semiconductor Workforce Development Program (ISWDP), a comprehensive initiative designed to bridge the technology and device design skill gap in the expanding semiconductor sector. This program offers a meticulously designed course that covers foundational aspects and delves deeply into device and technology development skills. It also provides a hands-on approach through the microelectronics lab experience, allowing participants to work on state-of-the-art research and development tools used by the semiconductor industry[16].

In addition, the Indian government has formed crucial partnerships with international and national academic institutions, and industry leaders. For instance, Purdue University has become a flagship academic partner, collaborating with the India Semiconductor Mission on workforce development, joint research, and innovation in semiconductors and microelectronic[17]. Furthermore, the government has announced design and co-development pacts at events such as Semicon India 2022, aiming to foster collaboration between Indian research talent and industry experts from the US Semiconductor Research Corporation[18]

To bolster the ecosystem further, the Ministry of Electronics and IT (MeitY) has identified and supported new startups such as Aheesa Digital Innovations and Calligo Technologies under the Semicon India Future DESIGN DLI Scheme. Collaborations have also been established with institutions such as the IISc Bengaluru's Center for Nano Science and Engineering (CeNSE) and US based Lam Research India to develop semiconductor fabrication technology courses for Indian universities[19].

Moreover, the India Semiconductor R&D Committee submitted a report recommending the modernization of the Semiconductor Laboratory (SCL) and establishment of the India Semiconductor Research Centre (ISRC). This center is envisioned to become a core institution for advancing India's capabilities in semiconductors, comparable to global pioneers, such as Belgium's IMEC and MIT's micro-electronic labs[20]. All these initiatives represent a multifaceted approach to skill development – from top-tier research to vocational training. The scale is noteworthy: tens of thousands of engineers are to be trained or up skilled, aligning with industry needs. This is crucial because, while India produces a large number of engineering graduates annually, specific semiconductor skills (VLSI design, lithography techniques, packaging, etc.) were not widely taught until recently. By updating curriculum and providing incentives for students to enter this field (e.g., scholarships for semiconductor-related post-graduate studies), the government is trying to ensure

[16] Indian Institute of Science, "India Semiconductor Workforce Development Program," Department of Electronic Systems Engineering, Indian Institute of Science, January 2024, https://iisc-iswdp.org/.

[17] Brian Huchel, "Purdue Establishes Milestone Semiconductor Alliance With India Agreement Provides Foundation To Advance Workforce Development Joint Research And Innovation And Global Industry Collaborations," www.purdue.edu, January 2024, https://www.purdue.edu/newsroom/2023/Q2/purdue-establishes-milestone-semiconductor-alliance-with-india-agreement-provides-foundation-to-advance-workforce-development-joint-research-and-innovation-and-global-industry-collaborations/.

[18] PIB Delhi, "As Major Part of Catalyzing India's Semiconductor Ecosystem, Design and Co-Development Pacts Were Announced at SemiconIndia 2022," pib.gov.in, January 2024, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1821809.

[19] PIB Delhi, "Future Is Bright and the Future Is India in the Global Semiconductor Ecosystem: MoS Rajeev Chandrasekar," www.pib.gov.in, January 2024, https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1943942.

[20] PIB Delhi, "India Semiconductor R&D Committee Submits Report on India Semiconductor Research Centre (ISRC)," www.pib.gov.in, January 2024, https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1969400.

that lack of talent will not be a bottleneck when fabs and design houses expand in India. One tangible outcome is that global companies are already leveraging India's talent for design work. Qualcomm, Intel, NVIDIA, and others have major R&D centers in India employing thousands. Qualcomm's India centers, for instance, have been prolific in design contributions reportedly a significant portion of Qualcomm's patents globally list Indian inventors or were developed in India's design center. This demonstrates the existing strength of India's chip design human capital. The workforce initiatives aim to deepen and widen this talent pool, so that down the line Indian engineers cannot just staff MNC operations but drive homegrown firms and fabs.

For India's policymakers, the message is clear: a strong workforce is the backbone of any semiconductor strategy. Countries like Taiwan and South Korea invested in education decades ago (Taiwan sent students abroad in the 1970s, who later led its semiconductor revolution; South Korea built KAIST and other institutes focusing on semiconductors). India is now earnestly following suit, working to compress into a few years the kind of capacity-building that took others much longer. If sustained, these efforts will produce a generation of engineers capable of running advanced fabs, designing 5G/6G chipsets, and innovating in domains like quantum computing – a critical asset for India's tech future.

These initiatives collectively addressing skill gaps and ensuring the successful implementation of India's ambitious $10 billion semiconductor programme.

Semiconductor Industry Framework Reform in China

China's semiconductor industry has undergone a significant transformation over the past decade driven by rapid technological advancements and substantial increases in production capacity. The country's semiconductor production capacity is set to grow by 40% over the next five years, with the total silicon capacity projected to increase from 310 million square inches (msi) in 2018 to 875 msi in 2029 [21]. This growth is fueled by extensive investments in semiconductor fabrication facilities (fabs) and increased spending on wafer fabrication equipment, which has risen from $11 billion in 2018 to nearly $30 billion by 2023.

In 2024 alone, China is expected to lead the global expansion of semiconductor production, with 18 new fabs set to commence operations. This expansion will contribute to a 6.4% increase in global wafer processing capacity, reaching over 30 million wafer starts per month (WPM)[22]. The country focuses on developing leading-edge logic foundries to cater to the growing demand for AI and high-performance computing (HPC) applications[23].

Government policies have played a crucial role in this development, offering substantial funding and support to the domestic semiconductor industry. Strategic investments have led to a significant increase in the number of operational fabs in China. Recent reports indicate that China has 44 wafer fabs, including 25 12-inch facilities and 22 more fabs under construction, with plans to complete 10 additional wafer fabs by the end of 2024[24]. These investments aim to reduce China's reliance on semiconductor imports, which accounted for 83% of total chip sales in 2020.

China's ambition to achieve self-sufficiency in semiconductors is further highlighted by the fact that it remains the world's largest consumer of semiconductors, consuming over half of global chip sale[25]. The strategic importance of the semiconductor industry in the global high-tech arena has catalyzed China's efforts to transform its domestic landscape, positioning it as a leading player in the global semiconductor market.

[21] TechInsights, "Chinas Semiconductor Production Capacity Grow 40 Five Years," www.techinsights.com, January 2024, https://www.techinsights.com/blog/chinas-semiconductor-production-capacity-grow-40-five-years.

[22] Anton Shilov, "China To Lead Semiconductor Industry Expansion With 18 New Fabs In 2024 Global Chipmaking Capacity To Reach Record Heights," www.tomshardware.com, January 2024, https://www.tomshardware.com/tech-industry/semiconductors/china-to-lead-semiconductor-industry-expansion-with-18-new-fabs-in-2024-global-chipmaking-capacity-to-reach-record-heights.

[23] Dan Robinson, "China Semiconductor Recovery," www.theregister.com, January 2024, https://www.theregister.com/2024/01/04/china_semiconductor_recovery/.

[24] Aijiwei, "News Chinas Chip Production Capacity Reportedly Set To Grow 60 In 3 Years Doubling In 5 Years," www.trendforce.com, January 2024, https://www.trendforce.com/news/2024/01/15/news-chinas-chip-production-capacity-reportedly-set-to-grow-60-in-3-years-doubling-in-5-years/.

[25] Acclime China, "China's Semiconductor Industry: The Path to Self-Sufficiency," china.acclime.com, January 2024, https://china.acclime.com/news-insights/semiconductor-industry/.

China's approach to semiconductor industry framework reform has gained international attention, with significant policy shifts occurring in 2022. The most notable of these was the US government's enactment of new export control regulations on October 7, 2022, which aimed to curb China's advancements in AI and semiconductor technology. This date is seen as pivotal in the broader context of US-China relations, marking the inception of a new era characterized by intense technological competition[26].

US Secretary of State Antony Blinken underscored the importance of this policy shift, stating that the world had reached an "inflection point." According to Blinken, the post-Cold War era ended, ushering in a period in which the competition to shape the future of global technology was at its zenith. Technology and, by extension, semiconductor prowess are at the core of this geopolitical struggle.

In response, China has been accelerating strategies to enhance its semiconductor industry. These strategies include substantial investments in research and development (R&D) and the formation of alliances and partnerships to mitigate the impact of foreign export controls. Beijing launched the National Integrated Circuit Investment Fund (the "Big Fund") in 2014, raising 138.7 billion RMB, followed by a second round of 200 billion RMB in 2019. Over the years, the Big Fund has injected capital into China's leading chip firms. China's semiconductor industry transformation over the past decade is evident in its capacity expansion and growing technical know-how. By late 2023, China had 44 operational wafer fabs (25 of them 12-inch facilities) with 22 more under construction. It planned to complete 10 additional fabs by end of 2024. These investments aim to curb China's heavy import dependence. China consumes more than half of the world's chips by value, yet produces only around 15% domestically (a figure that includes foreign-owned fabs in China). The nation's ambition is to raise self-reliance to 70% by 2025 in key chip categories an ambitious target.

Semiconductor Manufacturing International Corp (SMIC), Hua Hong Semiconductor, Yangtze Memory Technologies (YMTC), and numerous startups. Despite those investments, China's chip industry still struggles at the leading edge (7nm and below), prompting a planned third Big Fund of 300 billion RMB (~$41 billion) focusing on semiconductor equipment. This proactive stance aims to secure China's position in the global semiconductor market and reduce its dependency on foreign technology.

One area where China made notable progress is in packaging and testing (OSAT) and memory. ChangXin Memory (CXMT) shipped domestically made DRAM (albeit one generation behind leaders) and YMTC was, before sanctions, approaching competitiveness in NAND Flash. These successes show that given time and support, Chinese firms can narrow technology gaps in certain segments. However, U.S. and allied export controls – especially on EUV lithography and EDA software have effectively stalled China's advancement at the bleeding edge.

China's industrial reforms also extended to education and talent recruitment. Over 100 new-semiconductor faculties or departments have been established in Chinese universities in the past five years. The government incentivized overseas Chinese engineers to return (through programs like the "Thousand Talents Plan"), luring experts from TSMC, Samsung, and others with high salaries – though this sometimes sparked IP theft controversies. The net effect is a growing domestic talent pool which, combined with enormous market scale, gives China an advantage in the long run if external barriers soften.

Critically, China's export control regime internally has also tightened – not just in retaliation to the U.S., but to prevent critical tech outflow. In late 2023, China expanded its "Catalogue of Technologies Prohibited and Restricted from Export," adding advanced chip manufacturing techniques to the list. It also enforced a law requiring Chinese companies to get permission before sharing certain chip designs or source code with foreign entities. This paradoxical stance China as both sanctioned and sanctioner – makes it a unique case in the global landscape.

From an Indian perspective, China's trajectory underscores that building a semiconductor industry is a marathon, not a sprint. The Chinese ecosystem benefited from massive government patience and pockets, yet it still hits walls where international cooperation is denied. India, might do well to pursue a more open, collaborative approach (leveraging

[26] Gregory C. Allen, "China's New Strategy for Waging the Microchip Tech War," Center for Strategic and International Studies, May 2023, https://www.csis.org/analysis/chinas-new-strategy-waging-microchip-tech-war.

partnerships with the U.S., Japan, etc., as discussed) instead of solely relying on import substitution. Additionally, China's experience shows the importance of focusing on niches of excellence: memory chips became a beachhead for China (for which the know-how was slightly more attainable), whereas logic foundries remain elusive. India similarly might target specific niches (like compound semiconductors, or certain automotive chips) where it can realistically excel, rather than trying to do everything at once.

China's Response to US Export Controls

In response to US export controls that significantly impact China's semiconductor industry, Beijing has taken several measures to counter these restrictions. One of the first significant steps was initiating a dispute against the US at the World Trade Organization (WTO), accusing the US of abusing export control measures and obstructing normal international chip trade [27] [28]. This legal action underscores China's intent to challenge US policies on a global platform.

In addition to the WTO dispute, China implemented strategic countermeasures to target key raw materials used in semiconductor manufacturing. The Chinese Ministry of Commerce announced a new export license system for gallium (Ga) and germanium (Ge), two critical elements used in the manufacturing of computer chips, fiber optics, solar cells, and other tech devices[29]. This move is widely seen as one of China's most significant retaliations against the US semiconductor technology blockade, aiming to disrupt supply chains critical to Western technology industries. By August 2023, exporters of these materials from China were required to obtain licenses, introducing uncertainty and potential delays to the global supply chain. China has also openly criticized the US for its restrictive measures. The Chinese foreign ministry has labeled US export controls as violations of market economy principles and fair competition[30]. This rhetoric emphasizes the political and economic grievances Beijing holds against Washington's policies, portraying the US actions as forced decoupling intended to weaken China's technological advancements[31].

Beyond rhetoric, China is investing heavily in self-sufficiency. The country's semiconductor production capacity is set to grow by 40% from 2018 to 2029, with total silicon wafer output projected to rise from 310 million square inches to 875 million. In 2024 alone, China was expected to open 18 new fabs, adding 6.4% to global wafer capacity. By focusing on mature and some advanced nodes domestically, China aims to reduce its reliance on foreign suppliers – still a glaring weakness as 83% of China's $143 billion in 2020 chip consumption was imported. The government's "Made in China 2025" policy and subsequent initiatives have offered tax breaks and subsidies to local chip firms, fueling hundreds of new projects. However, not all have succeeded:

SMIC vs. Wuhan Hongxin (HSMC):

SMIC, China's flagship foundry, has steadily progressed (now producing 7nm chips using DUV lithography), thanks to continuous state support. In contrast, HSMC – a high-profile local government-backed fab in Wuhan aiming for 14nm and 7nm – collapsed in 2020 amid mismanagement. Despite an announced $18.5 billion budget, HSMC ran out of funds, and its CEO vanished, leaving an unfinished fab dubbed China's "semiconductor Theranos". Similarly, other ventures like Jinhua's memory fab and Qingdao's Xingular failed, highlighting that money alone cannot buy cutting-edge capability without human capital and sound governance. China is now investigating and prosecuting officials involved in some of these failed projects. Overall, China's response to external pressure has been to double down on indigenization – from chip design tools to talent recruitment – even as it seeks loopholes (e.g. using overseas subsidiaries to bypass export bans). For India, China's experience offers lessons on the importance of balanced growth: big funds and

[27] Arjun Kharpal, "China Brings WTO Case against US Chip Export Restrictions," CNBC, December 2022, https://www.cnbc.com/2022/12/13/china-brings-wto-case-against-us-chip-export-restrictions.html.

[28] Lin Feng and Liam Scott, "China Launches WTO Dispute Over US Chip Export Controls," Voice of America, December 2022, https://www.voanews.com/a/china-launches-wto-dispute-over-us-chip-export-controls/6885310.html.

[29] Zeyi Yang, "Us China Tech War Escalating," www.technologyreview.com, January 2024, https://www.technologyreview.com/2023/07/12/1076156/us-china-tech-war-escalating/.

[30] Mariko Oi, "US-China Chip War: Beijing Unhappy at Latest Wave of US Restrictions," www.bbc.com, January 2024, https://www.bbc.com/news/business-67141987.

[31] Elaine Kurtenbach, Associated Press, "China Bans Exports To Us Of Key High Tech Materials In Response To Chip Sanctions," www.pbs.org, January 2024, https://www.pbs.org/newshour/world/china-bans-exports-to-u-s-of-key-high-tech-materials-in-response-to-chip-sanctions#:~:text=The%20China%20Semiconductor%20Industry%20Association,inflating%20costs%20for%20American%20companies.

state directives must be coupled with technical expertise and international cooperation, lest billions be wasted.

These measures highlight China's multifaceted strategy in addressing US export controls, combining legal actions with strategic countermeasures and public diplomacy to safeguard its semiconductor industry[32] [33].

Key areas of focus for China include:

Memory Chips: Firms like YMTC (3D NAND) and CXMT (DRAM) have received government backing to challenge Samsung, SK Hynix, and Micron. YMTC reached 128-layer NAND and was poised to commercialize 232-layer NAND before U.S. export curbs cut off its access to latest lithography tools. The Big Fund's new tranche is expected to prioritize domestic semiconductor equipment to mitigate such chokepoints.

AI and Specialty Chips: Sectors like AI accelerators and power electronics are being bolstered. Huawei's 2023 release of the Kirin 9000S chip (manufactured by SMIC reportedly at 7nm) in its smartphones indicated China's determination to advance despite sanctions. The government is promoting chip design startups through incentives and a venture capital boom, over 3,000 semiconductor companies were registered in China in 2020 alone, though many struggle to compete globally.

Talent and IP: China has set up specialized IP courts and improved patent laws to encourage innovation (e.g., establishing punitive damages for IP infringement). Enforcement remains mixed, but there is clear progress; for instance, Chinese courts have ruled in favor of foreign patent holders in some recent cases, a sign of maturing legal frameworks. Still, industrial espionage and IP leakage concerns persist. Taiwan has accused China of poaching chip engineers and stealing trade secrets, leading Taiwan to tighten talent outflow laws.

In summary, China's semiconductor framework reform is characterized by state capitalism at scale: huge funding, government-guided objectives, and retaliatory control of upstream resources. For India and others, China's journey underscores the value of consistent long-term investment, but also the pitfalls of top-down excess. Coordination with international norms (e.g. WTO rules, avoiding IP theft) ultimately affects success; China's friction with the U.S. and allies has proven a double-edged sword, spurring self- reliance yet restricting access to global tech. As India crafts its path, it can selectively emulate China's successes (such as strategic investment funds) while steering clear of its mistakes (like indiscriminate local fab projects and IP controversies).

South Korea's Semiconductor Industry Support

South Korea has implemented a series of robust government policies and incentives aimed at bolstering its semiconductor industry, recognizing it as a critical sector for national security and economic growth. In March 2021, President Yoon Suk Yeol announced a historic $19 billion support package designed to provide financial assistance for infrastructure development, and R&D funding[34]. This comprehensive package aims to ensure South Korea's leading position in the global semiconductor market, particularly in the memory chip sector, where companies such as Samsung Electronics and SK Hynix dominate[35].

Further solidifying this commitment, significantly, the South Korean National Assembly passed the K-Chips Act in 2023 (building on earlier legislation in 2021). The Act aims to secure the nation's economic priorities while fostering a vibrant and competitive semiconductor industry. The K-Chips Act also positions South Korea to better navigate the complexities of international trade and strategic priorities between major global players such as the United States and China. This law underscores South Korea's strategy to bolster domestic technological innovation, thereby gaining leverage in shaping the global semiconductor market [36] .

[32] Kayla Tausche and Michelle Toh, "US Escalates Tech Battle by Cutting China off from AI Chips," edition.cnn.com, January 2024, https://edition.cnn.com/2023/10/18/tech/us-china-chip-export-curbs-intl-hnk/index.html.

[33] Gregory C. Allen, "China's New Strategy for Waging the Microchip Tech War," Center for Strategic and International Studies, May 2023, https://www.csis.org/analysis/chinas-new-strategy-waging-microchip-tech-war.

[34] Song Kyung-Seok, "South Korea Unveils Record 19bn Package To Support Chip Industry," www.aljazeera.com, January 2024, https://www.aljazeera.com/economy/2024/5/23/south-korea-unveils-record-19bn-package-to-support-chip-industry.

[35] Hayoon Kim, "South Korea Unveils 19 Billion Boost For Semiconductor Industry," www.koreatechtoday.com, January 2024, https://www.koreatechtoday.com/south-korea-unveils-19-billion-boost-for-semiconductor-industry/.

[36] KOREA PRO, "Us And South Korea Discuss Chip Cooperation Amid Long Term Industry Concerns," koreapro.org, January 2024, https://koreapro.org/2024/03/us-and-south-korea-discuss-chip-cooperation-amid-long-term-industry-concerns/.

In addition to these legislative efforts, South Korea's Ministry of Trade, Industry, and Energy has unveiled a K-semiconductor strategy. This strategy includes generous tax credits and incentives to encourage investments in R&D and infrastructure. The Act provides lavish tax incentives: big companies can now deduct up to 15% of their semiconductor facility investments from taxes (up from 8%), while small-medium enterprises (SMEs) can deduct up to 25%.

An extra temporary 10% tax credit was also introduced for any firm expanding chip production in 2023, with small- and medium-sized enterprises (SMEs) benefiting the most. The policy aims to sustain Korea's leadership in semiconductor manufacturing by reducing the financial burden on companies and encouraging further innovation and expansion[37].

In addition to legislative efforts, South Korea's Ministry of Trade, Industry, and Energy unveiled a K- Semiconductor Strategy, which includes creating comprehensive industry clusters and supporting workforce development. The strategy entails establishing two huge semiconductor clusters (one near Seoul for memory and one in the south for system semiconductors) by 2024, with infrastructure ready for new fabs. To support R&D, the government encourages public-private consortia – for example, a national project on AI chips with participation from Samsung, Hyundai, academic institutions, etc.

Despite these efforts, South Korea faces challenges in diversifying its semiconductor industry. Currently, the country is heavily reliant on the memory sector, which constitutes nearly 20% of its GDP and where Korean firms hold ~60% global market share. However, in non-memory sectors (logic, analog, sensors), Korea's presence is minimal (<3% global share) [38] . Recognizing this imbalance, Korea is prioritizing growth in system semiconductors (logic chips, especially for AI and automotive). Samsung has committed $17B+ to foundry expansions and aims to catch TSMC in advanced process technology by late 2020s, while SK Hynix is expanding into image sensors and other non-memory fields. The government is supporting this through R&D grants and by setting up the "Semiconductor Design Talent Initiative" to train thousands of new chip design engineers (in cooperation with companies and universities).

One notable aspect of Korea's policy is attention to supply chain security. After Japan's 2019 export restrictions on critical semiconductor chemicals (photoresists, hydrogen fluoride, and fluorinated polyimide) to Korea – which created a mini-crisis – Korea launched programs to localize material production and diversify import sources[39]. By 2021, Korean companies had mitigated much of the risk by qualifying non- Japanese suppliers and improving domestic production. The K-Chips Act also allows the government to fast-track approvals and provide funds if needed to prevent supply disruptions.

Korea's DRAM Cartel Case: A historical footnote that informs current policy is the early-2000s price-fixing scandal. Samsung and Hynix (with others) were found to have colluded to control DRAM chip prices. The U.S. Department of Justice fined Samsung $300 million in 2005 – then the second-largest antitrust fine in U.S. history – and Hynix $185 million[40]. Executives even served jail time in the U.S. This served as a wakeup call; since then, Korean firms have generally complied with global competition laws. The government, for its part, became more vigilant; the Korea Fair Trade Commission now keeps a closer watch on tech sector competition[41]. This experience underscores that while government supports industry, it must also enforce fair practices to ensure sustainable global integration.

In sum, South Korea's multi-pronged strategy, generous incentives (the "Korean CHIPS Act"), supply chain resilience measures, talent development, and international cooperation – has thus far maintained its edge in memory chips and set the stage for growth in new areas. For India, Korea's

[37] LEE HO-JEONG, "New Gov't Support for Semiconductors Promised," koreajoongangdaily.joins.com, January 2024, https://koreajoongangdaily.joins.com/2021/05/13/business/economy/koreasemiconductor-Ksemiconductor-semiconductort-tax-credit/20210513170100470.html.

[38] Joo-Young Kim et al., "South Koreas Nationwide Effort For Ai Semiconductor Industry," cacm.acm.org, January 2024, https://cacm.acm.org/research/south-koreas-nationwide-effort-for-ai-semiconductor-industry/.

[39] Ryo Makioka and Hongyong Zhang, "The Impact of Export Controls on International Trade: Evidence from the Japan–Korea Trade Dispute in Semiconductor Industry," *Journal of the Japanese and International Economies* 74 (December 2024): 101336, https://doi.org/10.1016/j.jjie.2024.101336.

[40] "SAMSUNG AGREES TO PLEAD GUILTY AND TO PAY $300 MILLION CRIMINAL FINE FOR ROLE IN PRICE FIXING CONSPIRACY," Department of Justice,USA, October 13, 2005, https://www.justice.gov/archive/atr/public/press_releases/2005/212002.htm.

[41] "Country Comparative Guides | South Korea: Cartels," Country Comparative Guides | The Legal 500, accessed July 24, 2025, https://www.legal500.com/guides/chapter/south-korea-cartels/.

example highlights the importance of targeted incentives and the need to align them with national strengths (e.g., Korea doubled down on memory when it was ahead, and now is focusing on AI chips next). Additionally, Korea's ability to swiftly adjust policies in response to external shocks (like the Japan export curbs) is an important lesson in agility for policymakers.

South Korea's Collaboration Strategies

South Korea has adopted robust collaboration strategies with foreign technology firms and research institutions to maintain a competitive edge in the semiconductor industry. One of the key initiatives involves enhancing bilateral cooperation with the United States. For instance, South Korea's deputy trade minister Yang Byeong-mo met with John Neuffer, the president of the Semiconductor Industry Association, to discuss strategies such as the implementation of the US CHIPS Act and strengthening supply chain links between the two countries. This collaboration aims to bolster public-private partnerships, especially in areas like artificial intelligence chips, to navigate the uncertainties of the global trade environment[42].

Furthermore, high-level dialogue has been established to deepen cooperation between critical and emerging technologies. In December 2023, the US National Security Advisor Jake Sullivan and South Korean National Security Advisor Cho Tae-yong led the inaugural US-South Korea Next Generation Critical and Emerging Technologies Dialogue. This initiative is part of a broader strategy to establish whole-of-alliance cooperation among US allies, including the proposed trilateral cooperation between Japan and India [43] . South Korea's collaborative efforts include regular meetings between industry and government leaders to ensure a stable and advanced semiconductor supply chain. For example, in June 2023, semiconductor lobby groups from South Korea.

The United States convened in Washington to discuss expanding technological research and maintaining supply chain stability. Participants included high-ranking officials from both governments and representatives from leading chipmakers such as Samsung Electronics, SK Hynix, Intel, and IBM[44]. South Korea's collaboration strategies focus heavily on US partnerships in contrast to approaches taken by other leading countries. For example, China has focused on state-backed investments to reduce foreign dependency and achieve semiconductor self-sufficiency, as outlined in its Made in China 2025 policy[45].

South Korea complements its domestic policies with robust international collaboration to maintain a competitive edge in semiconductors. A cornerstone of this is the US- Korea tech alliance. Recognizing the symbiotic relationship – U.S. firms lead in chip design (fabless) and equipment, whereas Korean firms excel in manufacturing – both governments have sought closer ties. In May 2023, South Korea's trade minister met with the president of the U.S. Semiconductor Industry Association to discuss the implementation of the US CHIPS Act and strengthening supply chain links. Concrete outcomes of such talks include South Korea securing waivers/exceptions in U.S. export controls for its companies' fabs in China. For instance, SK Hynix and Samsung were given U.S. licenses to continue receiving chip equipment for their China plants despite the October 2022 U.S. rules – a result of Seoul's active diplomacy to protect its industry.

In return, Korea has aligned more closely with U.S. strategy, e.g., informally capping further Trilateral cooperation is also in focus: U.S., South Korea, and Japan have begun coordinating on semiconductor policy (Japan is a key supplier of materials/equipment). And the idea of a broader coalition including India alluded to in dialogues, is emerging.

South Korea has cautiously welcomed India's entry into chip manufacturing, seeing potential collaboration in non-competitive segments (such as packaging or specialty chips) and as a hedge to diversify production. South Korea also engages with Europe and Southeast Asia on talent and research. Agreements with countries like Belgium (home of

[42] KOREA PRO, "Us And South Korea Discuss Chip Cooperation Amid Long Term Industry Concerns."

[43] Scott A. Snyder, "Forging Us South Korea Alliance Powered Chips Batteries And Clean Technologies," www.cfr.org, January 2024, https://www.cfr.org/blog/forging-us-south-korea-alliance-powered-chips-batteries-and-clean-technologies.

[44] Kyung Mi, "South Korea And U S Strengthen Semiconductor Ties With New Cooperation Initiatives," www.koreatechtoday.com, January 2024, https://www.koreatechtoday.com/south-korea-and-u-s-strengthen-semiconductor-ties-with-new-cooperation-initiatives/.

[45] Chris Park, "Potential Dependency Oversight Us South Korea Chip Policy," www.cfr.org, January 2024, https://www.cfr.org/blog/potential-dependency-oversight-us-south-korea-chip-policy.

IMEC research center) facilitate Korean engineers' access to advanced R&D.

Domestically, Korea invites foreign experts; for example, to boost its fab automation and AI capabilities, it has collaborations with international institutes and employs foreign engineers in its mega-fabs. These collaborative efforts highlight differences in national approaches: South Korea leans heavily on alliance with the U.S. and partners, whereas China has pursued a more go-it-alone state-driven approach, and Taiwan balances between its U.S. alliance and a need to engage China's huge market under strict safeguards. Recognizing these varying paths helps India identify a suitable strategy, likely closer to the U.S./Korea model of partnership rather than China's insular model.

As noted, South Korea's semiconductor dominance (especially in memory) was achieved not only through internal measures but via smart collaboration. Historically, Korea leveraged foreign partnerships – the most famous being Samsung's early technical tie-up with Micron in the 1980s and Hynix's technology licensing from Toshiba – to climb the learning curve. Today's collaborations are more about securing supply chains and market access:

U.S.–Korea CHIPS Cooperation: After the U.S. CHIPS Act, both Samsung and SK Hynix announced major fab projects in the U.S. (Texas and possibly Ohio, respectively). The Korean government, while supporting these moves, ensured that the U.S. provisions (which come with strings like profit-sharing above certain thresholds) do not disadvantage Korean firms. It actively negotiated with the U.S. Commerce Department on behalf of its companies. This reflects government-to-government collaboration to complement corporate decisions.

Trilateral Export Controls (U.S.-Japan-Korea): In early 2023, news emerged that the U.S., Japan and Netherlands (key tool suppliers) agreed to coordinate on restricting advanced lithograph equipment to China. Though Korea was not part of that particular pact (as it's not an equipment maker), it nonetheless aligned by not allowing its firms to fill the gap. For instance, when China's SMIC tried to procure used ASML DUV machines, Korean firms (which sometimes trade used tools) reportedly steered clear, to not undermine the allied stance. Such implicit cooperation shows the trust and strategic alignment Korea has with Western partners, something India could emulate to integrate into the trusted tech supply network.

Joint R&D and Standards: Korea is also active in international semiconductor standards bodies and research consortia (it joined the U.S.'s Semiconductor Technology Center initiative under the CHIPS Act, and participates in global forums for chip materials standards). By being at the table, Korea influences emerging tech directions (e.g. in 2.5D/3D chip packaging standards, where Samsung is a leader). Korea's outward-looking strategy has clearly paid dividends: it maintained its access to the China market while staying in the good graces of the West – a delicate balance. The recent U.S.–Korea–Japan summit (Camp David, 2023) even highlighted semiconductors as a key area of cooperation among the three countries, indicating how geopolitical and tech interests are converging.

For India, South Korea's example underscores that joining forces with established players can accelerate capability building. Instead of reinventing the wheel, India can partner to get fabrication technology (as with ISRO's cooperation with Semikon, Belgium, for a gallium nitride fab) or to develop its semiconductor standards in alignment with global norms.

In all, South Korea's success shows that even for a strong incumbent, adapting through global cooperation and swift policy actions is vital in the fast-evolving semiconductor arena. The collective effort ensures supply chain stability and access to leading technology – priorities that India shares as it seeks credible entry into this domain.

Country	***IP-Index score / rank***	***Average patent-pendency (latest official figure)***	***Enforcement notes***
United States	*95.48 % (1 / 55)*	*24.0 months (traditional total pendency, FY-2021)*	*Strong; high volume of infringement suits heard in federal courts*[46]

[46] *U.S. Patent and Trademark Office - Fiscal Year 2021 Congressional Justification*, n.d.

South Korea	*84.94 % (~12 / 55; #2 in Asia)*	*16.1 months to first office action in 2023 (≈22 mo total)*	*Improving; specialist IP divisions in the judiciary*[47]
Taiwan	*67.34 % (#6 in Asia)*	*8.4 months (first action) / 14.2 months (disposal) in 2024*	*Strict; widely trusted by global fabless firms*[48]
China	*57.86 % (#7 in Asia)*	*16 months (avg. examination time, 2023)*	*Better, but gaps remain; on USTR Priority Watch List*[49]
India	*38.64 % (42 / 55)*	*49.5 months to disposal in 2023 (down from 84 mo in 2015)*	*Weak; litigation lengthy, also on USTR Priority Watch List*[50] [51]

Table 1: Comparative IP and Patent Landscape. Strong IP regimes correlate with semiconductor success.

The U.S., South Korea, and Taiwan score high on global IP index rankings and have relatively short patent processing times, reflecting effective enforcement. China has improved its IP laws (index score ~58%) and sped up patent grants (~20 months on average), but concerns linger over enforcement consistency. India trails significantly – ranked 42nd/55 with an index score of 38.6% and patent pendency averaging ~58 months (nearly 5 years). This underperformance in IP protection is a major competitiveness limitation for India's semiconductor aspirations.

Table 2: Comparative Analysis of Semiconductor Policies andCompetitiveness in India, China, the US, South Korea, and Taiwan

Country	**Key Strengths**	**Primary Policies**	**Challenges**	**Recommendations for India**
India	Emerging market; strong tech talent base (especially in design)	"Digital India", "Make in India" initiatives; ₹76,000 crore (~$10 B) semiconductor-ecosystem programme	Limited IP protection; infrastructure deficits; talent shortage; nascent supply chain	Strengthen IP laws (fast-track SemiconExpress); incentivize R&D (tax breaks, grants); boost public-private partnerships (with U.S., Taiwan)
China	Large-scale manufacturing capacity; massive domestic market	Government subsidies; National IC Investment "Big Fund"; "Made in China 2025" and other state-led tech programs	IP protection concerns; dependence on foreign core tech (tools, IP); facing export restrictions on key imports	Study China's investment in local infrastructure and subsidies; establish comparable long-term funding mechanisms (e.g., dedicated semiconductor fund) with accountability checks

[47] "Annual_Report_2023.Pdf," n.d., accessed July 24, 2025, https://www.kipo.go.kr/upload/en/download/Annual_Report_2023.pdf?utm_source=chatgpt.com.

[48] "2024 Filing Trends in Taiwan: Stability in Patent Filings, Recovery in Trademark Applications, and Improved Examination Efficiency - Lexology," accessed July 24, 2025, https://www.lexology.com/library/detail.aspx?g=4bce9211-567a-4f32-a838-8550b863c98f.

[49] "China National Intellectual Property Administration Media Perspective Heads of IP Administrations Meeting Reviews a Fruitful Year," accessed July 24, 2025, https://english.cnipa.gov.cn/art/2024/1/10/art_2975_189608.html.

[50] "ipoAchievements.Pdf," n.d., accessed July 24, 2025, https://www.ipindia.gov.in/writereaddata/Portal/Images/pdf/ipoAchievements.pdf.

[51] "2025 Special 301 Report (Final).Pdf," n.d., accessed July 24, 2025, https://ustr.gov/sites/default/files/files/Issue_Areas/Enforcement/2025%20Special%20301%20Report%20%28final%29.pdf.

United States	World-leading fabless firms; advanced R&D; strong IP laws; robust industry standards	CHIPS Act 2022 – $52.7 B in subsidies + 25 % tax credit; focus on high-end R&D and on-shore manufacturing; strict export controls (EAR) and Entity List to protect tech lead	High production & labor costs; manufacturing skills shortage (talent gap in fabs); supply-chain vulnerabilities (few domestic fabs for certain nodes)	Invest in high-value R&D partnerships with India (joint centers on AI chips); strengthen secure IP framework in India to reassure U.S. investors; attract U.S. fabs via incentives & skilled-labor programs (learn from TSMC Arizona experience)
South Korea	Memory-chip leaders (Samsung, SK Hynix); highly developed fab infrastructure; strong public-private collaboration	K-Chips Act (heavy tax incentives); government export support and financing; public-private R&D consortia (e.g., AI chips)	Heavy reliance on memory segment (over 90 % of semiconductor exports); export-market concentration (China > 40 % of sales); need diversification into logic chips	Adopt Korea’s tech-focused education model (specialized semiconductor training); diversify export markets (India can offer itself as a market and partner); encourage development of non-memory segments (via fabless-startup support and JVs with Korean firms in India)
Taiwan	Foundry dominance (TSMC); tightly integrated local supply chain; strict IP enforcement; “silicon shield” geopolitical leverage	Export-control alignment with allies (added Huawei/SMIC to control list); 25 % R&D tax credit; talent-retention programs; overseas fab expansion (U.S., Japan) with government support	Geographic/seismic risk (earthquakes); cross-strait political tensions with China (potential supply disruption)	Enforce robust IP to attract Taiwan’s investment (assure their IP is safe in India); build resilient ties – joint ventures and invite Taiwan to set up fabs in India (possibly with U.S. collaboration), creating a backup to Taiwan’s geospatial risk

Abbreviations: IC = integrated circuit; R&D = research and development; FDI = foreign direct investment.

Recommendations

i. Fast-Track IP and Design Ecosystems: Establish a dedicated "SemiconExpress" fast-track IP unit for semiconductors to cut patent approval times. This mirrors initiatives like South Korea's expedited semiconductor patent examinations. By hiring more examiners and leveraging global patent cooperation treaties, SemiconExpress can rapidly protect chip designs. Additionally, incentivize design activity: India already hosts top chip-design talent (e.g. Qualcomm India accounts for an estimated 60 % of Qualcomm's patent filings). This advantage should be solidified by enhancing design IP protections and offering tax credits for chip-design houses.

ii. Strengthen Export Controls and Trust with Allies: Upgrade India's SCOMET list to include latest semiconductor manufacturing equipment and EDA software, aligning it with U.S. EAR and Wassenaar lists. Rigorously enforce export licensing for sensitive tech transfers. A U.S.–India export-control working group should coordinate on emerging tech (AI chips, 5G, <15 nm fab equipment) – akin to treating sub-15 nm process technology as the "DNA" of modern chips, requiring careful custody. By jointly safeguarding this "technological genome," India can gain access to more U.S. technology under export exceptions and trusted-foundry arrangements. India's recent entry into U.S.-led frameworks (e.g. Strategic Trade Authorization-1 status) should be leveraged to deepen tech-sharing.

iii. Catalyze Private R&D and Fabrication: Launch an R&D policy reset with the goal of tripling R&D spend to ~2 % of GDP by 2030. This includes expanding grants for university-industry semiconductor research centers and matching-fund programs with countries like the U.S., Japan, and Taiwan. Public-private "chip hubs" should be established (on the lines of Taiwan's ITRI-Science Park model) to foster collaborative innovation. For manufacturing, focus fiscal support on one or two proven players (global or domestic) to ensure at least one 28 nm-or-better fab is operational in India by 2026. Avoid spreading subsidies too thin – a lesson from China's failures where numerous local fabs never materialized. Tie grants to clear milestones (technology transfer, yield targets) to prevent waste.

iv. Improve the Startup Exit Climate**:** India must remove bottlenecks that drive startups to flip overseas. Exempt long-term capital-gains tax on startup equity sales (or defer it if proceeds are reinvested in new Indian startups). This aligns with global practices – Singapore imposes 0 % capital-gains tax, and UK offers Entrepreneurs' Relief on exits. Recent steps in Budget 2024 – abolishing the "angel tax" on startup funding and reducing LTCG tax on unlisted shares from 20 % to 12.5 % – are a good start. Further, streamline regulations to enable Indian startups to list on global exchanges or be acquired by foreign firms without onerous approval delays. Two specific reforms are recommended: (a) automatic approval for foreign M&A exits under a certain valuation threshold, and (b) allowing direct overseas IPOs for startups in sectors where domestic listing appetite is low. These will give investors' confidence that they can smoothly exit, spurring more venture funding into Indian deep-tech startups.

v. Leverage Trade Negotiations for Market Access**:** Proactively use trade agreements and strategic forums to India's advantage in semiconductors. In Free Trade Agreement (FTA) talks with key partners (US, EU, Japan), India should seek commitments on supply-chain security and co-development of semiconductor tech, while offering tariff reductions on critical chip inputs. Within the Quad and other alliances, India can champion a "Chip Alliance" that coordinates export-control policies and talent exchanges, positioning itself as a credible alternative manufacturing hub to China. The Indo-Pacific Economic Framework (IPEF)'s supply-chain pillar should be used to secure funding for capacity-building in India's semiconductor value chain, and to establish early-warning systems for chip-supply disruptions. By aligning its trade stance with export-control goals, India reinforces partner trust that sensitive technologies shared with India will remain secure.

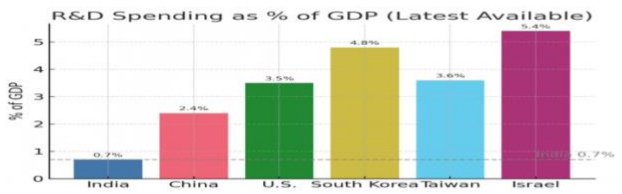


Figure 1: R&D Spending as a Percentage of GDP – India vs. Peers**.** Nations with robust semiconductor industries invest heavily in R&D. India's R&D spend (~0.7 % of GDP) is a small fraction of that in South Korea (~4.8 %), the U.S. (~3.5 %), China (~2.4 %), or Israel (~5.4 %). This investment gap is reflected in relatively low indigenous innovation and must be addressed through bold policy measures.

By implementing these recommendations, India can significantly bolster its semiconductor ecosystem. In doing so, it will complement the strategies of the U.S., Japan, Taiwan, and South Korea – countries that are keen to diversify supply chains away from China's dominance. India's large talent pool (500+ chip-design startups and thousands of engineers), if backed by effective policies, is a formidable asset. The next section provides a detailed comparative analysis of each country's framework, followed by a deeper discussion of how India can leapfrog ahead.

Conclusion

The semiconductor industry is at the heart of modern innovation, driving advancements across critical sectors, from consumer electronics to national defense. This comparative analysis of policy frameworks in India, China, the US, South Korea, and Taiwan highlights the essential role of strategic investments, robust intellectual property protection, and secure supply chains in fostering a competitive semiconductor ecosystem. While global leaders such as the US and Taiwan have established resilient semiconductor industries through sustained R&D investment and comprehensive IP protection, countries such as China and South Korea have rapidly strengthened their positions by leveraging government support and strategic industrial partnerships.

For India, these insights underscore both challenges and opportunities in developing a globally competitive semiconductor industry. Addressing infrastructure deficits, enhancing IP enforcement, securing supply chains, and cultivating a skilled workforce are vital steps to achieve this vision. Strategic policy reforms that encourage public-private collaboration, incentivize foreign investment, and prioritize R&D will be instrumental. Additionally, India's unique advantage in talent potential should be harnessed through specialized training programmes to bridge the existing skills gap. Ultimately, a tailored and cohesive policy framework, drawing from the successes and lessons of global semiconductor leaders, will be critical for India's success in this high-stakes industry. By adopting a holistic approach, India can transform its semiconductor landscape, contributing not only to its economic security but also to the resilience of global supply chains. This positioning enables India to play a pivotal role in the future of global technology and innovation.

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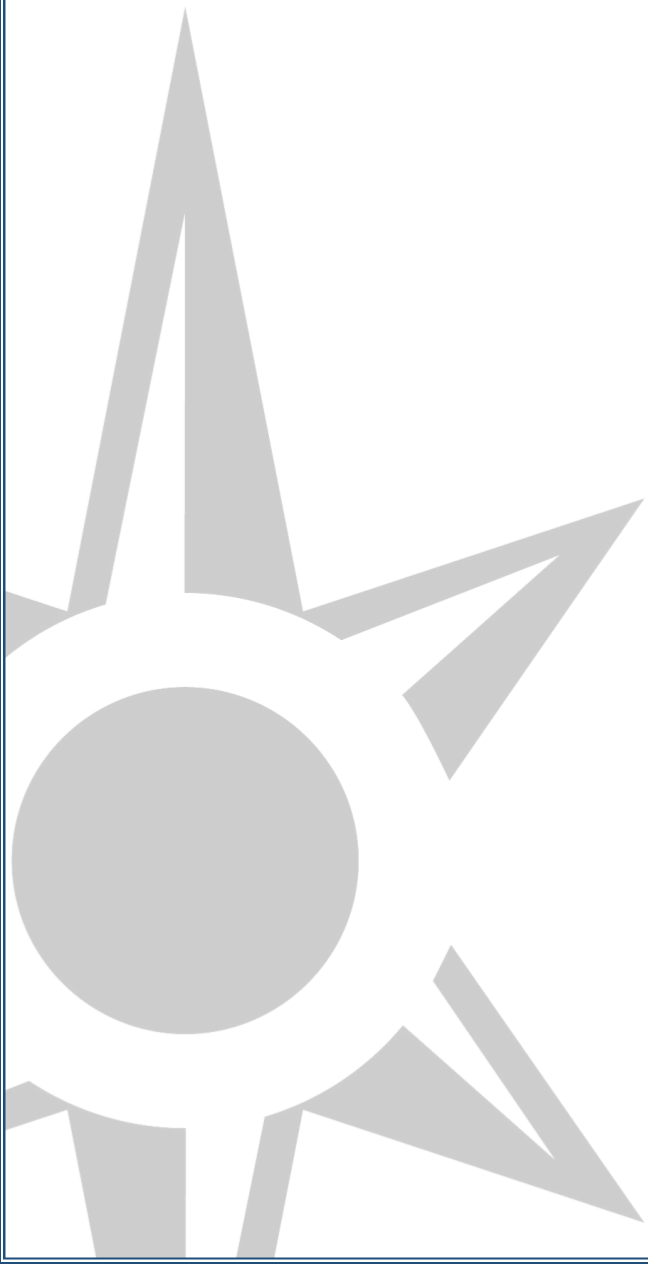
PACIFIC FORUM INTERNATIONAL

India's Semiconductor Ecosystem: Past, Present, and Strategic Future

By
Mmhonlumo Kikon



Executive Summary

Mmhonlumo Kikon

India's semiconductor ecosystem is at a critical inflection point, shaped by decades of missed opportunities but propelled today by unprecedented geopolitical, economic, and technological momentum. This paper traces India's semiconductor journey from its post-independence techno-nationalist initiatives—such as the establishment of BEL, DRDO, ISRO, and SCL—to its rise as a global semiconductor design hub in the 2000s, and finally to the current policy-driven push to develop domestic fabrication capacity.

The analysis highlights the launch of the Indian Semiconductor Mission in 2021, a $9 billion initiative that consolidates incentives for fabs, ATMP/OSAT facilities, and design-linked innovation. It details strategic partnerships with the United States, Japan, Taiwan, the EU, and Singapore, emphasizing their role in bringing investment, technology transfer, and workforce development to India's emerging semiconductor sector.

Key systemic challenges are explored, including the lack of domestic fabrication infrastructure, gaps in specialized talent, dependence on foreign suppliers for critical materials, and a weak intellectual property enforcement framework. The paper calls for the creation of a national IP task force, specialized tribunals, and mandatory IP audits to strengthen innovation and commercialization capabilities.

The study situates India within the broader US–China chip war, arguing that global supply chain realignments create a rare window for India to emerge as a trusted manufacturing and design hub. Recommendations include modernizing export control laws, accelerating project implementation under ISM, aligning education with industry needs, and deepening participation in global technology governance.

Ultimately, India's success will depend on its ability to move from aspirational policy announcements to disciplined execution—building an integrated, innovation-led semiconductor ecosystem capable of creating over one million jobs, reducing import dependency, and positioning India as a trusted node in global value chains over the next five years.

Introduction

India's semiconductor journey is at a critical inflection point. As geopolitical shifts impacted by the war in Ukraine and the global tariff realignment reshape global supply chains, India's ambitions to emerge as a key semiconductor hub are backed by unprecedented government investments, strategic partnerships, and a growing emphasis on domestic self-reliance. This paper explores India's semiconductor trajectory in seven parts—historical evolution, global collaborations, systemic challenges, policy interventions, the global chip war, regional geopolitics, and the way forward—while furnishing a critical, policy-oriented examination of opportunities and hurdles in each phase.

This paper deepens its analysis by situating India's semiconductor ambitions within the context of shifting international export controls, supply chain realignment, and evolving trade partnerships. In addition to examining historical legacies and domestic reforms, it offers forward-looking recommendations for global policy stakeholders engaging with India's emerging role in the post-China reconfiguration of semiconductor value chains.

India's Semiconductor Ecosystem: Historical Trajectory

1950s–1990s: Foundational Efforts Amidst Challenges

In the immediate post-independence decades, India embarked on a mission of "techno-nationalism." as it were. Institutions like the Indian Institute of Science (IISc), founded in 1909 with support from the Tata family,[1] were revitalized to provide a knowledge base for scientific pursuits. The Indian Institutes of Technology (IITs), beginning with IIT Kharagpur in 1951, served as the vanguard of engineering talent development. This state-led educational expansion, modeled on the Massachusetts Institute of Technology (M.I.T). system, was intended[2] to anchor national industrialization strategies through import substitution and indigenous capability development. These policies were aspirational and ambitious.

The establishment of Bharat Electronics Limited (BEL) in 1954, DRDO in 1958, and ISRO in 1969[3] signaled strategic intent toward self-reliance, particularly in defense and space technologies. BEL's fabrication facility, set up in 1962, was one of the earliest attempts to engage with silicon technology. However, due to lack of policy coherence, inadequate infrastructure, and absence of a commercial electronics market, such efforts remained isolated and unsustainable.[4]

A significant initiative during this period was the formation of the Semiconductor Complex Limited (SCL) in Chandigarh in 1984, envisioned as a high-end node for application-specific integrated circuits (ASICs) and supported by foreign technical collaboration. However, the SCL fire in 1989 not only physically destroyed equipment worth millions but symbolically extinguished India's early momentum.[5] Bureaucratic inertia, import substitution policy contradictions, and failure to scale commercialization compounded the loss.

2000s–2020s: Design Hub Emergence Without Manufacturing Backbone

The liberalization of India's economy in 1991 created conditions for global technology companies to enter India, leading to the emergence of the country as a significant hub for semiconductor design and embedded systems development. Texas Instruments pioneered the entry of global technology companies into India by establishing its R&D centre at Bangalore in 1985.[6] This move was followed in the 2000s by companies such as Intel, AMD, Qualcomm, and Broadcom, which also set up design centres in key Indian tech hubs including Bengaluru, Hyderabad, and Noida.[7] This shift occurred in a context where India lacked advanced fabrication capabilities but had abundant engineering talent trained in electrical and computer engineering.

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1. William Keller and Louis Pauly, *Innovation in the Indian Semiconductor Industry: The Challenge of Sectoral Deepening* (*Business & Politics, Vol. 11, No. 2, 2009*), 1-2.
2. Ibid
3. Pankaj Phanase, *"The Strategic Implications of Chip War for India,"* CENJOWS. July 4, 2024. https://cenjows.in/the-strategic-implications-of-chip-war-for-india.
4. Ibid
5. Trisha Ray, *"Lessons from India's Past for Its Semiconductor Future,"* ORF., December 4, 2023, https://www.orfonline.org/expert-speak/lessons-from-indias-past-for-its-semiconductor-future.
6. Dr. N.G.P. Institute of Technology, *"Electrical and Electronics Engineering: Ngpitech,"* https://www.drngpit.ac.in/study/undergraduate/elec-elect-eng/industry-powered-centre/textas-inst-center#:~:text=Texas%20Instruments%2C%20actively%20driving%20the,an%20R%26D%20facility%20in%20India

Despite the rise of a vibrant design services sector, manufacturing continued to be out of reach. The government attempted to address this asymmetry through several policies. The Special Incentive Package Scheme[8] (SIPS) in 2007 was the first major policy to promote semiconductor fabrication. Stringent investment requirements and slow approval processes deterred potential investors like Intel and AMD. A KPMG report from 2010[9] observed that India was seen as "'over-regulated and under-incentivized"' by the global semiconductor industry. The National Policy on Electronics[10] (2012) and its Modified SIPS variant sought to create a broader ecosystem for electronics manufacturing, which included but did not prioritize semiconductor fabs. The Phased Manufacturing Programme[11] (2017), although successful in boosting mobile phone assembly, failed to develop an end-to-end supply chain. The Make in India[12] and Digital India[13] programs helped drive demand for digital infrastructure, however the next challenge was to create domestic foundries to reduce India's dependence on import of semiconductors. These trends triggered a new wave of policy thinking post-2020.

2021–2025: Strategic Initiatives and Renewed Focus

Seizing the opportunity provided by the global chip shortage during the COVID-19 pandemic and rising geopolitical tensions, the Indian government launched the Indian Semiconductor Mission (ISM) in December 2021 with a financial outlay of $9 billion.[14] The program marked a departure[15] from earlier fragmented approaches by offering comprehensive support for fabrication plants (fabs), ATMP/OSAT facilities, and semiconductor design under four key schemes.

These include the Modified Scheme for Semiconductor and Display Fabs, the Scheme for Compound Semiconductors[16] and ATMP, the Design Linked Incentive (DLI) Scheme, and the Electronics Manufacturing Clusters 2.0 program. The DLI, for instance, provides up to ₹15 crore per startup and reimbursement of design and IP development costs, signaling a recognition of India's strength in chip design.

The ISM also aligns with broader industrial policy trends such as the Production Linked Incentive (PLI) schemes and the emphasis on *Atmanirbhar Bharat* ("self-reliant India"). While initial proposals—such as the Vedanta-Foxconn fab in Gujarat—have faced implementation delays and funding bottlenecks, the strategic pivot reflects a process of policy adaptation and learning. Future iterations of ISM are likely to incorporate public-private partnership models, increased transparency in evaluation, and most importantly, a closer alignment with state governments.

Global Partnerships: Diversifying Collaborations

United States: Strategic Alignment and Technological Synergy

The United States remains India's most significant strategic and technological partner in the semiconductor domain. Under the framework of the US–India Initiative on Critical and Emerging Technology (iCET), both governments have emphasized co-development and co-production in semiconductor manufacturing, quantum computing, and AI. Micron Technology's $2.75 billion ATMP investment[17] in Gujarat, announced in June 2023, is, therefore, a landmark deal. The facility, backed by a 50% grant[18] from the central and state governments, is expected to generate[19] over 5,000 direct and 15,000 indirect jobs.

Lam Research and Applied Materials have similarly committed to building R&D centers and training programs, including a Center of Excellence for Semiconductor Equipment. These partnerships are being promoted not only through bilateral mechanisms but also under Quadrilateral Security Dialogue ("Quad") frameworks where supply chain resilience is a shared concern. However, critics argue that US investments are heavily inclined towards low-capex ATMPs and less toward full-fledged fabs,

[15] Dr. NGP. Institute of Technology, *"Electrical and Electronics Engineering: Ngpitech"*

[16] . Sitakand Mishra and Nishrang Jani, *"The Dawn of India's Semiconductor Era,"* The Diplomat, https://thediplomat.com/2024/03/the-dawn-of-indias-semiconductor-era/

[17] *"Micron Announces New Semiconductor Assembly and Test Facility in India," https://investors.micron.com/news-releases/news-release-details/micron-announces-new-semiconductor-assembly-and-test-facility.*

[18] *"India's High-Tech Revolution: Driving Global Leadership in Advanced Technology & Manufacturing," Press Information Bureau, https://pib.gov.in/PressNoteDetails.aspx?NoteId=152130&ModuleId=3.*

[19] *"Micron Announces New Semiconductor Assembly and Test Facility in India," https://investors.micron.com/news-releases/news-release-details/micron-announces-new-semiconductor-assembly-and-test-facility.*

compounding India's mounting challenges in building core IP.

Japan: Complementary Strengths and Mutual Interests

Japan's collaboration with India is rooted in a shared interest in supply chain security and reduced dependency on China. Japanese companies such as Renesas and Tokyo Electron have partnered with Indian firms like Tata Electronics to supply critical equipment for packaging units. The 2023 MoC memorandum of cooperation between Ministry of Economy Trade and Industry, Japan and India's Ministry of Electronics and Information Technology outlined cooperation[20] across five pillars: design, manufacturing, R&D, workforce development, and infrastructure.

Japan's participation is also strategic. Given its leadership in semiconductor equipment (e.g., Nikon and Tokyo Electron in photolithography and etching), India offers a large market, a skilled workforce, and geopolitical alignment. In return, India gets access to technology, equipment supply, and technical training. Experts see this as part of Japan's Indo-Pacific strategy to rebalance manufacturing centrality away from China.

Taiwan: Leveraging Expertise for Mutual Growth

Taiwan's role as the global hub for contract chip manufacturing—through TSMC, UMC, and Powerchip—makes it a crucial partner in India's fab aspirations. In 2023, Tata Electronics signed a technology transfer agreement with Powerchip Semiconductor Manufacturing Corporation to build India's first 28nm chip manufacturing plant in Dholera, Gujarat.

Foxconn, the world's biggest contract manufacturer and a client of TSMC, first teamed up[21] with Vedanta to build a semiconductor plant in India. This plan failed because of technical disagreements and other issues, so Foxconn left the joint venture.[22] However, Foxconn is still interested in India and is now working with new partners to set up chip factories.

Taiwan's involvement in India's chip industry is cautious due to political risks[23], especially tensions with China, which affect decisions about where to build factories and diversify supply chains. Taiwan sees India as an important alternative market[24] in its "China-plus-one" strategy, but real progress depends on India's ability to provide reliable electricity, good logistics, and enough skilled workers.

Other Nations: Expanding the Collaborative Horizon

The imposition of semiconductor export controls by the United States, European Union, Japan, and allied nations has upended the geography of global technology flows. While these restrictions predominantly target China, they have triggered ripple effects for multinational companies and international partners. As firms reassess their compliance obligations, India has emerged as a potential destination for high-trust semiconductor operations. These global trends reinforce the urgency of aligning India's policy, regulatory, and technological frameworks with evolving international expectations.

In addition to its key partnerships with the US, Japan, and Taiwan, India has enhanced its semiconductor diplomacy to include the European Union, Israel, Singapore, and the Netherlands.[25] Each of these countries or blocs brings specific strengths—ranging from R&D expertise to equipment manufacturing and materials supply—that can help plug critical gaps in India's ecosystem.

The EU–India MoU on Semiconductors[26] (2023) marks a notable shift in India's approach to engaging with Western technology regimes. The agreement seeks to promote joint R&D, foster innovation, and develop a skilled workforce through transnational

20. Gayatri Singh, *"India-Japan Semiconductor Supply Chain Partnership,"* Indian Council of World Affairs, https://www.icwa.in/show_content.php?lang=1&level=1&ls_id=11646&lid=7092.

21. *"Foxconn Submits Application for Setting Up Semiconductor Unit: MoS IT," The Economic Times,* https://economictimes.indiatimes.com/industry/cons-products/electronics/foxconn-submits-application-for-setting-up-semiconductor-unit-mos-it/articleshow/106157847.cms.

22. Ibid

23. *"Beyond the Strait: Taiwan-India Chip Cooperation and Taiwan's Role in India's Semiconductor Rise," India Strategic,* https://www.indiastrategic.in/beyond-the-strait-taiwan-india-chip-cooperation-and-taiwans-role-in-indias-semiconductor-rise.

24. Ibid

25 *"India's Semiconductor Ambitions Surge with Global Partnerships and Domestic Initiatives," Astute Group, September 26, 2024,* https://www.astutegroup.com/news/general/indias-semiconductor-ambitions-surge-with-global-partnerships-and-domestic-initiatives.

26 *Cabinet Approves Memorandum of Understanding Between India and the European Commission on Working Arrangements on Semiconductors Ecosystems Under the Framework of EU-India Trade and Technology Council,"* Press Information Bureau, January 18, 2024, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1997198.

27. Ibid

28. Ibid

initiatives. Programs like the European Chips Skills Academy (ECSA), developed in collaboration with Synopsys, hopes to serve as a model for India to institutionalize technical education partnerships across borders.

Singapore's collaboration focuses on startup incubation and knowledge transfer, particularly through Temasek-backed technology platforms and venture capital investments. In September 2024, India and Singapore signed an MoU to co-develop initiatives for talent exchange, fabrication training, and AI-chip integration—indicating a preference for agile, industry-led frameworks over state-heavy models.

The Netherlands, home to ASML—the world's only manufacturer of Extreme Ultraviolet Lithography (EUV) machines—has shown interest[27] in skill-sharing arrangements with India. In April 2024, Dutch universities and chip companies proposed collaborative R&D hubs and technician training programs.[28] While ASML does not plan to manufacture in India, access to its equipment and training is pivotal to enabling India's fabs to operate at global standards.

In October 2024, the Adani Group decided to pause[29] its $10 billion semiconductor joint venture discussions with Israel's Tower Semiconductor after an internal review. The decision was driven by strategic and commercial considerations, including uncertainties about domestic market demand and the level of financial commitment from Tower Semiconductor. While Tower was to provide technology, Adani sought a greater financial investment[30] from its partner. The pause reflects the evolving nature of India's semiconductor sector, where market maturity and investment clarity remain key factors. Both companies have indicated that talks could potentially resume in the future.

Confronting Ground Realities

Manufacturing and Design: Bridging the Decades-Long Gap

India's late entry into the semiconductor value chain has resulted in a wide catch- up chase with nations like Taiwan, South Korea, and Japan. While these countries pursued coherent industrial policy coupled with large-scale state investment as early as the 1980s, India's fragmented approach delayed commercial manufacturing. India's impressive capabilities in chip design are yet to be fully complemented by domestic foundry infrastructure, resulting in a gap when it comes to large-scale manufacturing of legacy nodes such as 65nm.

Bridging this gap requires a coordinated strategy that aligns fiscal incentives, public-private R&D, IP support, and export competitiveness. Countries such as Vietnam and Malaysia[31] have shown how well-designed SEZs, tax incentives, and business-friendly reforms can successfully attract major supply chain players. India is already making significant strides in this direction, with robust government initiatives, substantial investments, and strategic partnerships fueling rapid growth in semiconductor manufacturing and electronics.

Talent Pool: Cultivating and Retaining Specialized Skills

India produces over 1.5 million engineering graduates annually[32], yet only a fraction[33] are trained in semiconductor-specific disciplines such as VLSI (Very Large Scale Integration) design, fabrication process engineering, and materials science. The industry-academia disconnect persists, wherein outdated curricula and lack of hands-on lab experience fail to equip students for the complexity of chip manufacturing.

Government programs like the India Semiconductor Workforce Development Program[34] (ISWDP), launched with IISc, Synopsys, and Samsung Semiconductor India Research (SSIR), aim to address this skills gap. The program has introduced modular

29. *"Adani Group Partners Israel's Tower Semiconductor to Build $10 Billion Chip Plant in India: All Details," The Times of India*, September 6, 2024, https://timesofindia.indiatimes.com/technology/tech-news/adani-group-partners-israels-tower-semiconductor-to-build-10-billion-chip-plant-in-india-all-details/articleshow/113132692.cms.

30. Ibid

31. Sitakand Mishra and Nishrang Jani, *"The Dawn of India's Semiconductor Era,"* The Diplomat, https://thediplomat.com/2024/03/the-dawn-of-indias-semiconductor-era/

32. Deepto Banerjee, *"Pursuing Engineering Once a Fad, Now a Dilemma: Only 10 Percent of 15 Lakh Graduates Likely to Land Jobs This Year," The Times of India*, October 28, 2024, https://timesofindia.indiatimes.com/education/news/pursuing-engineering-once-a-fad-now-a-dilemma-only-10-percent-of-15-lakh-graduates-likely-to-land-jobs-this-year/articleshow/114686084.cms.

33. Ibid

34. *"India Semiconductor Workforce Development Program," ISWDP, https://iisc-iswdp.org/.*

courses[16] in process node design and physical verification, with additional funding for "train the trainer"[16] initiatives at tier-2 engineering colleges. Still, critics point to[35] a lack of standardization in coursework and limited industry certification as hurdles to mass deployment of talent.

Globally, examples abound where countries have adopted specialized strategies to ensure supply of semiconductor workforce. Taiwan's National Taiwan University (NTU) collaborates directly[36] with TSMC to offer chip prototyping labs. The Netherlands has vocational partnerships[37] between ASML and local polytechnic schools. India's challenge is to replicate such models while expanding access to underrepresented groups and regions.

Supply Chain: Securing Critical Components and Materials

The global semiconductor supply chain is multi-tiered, stretching across continents and involving hundreds of firms. As mentioned before, India's current vulnerabilities stem from its reliance on foreign suppliers for key raw materials (e.g., gallium, germanium), ultra-pure gases, and lithography equipment. The ongoing U.S.US–China tech war has further exacerbated[38] the difficulties in accessing to these inputs.

To enhance supply chain resilience, the Indian government has incorporated upstream and midstream stakeholders into Phase 2 of the Indian Semiconductor Mission. In Odisha, a pilot Silicon Carbide plant has been established in partnership with RIR Power Electronics with support from the Odisha government and central government incentive schemes. Additionally, India is exploring bilateral critical minerals agreements with Australia and Mongolia, much like the US Department of State's Minerals Security Partnership framework. These efforts remain nascent, and there are speculations[39] that experts urge the formation of a National Raw Materials Security Council for semiconductors to coordinate geological surveys, incentives, and recycling initiatives.

Domestically, India's gas suppliers (e.g., INOX Air Products) and specialty chemical firms (e.g., Gujarat Fluorochemicals) are scaling up.[40] However, the absence of semiconductor-grade certification, coupled with environmental regulatory delays, has slowed progress. Industry lobbies have advocated for global standard alignment with SEMI International benchmarks to ease this transition.

Intellectual Property Rights (IPR): Strengthening the Legal Framework

Intellectual Property Rights (IPR) are foundational to India's ambition to lead in semiconductor innovation and manufacturing. The government has launched initiatives under TRIPS and WIPO, and efforts have been made to streamline procedures and incentivize IP creation. Despite meaningful steps forward, significant issues remain in enforcement, commercialization, and capacity building, especially for MSMEs and startups.

Effective IP protection is fundamental to semiconductor innovation, given the enormous costs of R&D and the risks of design theft. India enacted the **Semiconductor Integrated Circuits Layout-Design Act in 2000**,[41] followed by the **National IPR Policy in 2016**.[42] However, issues persist around enforcement, patent overlap, and lack of damages awarded in infringement cases.

While India's copyright and patent systems adhere to TRIPS obligations, legal scholars **argue for**[43] a specialized Semiconductor IP Tribunal to fast-track disputes. The US **IPR Center**,[44] which brings together customs, FBI, and trade departments, serves as a benchmark in inter-agency coordination. A recent proposal by NITI Aayog recommends a similar cross-sectoral IP Task Force in India, focusing on chip

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35. *"India Semiconductor Workforce Development Program,"* ISWDP, https://iisc-iswdp.org/.
36. R. Anil Kumar, *"Beyond the Strait: Taiwan-India Chip Cooperation and Taiwan's Role in India's Semiconductor Rise," India Strategic*, November 18, 2024, https://www.indiastrategic.in/beyond-the-strait-taiwan-india-chip-cooperation-and-taiwans-role-in-indias-semiconductor-rise
37. *"Work-Study Jobs (BBL & Duaal Leerwerk) in the Netherlands,"* ASML, https://www.asml.com/en/careers/students-new-graduates/netherlands/work-study-jobs.
38. Christopher A. Thomas, *"Lagging but Motivated: The State of China's Semiconductor Industry,"* Brookings, January 8, 2021, https://www.brookings.edu/articles/lagging-but-motivated-the-state-of-chinas-semiconductor-industry/.
39. *India's First Silicon Carbide Manufacturing Facility to Be Set Up in Odisha," ET EnergyWorld, September 7, 2024,* *https://energy.economictimes.indiatimes.com/news/coal/indias-first-silicon-carbide-manufacturing-facility-to-be-set-up-in-odisha/113141675.*
40. Ibid
41. *"India - Protecting Intellectual Property,"* International Trade Administration | Trade.gov, December 1, 2024, https://www.trade.gov/country-commercial-guides/india-protecting-intellectual-property.
42. Ibid
43. Ibid
44. Ibid

design audits, IP renewal reminders, and border protection enforcement.

The **2021 amendment to India's Copyright (Amendment) Rules**[45] has streamlined the digital filing process, but the IP audit culture remains weak among startups. Increasing awareness through Semicon India Conferences, expanding industry access to WIPO's IP Diagnostic Tool, and offering tax breaks for successful IP filings are among the policy options discussed in recent industry forums. However, both the tribunal and the task force are at the stage of advocacy as the semiconductor IP framework is evolving, but enforcement and awareness lag behind legislative compliance.

India's IP output in semiconductors is disproportionately driven by multinational R&D centers, with domestic firms significantly lagging. In 2022, Indian entities filed fewer than 2,300 patents compared to over 68,000 by Chinese firms. Furthermore, only two certificates have been granted under the SCILD Act, signaling low awareness and uptake. While IP filings have surged 44% in five years, high-value, locally owned semiconductor IP remains minimal. There is a pressing need to mainstream IP audits, incentivize early filings, and embed IP strategy in startup ecosystems. Government initiatives like the IP Mitra scheme and the National Intellectual Property Awareness Mission (NIPAM) have enabled over two million students and startups to access foundational IP training and support. The IP Mitra initiative provides expert assistance to startups seeking protection for patents, trademarks, and designs[45].

Indian industry remains heavily dependent on foreign technology, often incurring high licensing costs. Licensing and technology transfer mechanisms are largely ad hoc and unstructured. In contrast, countries like South Korea and Japan use consortia and public–private partnerships (PPPs) to drive collaborative R&D and IP commercialization.

India's IP enforcement is fragmented across multiple agencies, resulting in weak inter-agency synergy. While models like Maharashtra's IP Crime Unit offer promise, a nationwide digital enforcement ecosystem is still nascent. A national IP task force, modeled on the U.S. IPR Center, is essential for real-time coordination on IP audits, border protection, and digital piracy mitigation.

Key policy proposals include the formation of a national IP Task Force, creation of specialized IP tribunals, mandatory IP audits for incentive recipients, and the development of Patent Facilitation Cells (PFCs) in academic institutions. Rs 11,000 crore in targeted semiconductor incentives now include IP ownership criteria. SEZ reforms are also underway to integrate IP protection with export-driven semiconductor manufacturing.

Strategic Responses and Policy Measures

Supply Chain Resilience: Building a Robust Ecosystem

Recognizing its late start in semiconductor manufacturing, India has adopted a multi-layered approach to securing its supply chain. Central to this strategy are Production Linked Incentive (PLI) schemes, infrastructure investments in Electronics Manufacturing Clusters (EMCs), and diplomatic initiatives to diversify raw material sources. States like Gujarat, Tamil Nadu, and Telangana are competing to offer tax breaks, power subsidies, and single-window clearances[46] for new fabs. Gujarat's Dholera SIR project and Tamil Nadu's Semiconductor Fab City are notable examples.

At the national level, the Ministry of Electronics and IT (MeitY) has launched the Semiconductor Laboratory (SCL) modernization plan[47] to upgrade legacy infrastructure in Chandigarh for use in defense and high-reliability sectors. Moreover, India's entry into the Minerals Security Partnership[48] (MSP) alongside the US, Japan, and Australia is designed to mitigate dependence on China for critical inputs like gallium and antimony.

Debates remain over India's reliance on assembly versus true fabrication. Some experts warn that over-incentivizing ATMPs could create a low-value assembly trap. The government has responded by

[45]. *"Indian Copyright (Amendment) Rules, 2021,"* Selvams, https://selvams.com/blog/indian-copyright-amendment-rules2021/#:~:text=Vide%20the%20amendment%2C%20the%20CRO,communication%20for%20all%20official%20purposes.

[45] Interview with Shri Amardeep Singh Bhatia, Secretary, DPIIT, Ministry of Commerce and Industry, Government of India. Conducted by Mmhonlumo Kikon, Pacific Forum Fellow, 2025.

[46]. *Gujarat Semiconductor Policy,"* https://gsem.gujarat.gov.in/Home/GujaratSemiconductorPolicy.

[47]. Ibid

[48]. *Gujarat Semiconductor Policy,"* https://gsem.gujarat.gov.in/Home/GujaratSemiconductorPolicy.

increasing fiscal support for full-fledged fabs from 40% to 50% of capital expenditure, conditional upon technology transfer (e.g., Tata's partnership with Powerchip) and local sourcing requirements. Critics still argue for more granular metrics and sunset clauses in these subsidies to ensure long-term viability.

IPR Enforcement: Learning from Global Best Practices

India's export controls—enforced through the SCOMET (Special Chemicals, Organisms, Materials, Equipment, and Technologies) list—only partially align with multilateral export control regimes such as the Wassenaar Arrangement, NSG, and Australia Group. Compared to frameworks like the U.S. EAR or the EU's dual-use regulations, India's controls lack the technical granularity, dynamic updates, and enforcement capability required for global trust. As India seeks deeper integration with U.S., EU, and Japanese semiconductor ecosystems, alignment with global export control norms becomes imperative. Modernizing India's regulatory instruments and building transparent compliance protocols can boost its attractiveness for advanced nodes, sensitive materials, and co-development initiatives.

India's approach to intellectual property in semiconductors is evolving, with growing recognition[49] that robust IPR enforcement is essential for attracting design-centric startups and global chipmakers. The US example offers key insights—wherein cross-agency collaboration, IP audits, customs enforcement, and mandatory IP filings for government procurement have created a comprehensive framework.

India's current enforcement is primarily judicial, often slow and retrospective, though interim injunctions mitigate delays. The absence of specialized IP courts further exacerbates delays and costs. Litigation is expensive and time-consuming, especially for MSMEs and startups, deterring them from proactive IP management. In contrast, the U.S. and Taiwan offer fast-track adjudication systems with interim injunctions that secure competitive advantages quickly.

To address this, a recent NASSCOM–MeitY consultation recommended establishing dedicated IPR benches in High Courts, enabling ex-parte injunctions, and setting up a central repository of semiconductor-related patents accessible to industry (NASSCOM's IP advocacy and existing High court reforms align with the proposed measures). There is also momentum behind creating public-private Patent Facilitation Cells (PFCs) in IITs and NITs, modeled on Japan's University–Industry Collaborations for IP commercialization.

Emerging Policy Gaps and Future Priorities

1. Holistic Integration with Industrial/SEZ Policy: SEZ reforms need to be aligned with IP protection strategies to facilitate domestic filings and IP-led exports.
2. Standard-Essential Patents (SEPs): India's legal framework needs to address SEPs to ensure fair access without disadvantaging new entrants.
3. Environmental and Social IP: India lacks incentives for ESG-linked innovation in green semiconductors, which are increasingly critical to global supply chains.
4. Data Protection and Embedded Software: There is an urgent need for a legal framework to address embedded software, data provenance, and digital design security.
5. International Litigation and Arbitration Readiness: Indian companies must be better prepared for IP disputes in foreign jurisdictions to protect their innovations globally.
6. Foster IP management capacity for SMEs through training in compliance, royalty frameworks, and audits.
7. Extend incentives to cover green and socially impactful IP to future-proof the semiconductor ecosystem.
8. Link SEZ benefits to export-oriented IP creation and streamline global certification pathways for Indian IP assets.

India stands at a pivotal juncture in its journey to become a global semiconductor powerhouse. While commendable progress has been made in aligning with international IPR norms, the path ahead requires deeper structural reforms that move beyond compliance. A robust, innovation-driven IPR ecosystem—supported by fast-track adjudication, mandatory audits, and real-time enforcement—is not just a legal necessity but a strategic imperative. India must evolve from a passive IP user to an active IP

49. *"Intellectual Property Rights for Startups in India,"* Arohana Legal Advocates, April 1, 2024, https://arohanalegal.com/intellectual-property-rights-ip/#:~:text=India's%20approach%20to%20intellectual%20property,socio%2Deconomic%20and%20cultural%20development.

creator and enforcer, capable of defending its semiconductor assets globally.

To ensure sustainable growth in semiconductor R&D and manufacturing, India should adopt a comprehensive, forward-looking IPR strategy that integrates policy, industry, academia, and enforcement agencies. This includes setting up a national IPR Enforcement Task Force, establishing specialized semiconductor IP tribunals, mainstreaming IP education, and building institutional capacity at all levels. Simultaneously, Indian firms—particularly startups and MSMEs—must be empowered with tools, training, and incentives to develop, protect, and commercialize their IP portfolios.

As the global chip war intensifies and the demand for secure, sovereign, and green semiconductor ecosystems grows, India has a unique opportunity to define its own model of IP-led innovation. A proactive and harmonized IPR regime will not only attract investment and foster indigenous capacity but also elevate India as a trusted leader in the global semiconductor value chain.

Talent Development: Aligning Education with Industry Needs

Policy focus has now capitulated a shift toward aligning technical education with semiconductor industry needs. The government has mandated that the All-India Council for Technical Education (AICTE) develop a standardized syllabus on Electronics and VLSI Design, supported by industry advisory boards. IIT Bombay, IISc, and Purdue University have emerged as anchor institutions in this domain, with advanced certificate courses and chip prototyping labs funded by government and corporate sponsors.

The Chips to Startup (C2S) program under MEITy has selected[50] over 265 academic institutions to implement Field Programmable Gate Arrays (FPGA)-based design projects, IP core development, and embedded systems training. Cadence and Synopsys have offered EDA tool licenses to participating colleges, a model that could be scaled nationally through open hardware platforms. A parallel effort is being led by the Electronics Sector Skills Council of India (ESSCI), which collaborates[51] with vocational institutions to offer diploma courses and placement support in semiconductor testing and packaging.

A 2024 industry report estimates[52] that India will require over 300,000 chip professionals by 2027. To meet this goal, policy experts have proposed[53] a National Semiconductor Fellowship Scheme to fund doctoral research, internships at global fabs, and exchange programs. The need for curriculum innovation, faculty development, and certification is widely acknowledged across stakeholder forums such as Semicon India, India Electronics Week, and Global Innovation Summits.

The U.S.US–China Chip War: Implications for India

China's Strategic Advancements Amidst Restrictions

The U.S.–China chip war escalated after the U.S.US imposed sweeping export restrictions on advanced semiconductors and manufacturing equipment in 2019 and 2022,[54] targeting Chinese firms such as Huawei, SMIC, and YMTC (the restrictions disrupted Huawei's supply chain, notably its access to TSMC's 7nm process for HiSilicon's Kirin chips). These measures were aimed at curbing China's access to 7nm and below process nodes crucial for AI, military, and surveillance applications. As a strategic response, China initiated an aggressive localization drive,[55] backed by the US$47 billion Phase 3 of its Integrated Circuit Fund (ICF).

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50. *"Renesas, Meity Partner to Support Startups & Academic Institutions," CW*, May 16, 2025, https://www.constructionworld.in/policy-updates-and-economic-news/renesas--meity-partner-to-support-startups---academic-institutions--/73695.

51. *"Renesas, Meity Partner to Support Startups & Academic Institutions," CW*, May 16, 2025, https://www.constructionworld.in/policy-updates-and-economic-news/renesas--meity-partner-to-support-startups---academic-institutions--/73695.

52. Ayushman Baruah, *"Semiconductor Companies Partner with Academia to Bridge Skills Gap," Entrepreneur*, September 16, 2024, https://www.entrepreneur.com/en-in/technology/semiconductor-companies-partner-with-academia-to-bridge/479886.

53. Ibid

54. *"Chip War: China Claims Breakthrough in Silicon Photonics That Could Clear Technical Hurdle,"* Yahoo Finance, October 6, 2024, https://finance.yahoo.com/news/chip-war-china-claims-breakthrough-093000307.html?guccounter=1.

55. Michael Amato-Montanaro, *"The Chip War: Assessing US Policy Against China Moving Forward," Columbia Political Review*, January 21, 2025, https://www.cpreview.org/articles/2024/11/the-chip-war-assessing-us-policy-against-china-moving-forward#:~:text=In%20response%2C%20beginning%20in%202019%2C%20the%20US,underscore%20much%20of%20the%20international%20tension%20between.

Despite these curbs, Chinese companies have demonstrated remarkable improvisation. Huawei's Mate 60 Pro smartphone, powered by SMIC's 7nm Kirin 9000s chip, was reportedly fabricated using Deep UV (DUV) equipment and multiple patterning—a significant technical feat without EUV technology. Furthermore, JFS Laboratory in Wuhan has made progress in silicon photonics, potentially enabling chip-level optical communication to circumvent traditional limitations of copper interconnects.

China has also diversified its sourcing strategies. It has turned to domestic toolmakers like Naura and AMEC for etching and deposition tools. In addition, it has sought support from neutral trade partners in Southeast Asia (e.g., Singapore and Malaysia) and continued IP acquisition through state-supported cyber-espionage—an issue flagged by multiple Western agencies including CEPA and NATO.

The imposition of semiconductor export controls by the United States, European Union, Japan, and their partners has upended the geography of global technology flows. While these measures predominantly target China, they shape the opportunities and constraints for a broad array of international partners, including India. The ripple effects have led multinationals to reconsider supply chain geographies and compliance practices, creating a complex landscape for all aspiring semiconductor players.

Opportunities for India in a Shifting Geopolitical Landscape

India now has a strategic opportunity to position itself as a trusted node in global semiconductor value chains. By modernizing export control laws and committing to compliance transparency, India can attract global players seeking secure alternatives to China.

Additionally, India needs to pursue targeted diplomacy to deepen its participation in international technology regimes and standard-setting bodies. Strengthening its regulatory compatibility with the U.S. and EU will not only unlock access to advanced chip tools and rare materials but also facilitate smoother technology transfer agreements with global partners.

The global reconfiguration of semiconductor supply chains due to rising techno-nationalism offers India a unique opportunity to become a credible alternative manufacturing base. The "'China+1"' strategy adopted by companies such as Apple, HP, and Dell is reflective of broader sentiment favoring diversification.

India's democratic governance, robust legal system, and large English-speaking STEM workforce position it well to attract strategic investments. This geopolitical tailwind is already visible in Micron's ATMP facility[56] and proposed expansions by Applied Materials and AMD.[57] Furthermore, India's participation in Quad dialogues has led to new working groups[58] on semiconductor supply chain security, underlining its rising profile in techno-strategic arenas.

Nonetheless, India must avoid the trap of over-promising and under-delivering—a criticism often leveled at earlier attempts such as the 2007 SIPS policy. Accelerating land reforms, improving IP enforcement, ensuring timely disbursement of subsidies, and fostering a startup-friendly regulatory climate are essential to convert this geopolitical opportunity into a sustainable industrial advantage.

Regional Geopolitics: Navigating Challenges and Leveraging Opportunities

Border Tensions and Strategic Imperatives

India's strategic posture in South Asia is shaped by its complex relationships with neighboring countries such as China, Pakistan, and Bangladesh. Border tensions with China—especially after the 2020 Galwan clashes—have heightened the urgency for technological self-reliance. The perception that China could weaponize technology access, including critical components and rare earth materials, has pushed India to prioritize secure semiconductor supply chains as a matter of national security.

This sense of urgency is reflected in defense procurement policies that now mandate domestic

56. Subha Mitra, *"India's Semiconductor Growth, Opportunities and Challenges, as Experts Say," Electronics For You BUSINESS*, December 31, 2024, https://www.electronicsforyou.biz/editors-choice/indias-semiconductor-growth-opportunities-and-challenges-as-experts-say/

57. Ibid

58. Ibid

sourcing for electronics systems. The DRDO, BEL, and ISRO have begun coordinating with the Indian Semiconductor Mission (ISM) to secure trusted fabrication sources for strategic-grade ICs. The revival of the Semiconductor Complex Limited (SCL) in Chandigarh is directly linked to this push for a secure, sovereign chip design and production base, especially for avionics, radar, and missile systems.

Moreover, illegal immigration and demographic changes in India's eastern states—particularly Assam and parts of Bengal—create friction that complicates the establishment of industrial clusters in border regions. Securing and stabilizing these areas through economic development, including high-tech hubs, is being discussed[59] within security agencies as a long-term strategy.

Regional Initiatives and Diplomatic Engagements

India is leveraging regional platforms such as the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), the Indian Ocean Rim Association (IORA), and the Mekong–Ganga Cooperation (MGC) to expand its technological and economic influence. These platforms serve as alternatives to China-led initiatives like the Belt and Road Initiative (BRI), and can be used to foster joint research, logistics corridors, and capacity-building in the digital economy.

India's Act East Policy has facilitated semiconductor-related dialogues with ASEAN nations. For instance, Malaysia and Vietnam[60] have been explored as logistical partners for packaging and substrate manufacturing. Furthermore, tThe India–Australia Economic Cooperation and Trade Agreement (ECTA) also includes provisions[61] for joint R&D in high-tech sectors and could become a springboard for raw material sourcing partnerships.

Finally, India's diplomatic corps is increasingly active in semiconductor diplomacy—engaging with embassies, technology attachés, and multilateral forums to secure know-how and investments. The Ministry of External Affairs (MEA) has set up a “'Technology and Strategic Trade”' division (NEST) that works with MEITy, Commerce Ministry, and NITI Aayog to align foreign policy with semiconductor goals.

Beyond investment and infrastructure, India's strategic utility in the global semiconductor equation lies in its normative influence. As a democracy with strong legal institutions,[62] India offers predictability and rule-of-law assurances to global companies navigating geopolitical risks. This aligns well with efforts by like-minded nations to create a values-based technology architecture that excludes authoritarian surveillance regimes. India can leverage its G20 presidency and leadership roles in multilateral forums to frame global norms on secure chip design, ethical AI processing, and data localization—domains tightly interwoven with semiconductor architecture.

Furthermore, India can serve as a neutral testing ground for open-source chip design and RISC-V architecture development. Institutions like IIT Madras, under the SHAKTI processor initiative, have already demonstrated capabilities[63] in indigenous microarchitecture. If supported with international IP sharing and fabrication access, these initiatives can seed a globally competitive design ecosystem free from licensing bottlenecks associated with ARM or x86 ecosystems.

India's regional semiconductor strategy must also account for China's growing footprint[64] through digital infrastructure investments across South Asia. Initiatives like Huawei's fiber-optic networks in Nepal and submarine cable projects in the Maldives reflect Beijing's ambition to control not only terrestrial but also digital chokepoints. India's counter-strategy should include tech diplomacy tools that integrate chip and telecom supply chains, offering secure alternatives via EXIM financing, joint R&D, and local manufacturing support in neighboring states.

In this context, India's collaboration with Bangladesh, Sri Lanka, and Myanmar could have been pivotal, although it may take sometime for that to start given

59. *“Illegal Migration: Current Affairs,”* Vision IAS, March 21, 2024, https://visionias.in/current-affairs/monthly-magazine/2024-02-15/security/illegal-migration.
60. *“Act East Policy,”* Press Information Bureau, December 23, 2015, https://pib.gov.in/newsite/printrelease.aspx?relid=133837.
61. Ibid
62. Ibid
63. Ryōhei Kasai, *“Collaboration and Confrontation: Geopolitics, Global Affairs, and the India-China Relationship,” nippon.com*, March 11, 2024, https://www.nippon.com/en/in-depth/a09503/collaboration-and-confrontation-geopolitics-global-affairs-and-the-india-china-relationshi.html.
64. Ibid

the geopolitical shifts. Offering design centers, training exchanges, and subsidies for packaging units in these countries may not only expand India's chip ecosystem footprint but also build strategic goodwill and dependency. This model, akin to Japan's post-war industrial diplomacy in Southeast Asia, enables India to project soft power while ensuring that regional semiconductor value chains remain outside China's coercive reach.

Conclusion: Charting the Path Forward

India's rise in the semiconductor domain will depend not only on internal capabilities but also on its external credibility. As multilateral export controls become a defining feature of global chip governance, India's alignment with trusted trade and technology regimes will be vital. By presenting itself as a transparent, rule-abiding, and democratic partner, India can help re-anchor the global semiconductor value chain in an era of realignment.

Proactive engagement with regulatory coalitions, investment in export control infrastructure, and participation in supply chain harmonization efforts will transform India from a reactive beneficiary to a co-shaper of global semiconductor norms.

India stands at a pivotal juncture in its semiconductor journey. With decades of missed opportunities behind it, the convergence of global geopolitical realignments, domestic policy momentum, and strategic collaborations offers a rare second chance to build a resilient and competitive semiconductor ecosystem. However, the path ahead demands not just ambition but executional discipline and institutional coherence.

First, India must move beyond aspirational announcements and focus on delivery. Projects under the Indian Semiconductor Mission must be monitored through rigorous KPIs—such as construction milestones, job creation, IP filings, and export readiness. Mechanisms like the Project Management Group (PMG) at Invest India must be empowered to troubleshoot delays and ensure coordination among ministries, states, and private players.

Second, policy must evolve from static subsidies to dynamic ecosystem-building. This includes reducing input costs (land, energy, water), developing global R&D alliances, and enabling venture capital access for semiconductor startups. States must also be active stakeholders, tailoring industrial policies to their local strengths in logistics, manpower, or minerals.

Third, India's higher education and skilling systems need structural transformation to meet the industry's demand for specialized roles—from lithography engineers to EDA tool developers and materials scientists. Cross-border academic partnerships, industry sabbaticals for faculty, and outcome-based technical certification must become the norm rather than the exception.

Fourth, India should approach the geopolitical opportunities arising from the U.S.US–China chip war with strategic clarity. By positioning itself as a neutral, democratic, and reliable partner, India can offer an attractive alternative for firms seeking to diversify beyond China. Leveraging initiatives such as the Quad Semiconductor Supply Chain Partnership and strengthening the role of diplomatic technology attachés can help attract foreign direct investment, expand market access, and secure critical imports.

Finally, India must develop its own vision for semiconductor sovereignty—wherein national security, economic competitiveness, and technological self-reliance intersect. This means balancing global partnerships with domestic innovation, openness with strategic caution, and state support with entrepreneurial freedom.

If India succeeds, its semiconductor ecosystem could generate[65] over a million direct and indirect jobs, reduce the electronics import bill by billions, and enable technological breakthroughs in AI, defense, space, and green energy. The moment is now—what India does in the next five years will determine whether it becomes a hub in the global semiconductor map or remains a hopeful peripheral player.

65. *Semiconductor Sector to Create 1 Million Jobs in India by 2026, Says Report,"* *The Economic Times*, November 11, 2024, https://economictimes.indiatimes.com/industry/cons-products/electronics/semiconductor-sector-to-create-1-million-jobs-in-india-by-2026-says-report/articleshow/115185757.cms?from=mdr.

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Securing India's Semiconductor Supply Chain—A Strategic Outlook

By
Vidhyashankar Sathyamurthi

Executive Summary

Vidhyashankar Sathyamurthi

India's semiconductor and electronics manufacturing ecosystem is undergoing a transformative phase, driven by strategic policy initiatives, geopolitical imperatives, and rapid technological advancements. With a projected $100 billion domestic semiconductor demand by 2030, India aims to transition from a global design hub to a full-stack semiconductor powerhouse. Key developments include:

- **Strategic Investments**: Over $20 billion in semiconductor projects announced under the India Semiconductor Mission (ISM), including Tata's 28nm Dholera fab (mass production by Q4 2025) and Micron's Sanand ATMP facility (operational by 2026).
- **Geopolitical Alignment**: Enhanced US-India collaboration through initiatives like iCET/TRUST and the $100 million ITSI Fund, focusing on dual-use technologies and supply chain resilience. With relaxation of AI diffusion framework, it will augur well for India AI Mission and India Quantum Mission directives directly impacting access to GPUs.
- **Supply Chain Risks**: Recent incidents (e.g., tampered pagers in the Israel-Hezbollah conflict) underscore vulnerabilities in outsourced electronics manufacturing, accelerating India's push for indigenization. The rare earth mineral access (40% imported from China). The impending trade deal between US-India will play a decisive role in shaping the future of global partnerships, India's foreign policy push areas.
- **Talent & Ecosystem Gaps**: Despite a robust fabless design talent pool, challenges persist in skilled workforce availability, ecosystem of ancillaries/SMBs and overall infrastructure. Fortunately, India has a great base of STEM graduates, skill development through National Skills mission program and private sector focus on continued workforce development.

India's policy successes in mobile manufacturing (97% localization, $4.1 lakh crore production in 2024) and Production Linked Incentives (PLI) schemes provide a blueprint for semiconductor growth. However, strategic imperatives include scaling R&D, support the proliferation of private capital industry like venture capital, private equity and private debts, securing critical minerals, and balancing export controls with innovation through policy measures like Design Linked Incentives (DLI) and like Chips-2-start-ups programs.

Introduction

As India steps into the second half of the decade, it is no longer just a participant in the global technology race—but a contender for leading the world economy—IMF estimates more than 6% growth for the next two years.[1] The year 2025 marks a watershed moment: India has consolidated its position as the world's fourth largest economy and is rapidly transforming into a technology manufacturing powerhouse with a strong policy push to Make in India.

Central to this trajectory is India's fast paced digital economy fueled by its semiconductor strategy—a self-sustaining mission that transcends industrial policy into the realms of national security, digital sovereignty led public infrastructure and electronic warfare supremacy.

India's chips race albeit two decades late, started in the '80s through the Semi-conductor Laboratory (SCL), it regained momentum with the India Semiconductor Mission (ISM) in 2021, that has unlocked nearly $10 billion worth of semiconductor investments in the country spread across different regions, including ATMP+Fabs facilities by leading manufacturers like the TATA group, Micron Technologies, and Taiwan's PSMC.[2]

As AI and advance technologies like quantum computing accelerate and the space race heats up, the need to indigenize and protect the supply chain has become paramount for India—it has had a very strong fabless engineering design talent pool since the 1980s, starting with Texas Instruments opening shop in the salubrious clime of Bangalore, the garden city- with various science & technology establishments like the Indian Institute of Science (IISc) and Hindustan Aeronautics Ltd (HAL), fast growing metropolis has over the years attracted a very strong technology talent pool, earning the moniker Silicon Valley of India[3]—today the city is a thriving bedrock of start-ups both software and hardware, in addition to a huge number of Global Capability Centers (GCC)—Goldman Sachs has the second-biggest office.[4] In a world gripped by great-power rivalries and dual-use technology dilemmas, India's policy initiatives in electronics manufacturing and chip indigenization have become pivotal. The Indian Air Force, for example, has signaled a generational shift in its warfighting doctrine with the recent achievements in Operation Sindoor, pin-point accuracy led combat against terrorism arising from Pakistan. The recent *Gagan Shakti 2025* exercise featured electronic warfare simulations powered by indigenous AI-enabled chips developed through a joint initiative between Bharat Semi and 3rdI Technologies. India now possesses electronic countermeasures (ECM) and electronic counter-countermeasure (ECCM) capabilities rivalling global standards, leveraging custom silicon designed and fabricated onshore.

During a recent visit to India, the CEO of Nvidia, a leading chip design and manufacturing company, which is one of the most valuable public listed company in the world—at a peak share price of $158 as of August 2024[5] (a 3,000% increase in the last five years) with a current market capitalization of nearly $3 trillion—a little more than the GDP of Brazil and only slightly short of France's GDP—unveiled various collaborations in India to support the AI needs of the data centers in India. The demand for Nvidia chips is fueled by the boost in AI-led computing and a robust supply chain with many partners, primarily TSMC, the Taiwanese integrated circuits (IC) manufacturing giant which has garnered 90% of the markets on high-end chips, which is less than 10nm and a 68% share in other nodes like 28nm and above. India's semiconductor mission is aimed at ensuring both technological self-reliance and national security, with ambitions to meet a projected $100 billion domestic demand by 2030. This mission is not just industrial—it's strategic.

Chip sovereignty is now deeply tied to battlefield superiority and digital resilience. India's one the largest conglomerate—Tata Electronics Limited's 28nm Dholera fab is slated to reach mass production

[1] "India: Fastest-Growing Major Economy," https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=2123826.

[2] Swarajya Staff, "India's Semiconductor Goals: Tata And Taiwan's PSMC Seal Deal For Technology And Design Support For Dholera's Wafer Fab," Swarajyamag, https://swarajyamag.com/news-brief/indias-semiconductor-goals-tata-and-taiwans-psmc-seal-deal-for-technology-and-design-support-for-dholeras-wafer-fab.

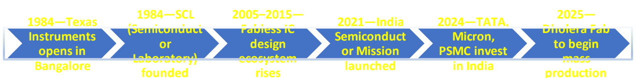
[3] Nucleus_AI, "From Garden City to Tech Titan: How Bangalore Became India's Silicon Valley," https://yourstory.com/2024/03/garden-city-tech-titan-bangalore-indias-silicone-valley.

[4] Business Standard, "Goldman Sachs' Biggest Office beyond New York Attests to India's Rise," https://www.business-standard.com/finance/news/goldman-sachs-biggest-office-beyond-new-york-attests-to-india-s-rise-123061400100_1.html.

[5] Reuters, "Nvidia Overtakes Apple as World's Most Valuable Company," Technology, *The Hindu*, Oct. 26, 2024, https://www.thehindu.com/sci-tech/technology/nvidia-overtakes-apple-as-worlds-most-valuable-company/article68799036.ece.

by Q4 2025, while USA's Micron's ATMP facility in Sanand will begin volume output of memory chips by early 2026; Japan's Renesas Technologies through the JV with CG Power group is all set to roll out their first chip by mid 2026. These timelines demonstrate India's accelerated shift from being a global design hub to a complete semiconductor ecosystem player capable of serving defense, space, and telecommunications sector needs. The thrust is one to be a significant player across the value chain—there are 6 fab facilities launched as part of ISM and the IT minister of India, Ashwini Vaishnav, recently, unveiled the design of a 3nm indigenous chip.[6]

India's Semiconductor Policy Timeline (1984–2025)



Where is India in the global chips order?

In India's "techade" of growth and the race to global pole position as the world's third-largest economy, the role of a robust domestic semiconductor industry is paramount if India must sustain its technological prowess and garner sustainable advantages of digitalization.

India's semiconductor mission is aimed at providing a boost to the indigenization of the silicon wafer supply chain to cater to the growing demand for chips, expected to reach $100 billion in 2030 by various estimates, and secure against export controls and geopolitical risks. The rare earth minerals for ICs and EVs are dominated by China, thus putting India at a significant disadvantage from a supply chain as well as trade imbalance perspectives.

Nation states have long competed for VRIN (valuable, rare, inimitable, and non-substitutable) resources—the new frontier for long-term sustainable competitive advantage is clearly in building patented digital technologies, particularly access to advanced ICs that drive almost all modern innovations including quantum computing, AI, space technology, and telecommunications.

For India to secure its chips supply chain, it ought to leverage its capability to "Make in India" and for the world. The five large fab projects announced through the Indian Semiconductor Mission—a policy-led growth framework helping attract investors in chip manufacturing—the TATA group, Micron etc.—for both fabs and OSAT/ATMP are a great start in the chip race to de-risk various ongoing geopolitical tensions that have become a real strain on multilateral relations, threatening the strategic autonomy of India, that believes in a multipolar world.

The domestic market for 28nm chips is massive and if we go by the latest announcements from the Indian IT minister, they should start yielding results from 2024 onwards. However, there are several unanswered questions with respect to the readiness of the regional Indian states in successfully operating the fabrication units either they lack the workforce and infrastructure or purely greenfield.

India has been well-known for fabless designs,, however, to secure the chips supply chain, indigenous manufacturing is the need of the hour—a robust ecosystem which is sorely lacking is a big stumbling block—particularly in regions that don't have a manufacturing base—lack of a skilled workforce, access to green power if we care for the environment (unlike China), the largest consumer of coal power; devoid of local issues unlike Singur in the Hooghly district of West Bengal; access to water, transport, and logistical support and, of course, a smooth land-acquisition process that supports the long-term viability of such highly capital intensive projects.

One might argue that domestic politics impact the choice of locations when regions like Karnataka and Tamil Nadu should have been frontrunners given their comparative advantage in access to talent, R&D,

[6] "[2025] Semiconductor Fabrication Plants in India | Latest Update," Latest Global Construction Industry Projects (2024) - Blackridge Research & Consulting, September 12, 2025, https://www.blackridgeresearch.com/blog/latest-list-top-semiconductor-chip-wafer-manufacturing-fabrication-plant-facility-projects-in-india.

and a manufacturing ecosystem. Be that may, what's important to understand is that we need to secure our supply chain at the earliest, however, only time will tell if these locations have been the right choice. Nevertheless, we ought to acknowledge the wisdom of the TATA group, Micron and others IC players besides the government of India who all are investing billions in capital outlay to build a fab industry in India, hitherto non-existent for many decades despite a robust fabless, IC design culture—responsible for churning high impact patents out of India but owned by large American multinationals like Intel, TI, Micron, AMD, Qualcomm to name few.

If we know the history of the semiconductor industry, The Chip War by Chris Miller captures the geopolitical impact of the chip industry and the clear role national governments have had in fueling their domestic chip industries. It is astonishing that Taiwan has managed to retain leadership in chip manufacturing with South Korea and China as alternatives.

Japan, despite being the early consumer electronics stalwart, has backslid in chip manufacturing and exports despite easy access to capital through cheap interest rates and a growing market presence in the US from the 1980s. The reason some of these Asian countries had a head start from the 1960s onwards is the policy focus of their respective governments in understanding the shift in the world power—from fossil fuel to chips. They understood that software will eat everybody's lunch and that silicon chips are fueling the appetite.

"Better late than never" seems to be the mantra for India to race against time to establish a secure integrated circuits supply chain. The role of US-India partnership through various initiatives like iCET[7] (Initiative for Critical and Emerging Technologies) now rebranded as TRUST[8] (Transforming the Relationship Utilizing Strategic Technologies), Innovation Handshakes, and MSP (mineral security partnerships) are paramount in spurring exciting Indian startups like Cosmic Circuits, Saankhya labs etc., that are building frontier technologies expected to Make in India program come alive.

The Quadrilateral Security Dialogue ("Quad") is going to be a significant game-changer—continuing to garner support on building fabless technologies and ensuring access to rare earth minerals that help in withstanding supply shocks. The race has just begun for India, and for initiatives like the Indian Semiconductor Mission, it is time to walk the walk.

India's policy success in electronics manufacturing

In the recent Israel-Palestine conflict, there is a credible explanation for the remote detonation of multiple pagers targeting Hezbollah in September'24—the tampering with pagers and walkie-talkies, inserting limited blast-range explosives to function like an IED. However, the overheating of pagers to explode is increasingly being ruled out. Nevertheless, the question remains: how did they manage to physically tamper with the pagers?

And furthermore, what can countries do to secure their supply chains against such tampering? India, a nation with ambitious plans for its semiconductor industry that faces a challenging security environment, is one example of a country that must start taking such steps.

This issue highlights the perils of a complex supply chain and contract manufacturing lapses. The intended motives, and the brazenness of the entire operation aside, the supply chain risks associated with outsourced electronics manufacturing is a huge warning for countries facing geopolitical risks who remain highly dependent on imports of electronics goods.

In this case, the Taiwan manufacturer Gold Apollo has been under media scrutiny and the statement by the CEO is alarming—indicating the use of its brand name by the Hungarian manufacturer BAC without oversight—one cannot simply wash away responsibility due to contract manufacturing, even if it remains to be seen whether the manufacturer was in cahoots with the perpetrators. A blatant case of tampering requires extensive knowledge of the communications devices, be it mobile pagers or walkie talkies, not only to escape surveillance but,

[7] "The US–India Initiative on Critical and Emerging Technology (iCET) from 2022 to 2025: Assessment, Learnings, and the Way Forward | Carnegie Endowment for International Peace," https://carnegieendowment.org/research/2024/10/the-us-india-initiative-on-critical-and-emerging-technology-icet-from-2022-to-2025-assessment-learnings-and-the-way-forward?center=india&lang=en.

[8] "The India-US TRUST Initiative: Advancing Semiconductor Supply Chain Cooperation | Carnegie Endowment for International Peace," https://carnegieendowment.org/posts/2025/04/the-india-us-trust-initiative-advancing-semiconductor-supply-chain-cooperation?lang=en&center=india.

unfortunately, rigged to deliver multiple blasts through a simple text code.

Policymakers and the security apparatus the world over have an urgent task at hand, lest again this type of technology hack be deployed as a tactic of scaled destruction. This incident reiterates the supply chain risks for countries like India, and why securing the electronic supply chain is so crucial. With a nascent semiconductor industry, India's Semiconductor Mission has its task cut out-go beyond the manufacturing of integrated circuits (ICs) in India—the various fabrication (fab) and assembly, testing, marking, and packaging (ATMP) facilities will come to fruition in few years' time-however, the rare earth supply is extremely critical and may stymy the entire effort. Taiwan is in the middle of it all because of the practice of contract manufacturing with minimal control, which after the Hezbollah attack may have effects including the possible banning of such devices in closed spaces including airports, airplanes, and trains.

Countries such as India have two big challenges arising from the pager/communications device blast incident—securing its critical mineral supply and indigenizing the manufacturing value chain. For example, can more than 50% of mobile phones and other communications consumed in India be localized?

Can a state or a non-state actor effect a disaster of such scale for mobile phone users in India, and will mobile phones be tampered with to create large-scale havoc? Behind chip production sits a vast network supplying equipment and all other items encompassing hundreds or more of raw materials, chemicals, consumable parts, gases, and metals without which the painstakingly precise process of chipmaking could not function. The PRC is directing a combined 1.5 trillion yuan ($221 billion) of public and private investments to replicate a chip supply chain within its own borders, with modest results to date.

How can India and other countries looking to secure their tech supply chains minimize such scenarios? By pushing for 100% localization in critical industries—be it in electronics or data centers—and is that even feasible? Furthermore, is the current policy framework sufficient to handle this?

The Semiconductor Laboratory (SCL)—established in Chandigarh in the 1980s and now under the control of Ministry of Electronics and Information Technology—has always been an R&D-led public sector unit (government-run business) with limited production of 180nm chips particularly for ISRO (Indian Space Research Organization), and was earlier under the control of the Department of Space. Now, with the change in guardship and increased impetus to the India Semiconductor Mission, SCL may want to increase capacity, be subject to higher accountability and more importantly, invest heavily in R&D for strategic industries to support critical technology. It will be worthwhile to see the changing fortunes of SCL, given the renewed faith of MEITY (Ministry of Electronics & IT) that will test its capability to carve a niche in the open market aiding indigenization at one level while securing the supply of ICs plus critical materials at a strategic level.

An Indo-US joint announcement during Prime Minister Modi's 2024 state visit, under the Global Digital Development Partnership promises indigenous development of ICs specifically for the US military through a three-way partnership between Bharat Semi, 3RDI Technologies, and the US Space Force. This is monumental in that a critical industry like Aerospace & Defense trusts in the technological advancements of Indian start-ups. The ongoing Operation Sindoor undertaken by the government of India to weed out cross border terrorism showcases the role of defense technology startups playing a crucial role in space age warfare doctrine of India.[9]

Bharat Semi, an upcoming defense business has an ongoing relationship with the US Space Force and 3rdI Tech, an extension of the Indian defense innovations entity IDEX. The chips to be named Shakti, is expected to power the frontier capabilities of US military through desi (colloquial for Indian or meaning native) innovations, signaling a huge thumbs up from both the countries.[10]

And, similarly, under the International Technology Security & Innovations Fund (ITSI), the US has

[9] Ashish Kumar, "Operation Sindoor: A Wake-Up Call for Indigenous Tech Startups and MSMEs," accessed September 14, 2025, https://smestreet.in/smestreet-exclusive/operation-sindoor-a-wake-up-call-for-indigenous-tech-startups-and-msmes-9063038.

[10] Prashant Jha, "This Is India's Taiwan Moment, There Is No Turning Back: Bharat Semi Founders," Hindustan Times, Sept. 23, 2024, https://www.hindustantimes.com/world-news/this-is-india-s-taiwan-moment-there-is-no-turning-back-bharat-semi-founders-101727102876329.html.

allocated about $100 million for various countries, including India to support IC design and manufacturing.[11] Now more than ever, to build upon mutual trust, the protection of IP and export control becomes a strong focus area given the dual-use nature of these critical technologies.

During the Semicon'24, a slew of fab investments was announced, though mainly in the ATMP areas except for Tata's plant in Dholera, in the state of Gujarat in the western part of India that also has a fab facility for 28nm nodes. We still need more such investments in fab foundries to manufacture; however, ISM has set the ball rolling and it is a matter of time for an entire ecosystem around high-tech manufacturing to spring up, be it in NOIDA, Dholera, or Sanand in the western state of Gujarat or even Morigaon, Assam in the north east mountainous state closer to national boundaries with China. However, localization of the electronics supply is crucial to sustain demand and hedge against geopolitical, supply chain risks which only seems to be rising in these tumultuous times.

Domestically, there is robust activity in the mobile phones sector, TATA recently consolidated their manufacturing of Winstrom facilities and Foxconn expanding footprints among others, bolstering the capabilities clusters across the country. In value terms, mobile phone production jumped 21-fold to Rs 4.1 lakh crore in India in the last 10 years as government policy measures like production linked incentives (PLI) played a critical role in attracting global players to boost local production, industry body ICEA said in a statement. India now produces 97 per cent of its total mobile phone demand locally and 30 per cent of the total production in financial year 2024 is meant for export, the India Cellular and Electronics Association (ICEA) said.

In May 2017, the Indian government announced the Phased Manufacturing Program (PMP) to promote the domestic production of mobile handsets. This initiative helped build a robust indigenous mobile manufacturing ecosystem in India and incentivized large-scale manufacturing. From just two mobile phone factories in 2014, India now has become the second-largest mobile phone producer in the world.[12] According to a note on manufacturing, in the field of smartphones, Apple and Samsung, have played a crucial role in boosting mobile phone exports from the country.[13] The Production Linked Incentive scheme for large-scale electronics manufacturing (LSEM) and for IT hardware has played an instrumental role in making India a competitive destination for electronics manufacturing. The PLI scheme offers incentives ranging from 3 to 5% of the incremental sales value for a stipulated period to eligible players. The PLI scheme has attracted leading global contract manufacturers, including Foxconn, Pegatron, Rising Star, and Wistron to set up production bases in India. Samsung, on the other hand, operates its second-largest mobile phone factory in Noida, in the largest populated state of Uttar Pradesh (UP).

The Indian government has launched a $3 billion incentive scheme for boosting electronics component production in India—the domestic demand is expected to raise from the current $45bn to $240bn by 2030. This is aimed at ensuring India captures 30-40% of the electronics value chain to augur the production of chips as already laid out for dual use purposes.

India-US Semicon partnership: Cornerstone of India's Chips mission

Semiconductors are the backbone of the digital economy. By 2030, digital technologies are expected to account for over 70% of global GDP, according to the World Economic Forum.[14] India's ambition is that Digital economy contributes at least 20% of its GDP by 2047,[15] making access to advanced technologies and resilient semiconductor supply chains central to its growth. In this context, the India–US technology partnership has emerged as a strategic pillar**,** accelerating India's semiconductor ambitions

[11] "Department of State Allocating $100 Million in FY 2023 for CHIPS Act Projects," *United States Department of State*, n.d., https://2021-2025.state.gov/department-of-state-allocating-100-million-in-fy-2023-for-chips-act-projects/.

[12] "India Rises to Become the World's 2nd Largest Mobile Manufacturer; From 2 Units in 2014, over 300 Units Are Operational Nationwide Today: Sh. Ashwini Vaishnaw," https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=2099656.

[13] "Mobile Phone Manufacturing Jumps 21 Times to Rs 4.1 Lakh Cr in 10 Yrs: ICEA," *The Economic Times*, March 10, 2024, https://economictimes.indiatimes.com/industry/cons-products/electronics/mobile-phone-manufacturing-jumps-21-times-to-rs-4-1-lakh-cr-in-10-yrs-icea/articleshow/108367726.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst.

[14] "Why Tech Diplomacy Is Key to Embracing the Digital Economy #wef24," World Economic Forum, Dec. 28, 2023, https://www.weforum.org/stories/2023/12/tech-diplomacy-harness-digital-economy/.

[15] "India to Become $1 Tn Digital Economy by 2028 - The Economic Times," accessed September 14, 2025, https://economictimes.indiatimes.com/news/economy/indicators/india-to-become-1-tn-digital-economy-by-2028-enabled-by-internet-4g-5g-and-digitalisation/articleshow/113875328.cms?from=mdr.

through collaborative frameworks, trade alignment, and supply chain diversification.

Strategic Momentum Under Renewed US Leadership
With former President Donald Trump returning to the White House, expectations are high that US trade and tech policies will become more security-driven and transactional, particularly in curbing China's rise in legacy and advanced nodes. However, India's net importer status and geopolitical alignment position it favourably amid shifting US trade barriers. With the change in AI diffusion framework, it remains to be seen of there's going to be a fundamental shift in restricting Chips access to China.

iCET/TRUST, and the Rise of INDUS-X

India's semiconductor playbook has been meaningfully shaped by the Initiative on Critical and Emerging Technologies (iCET) and its successor framework, Transforming Relationship Utilizing strategic Technologies (TRUST)—developed jointly by the National Security Councils of both countries. These initiatives enable dual-use tech transfer, accelerate innovation, and strengthen strategic trade alignment. A standout outcome is INDUS-X, a joint defense innovation accelerator powered by India's iDEX (MoD) and the US Defense Innovation Unit. It has already incubated start-ups in AI, quantum, biosecurity, space, and autonomous systems, laying the foundation for a new generation of trusted dual-use hardware.

India Semiconductor Mission: Policy, Production, and Partnerships

India's $10 billion India Semiconductor Mission (ISM) continues to gain traction, with marquee investments (Tata, Micron) backed by supportive state-level facilitation—land, utilities, and talent. The recently announced 5% cut in electronics hardware imports (from 2025) is a bold step toward strategic self-reliance and bolstering the rupee through electronics exports.

India's strength in chip design and software talent is proven—but high-tech manufacturing needs scale. Like Taiwan and China before it, India must unlock large-scale workforce pipelines for chip assembly, packaging, and testing. Initiatives like the Chips-to-Start-ups program, DLI scheme, and National Skills Mission aim to bridge this manufacturing talent deficit.

Critical Minerals and Supply Chain Geopolitics

Access to rare earths and critical minerals remains a vulnerability. India is working with the Minerals Security Partnership and Quad partners to de-risk the supply chain. As no country controls the entire semiconductor value chain—some dominate in materials, others in tools or IP—India's goal to localize >50% of mobile and whitegoods components is both necessary and achievable.

India's aspiration to become a preferred supplier for dual-use electronics, including chips for space and UAVs (e.g., the MQ-9B deal), marks a critical inflection point. This demands alignment not only in trade but also in export control regimes and trusted manufacturing standards.

Export Controls, Technology Trust, and Entity Screening

While India's multi-alignment foreign policy presents some friction, this has been deftly navigated. The US State Department and India's MEA have proactively organized compliance workshops with OEMs and start-ups (e.g., in Bangalore), and are working on jointly managing entity lists to avoid misuse of critical technologies. Export controls, therefore, serve not only as safeguards but also as enablers of deeper cooperation.

The India–US Tech Transfer Platform is now active, aligning defense, commerce, and digital policy bodies from both countries. The September 2022 announcement of a strategic partnership between MeitY and the US State Department under the ITSI Fund provides financial scaffolding to scale commercial and defense innovations.

Subnational Diplomacy and Competitive Federalism
The recently held Semicon India and ITU 2025 events in NOIDA showcased how Indian states are now directly pitching to investors, cutting red tape, and prioritizing zero graft environments. States with existing clusters and talent bases will gain faster traction—fueling cooperative and competitive federalism under the Atmanirbhar Bharat vision.

India's semiconductor roadmap is no longer aspirational—it's operational. The India–US partnership, rooted in trust, trade, and technology, is now the cornerstone of India's chips mission. The convergence of geopolitical strategy, policy alignment, and private capital flows positions India as a rising force in the global semiconductor supply chain.

As the new US administration recalibrates strategic priorities, India's role as a trusted, democratic, and capable tech partner should be central—not just to counterbalance China, but to co-create a secure, diversified, and innovation-led digital future.

De-risking dual-use technologies: a progressive IP protection & export controls mechanism required.

Given the Trump administration's priorities for the US and, as a continuation of extant policy, restrictive tariffs and outright sale of GPUs and other IC components of dual-use technology have been enforced by the US State Department and Bureau of Industry and Security (BIS) at the US Commerce Department.

The US department has an entity list of 150 such companies to restrict flow or technology products to Chinese companies and indirectly to the communist regime. Of course, China has a swift outright ban on Gallium, Germanium and Antimony as part of the critical minerals resource supply which is now under scanner to facilitate access to H20 chips from Nvidia. Now, this is very typical of adverse nations trade tariffs on dual use technologies from a technological progress perspective but given the way Deep Seek's success has reshaped narratives and the current geopolitical thinking, proliferation of ethical, IP backed critical technologies sounds a progressive approach to sustain democratic values whilst exercising control on dual use and rogue state/nonstate actors.

The India-US relationship is built on democratic values, albeit some discomfort over India's stated position in multipolarity and strategic autonomy. However, on the back of strong confidence building measures like TRUST and COMPACT—there is room for focused dialogues, assuaging doubts and problem-solving mindset in the interest of the larger trajectory of partnership between the nations.

Both countries have entity lists to prevent bad actors from accessing critical technologies which is an ongoing exchange of information to ensure checks and balances when it comes to dual-use technologies. India has also the SCOMET (Special Chemicals, Organisms, Materials, Equipment and Technologies) However, the policy towards adversaries and friendlies need distinction—for example, the earlier version of the AI Diffusion framework, the tiers were perceived as a setback to the relationship.

A balance of export controls and IPR protection laws are required to continue building trust and facilitate increasing transfer of technologies for mutual benefits as more and more private enterprises and startups are involved between the nations.

Distinct features of Export Control & IPR

Feature	Export Control	Intellectual Property (IP) Protection
Focus	Preventing proliferation of weapons of mass destruction and other military applications.	Protecting the rights of inventors and businesses to their creations.
Scope	Primarily concerned with the physical transfer of technology across borders.	Broadly encompasses patents, trademarks, copyrights, and trade secrets.
Legal Basis	International treaties, national laws, and regulations.	National and international laws, treaties, and conventions.
Enforcement	Government agencies (e.g., customs, intelligence)	Courts, law enforcement agencies
Key Mechanisms	Licensing requirements, end-use controls, embargoes	Patents, trademarks, copyrights, trade secrets
Benefits	National security, regional stability, non-proliferation	Innovation, economic growth, competitive advantage
Challenges	Balancing national security with economic interests, keeping pace with rapid technological advancements	Protecting against infringement, maintaining confidentiality, enforcing rights in different jurisdictions
Relationship	Export controls can indirectly impact IP protection by restricting the transfer of technology that may embody intellectual property.	IP protection can be a tool to enhance export control effectiveness by providing legal means to control the dissemination of sensitive technology.

Table 1: A comparison of features of IPR protection and Export control mechanisms

Dual-Use Technologies: Approaches to Protection

Dual-use technologies are those with both civilian and military applications. This dual nature presents unique challenges for their management and protection.

In essence:

- Export control aims to prevent the misuse of technology for harmful purposes.
- IP protection aims to incentivize innovation and reward creators for their work.

While distinct, these two areas are interconnected, and their effective implementation is crucial for managing the risks and rewards associated with dual-use technologies in the 21st century.
Export control mechanisms for dual-use technologies vary significantly across countries, but generally aim to prevent the proliferation of weapons of mass destruction and other military applications while allowing for legitimate civilian uses.

Key aspects of export control mechanisms:

- **Identification of controlled items:** Countries maintain lists of dual-use items subject to export controls, often based on their potential military applications. These lists can be extensive and complex, covering a wide range of technologies, from advanced materials and electronics to software and biotechnology.
- **Licensing requirements:** Exporters are typically required to obtain licenses from their government to export controlled items to certain destinations or end-users. The licensing process involves assessing the potential end-use of the technology and ensuring it will not be used for prohibited purposes.
- **End-use controls:** Many countries focus on controlling the end-use of exported technologies, rather than simply restricting exports to certain countries. This involves tracking the final destination and use of the technology to prevent its diversion to unauthorized activities.
- **International cooperation:** Several multilateral agreements and regimes facilitate international cooperation on export controls, such as the Wassenaar Arrangement, the Nuclear Suppliers Group, and the Australia Group. These forums help coordinate control lists, share information, and develop common approaches to addressing emerging technologies.

Examples of countries with notable export control regimes:

- **United States:** The United States has one of the most comprehensive and stringent export control regimes, administered by several government agencies, including the Department of Commerce and the Department of State.
- **European Union:** The EU has a unified export control regime that applies to all member states. It is based on the EU Dual-Use Regulation, which sets out detailed rules for the export, transfer, and brokering of dual-use items.
- **China:** China's export control regime has become increasingly sophisticated in recent years, with a focus on protecting critical technologies and preventing their unauthorized transfer.

Challenges and considerations:

- **Rapid technological advancements:** The rapid pace of technological innovation makes it challenging to keep export control lists and regulations up-to-date.
- **Global supply chains:** The complexity of global supply chains can make it difficult to track the movement of dual-use items and ensure they are not diverted to unauthorized uses.
- **Balancing national security with economic interests:** Export controls can have significant economic impacts, and governments must carefully balance national security concerns with the need to maintain a competitive global economy.
- **Emerging technologies:** The rise of new and emerging technologies, such as artificial intelligence and biotechnology, presents new challenges for export control regimes, as their potential military and civilian applications are often unclear.

It's important to note that export control regimes are constantly evolving in response to new threats and technological developments. Understanding the specific requirements and regulations of different countries is crucial for businesses involved in the export of dual-use technologies.

The US has increasingly stringent export controls on advanced technologies, particularly those with potential military applications, to limit their access by China. These controls aim to maintain US technological superiority and prevent China's military modernization.

Here's a comparison of US export control measures vis-à-vis the mentioned countries:

- **China:**
    - Most stringent: The US has implemented significant restrictions on the export of semiconductors, AI chips, and other advanced technologies to China.
    - Focus: Preventing China's military and technological advancement, particularly in areas like supercomputing, artificial intelligence, and hypersonic.
    - Impact: Significant disruptions to Chinese tech companies and industries reliant on US technology.

- **Japan, South Korea, Australia, EU:**

Less stringent: While these countries also have their own export control regimes, the restrictions on exports to them are generally less severe than those imposed on China.

Focus: Primarily on preventing proliferation of weapons of mass destruction and maintaining national security.

Cooperation: The US collaborates with these countries on export control matters through multilateral agreements like the Wassenaar Arrangement.

Key Considerations:

Technological Competition: The US-China technological competition is a major driver of these export control measures.

Global Supply Chains: These restrictions have significant impacts on global supply chains, particularly in the semiconductor industry.

Geopolitical Tensions: The broader geopolitical context, including the ongoing US-China strategic competition, influences the scope and intensity of these measures.

Disclaimer: This information is for general knowledge and should not be considered legal or professional advice. Export control regulations are complex and subject to change. For the most up-to-date and accurate information, please refer to official sources: US Department of Commerce, Bureau of Industry and Security (BIS): The primary agency responsible for administering US export controls. Government websites of the respective countries: For information on their specific export control regulations.

Aspect	United States	European Union	China	Japan	South Korea
Primary Legislative Framework	Export Administration Regulations (EAR), International Traffic in Arms Regulations (ITAR), Patent Act with national security provisions	EU Dual-Use Regulation 2021/821, EU Trade Secrets Directive, National IP laws of member states	Export Control Law 2020, Patent Law, Anti-Unfair Competition Law, Classified Technology Regulations	Foreign Exchange and Foreign Trade Act, Patent Act, Unfair Competition Prevention Act	Foreign Trade Act, Technology Development Promotion Act, Patent Act
Regulatory Bodies	Bureau of Industry and Security (BIS), Directorate of Defense Trade Controls, USPTO with security review powers	National export control authorities, EU Commission, European Patent Office	MOFCOM, State Intellectual Property Office, Ministry of Science and Technology	METI, Japan Patent Office, National Security Council	Ministry of Trade Industry and Energy, Korean Intellectual Property Office
Technology Classification	Commerce Control List (CCL), USML for defense items, Critical & Emerging Technologies List	EU Control List, Individual member state additions, Catch-all controls	Control List for Dual-Use Items, Military Items List, Strategic Technologies List	Export Control List, Sensitive Technology List, Catch-all controls	Strategic Technology List, Defense Articles List, Catch-all provisions
IPR Protection Mechanisms	Foreign filing licenses, Secrecy orders, Enhanced protection for trade secrets, Technical data rights	National security reviews, Trade secret protection, Technical protection measures	Security review requirement, Mandatory technology transfer reviews, Indigenous innovation focus	Security clearance system, Trade secret protection, Technology transfer controls	Security screening, Industrial technology protection, Core technology designation
Licensing Requirements	Individual validated licenses, Technical assistance agreements, Manufacturing license agreements	Individual licenses, Global authorizations, Union General Export Authorizations	Dual-use licenses, Technology transfer permits, End-user certificates	Individual export licenses, Bulk export licenses, Special comprehensive licenses	Individual export permits, Comprehensive permits, Strategic material permits
Enforcement Approach	Criminal penalties, Civil fines, Denial of export privileges, Required self-disclosure	Member state enforcement, Administrative penalties, Criminal sanctions, Coordination mechanism	Criminal penalties, Administrative sanctions, Blacklisting, Social credit impact	Administrative guidance, Criminal penalties, Export privileges suspension	Administrative sanctions, Criminal penalties, Export prohibition
Technology Transfer Controls	Deemed export rules, Technical data controls, Cloud computing restrictions	Intangible technology controls, Technical assistance rules, Digital transmission controls	Technology transfer security review, Outbound investment screening, Cyber controls	Technology transfer screening, Cloud service restrictions, Data transfer controls	Core technology protection, Technical data controls, Knowledge transfer restrictions
International Cooperation	Multilateral regime member, Bilateral agreements, Information sharing protocols	Multilateral regime member, Intra-EU coordination, Third country agreements	Limited regime participation, Bilateral arrangements, Strategic partnerships	Multilateral regime member, Regional cooperation, Intelligence sharing	Multilateral regime member, Regional partnerships, Information exchange
Emerging Technology Focus	AI/ML controls, Quantum computing, Biotechnology, Advanced semiconductors	Cyber-surveillance, Advanced computing, Advanced materials, Biotech	AI development, Quantum technology, Advanced manufacturing, New materials	Robotics, Advanced materials, Biotechnology, Quantum computing	Semiconductor technology, Advanced materials, AI systems, Biotechnology
Compliance Requirements	Internal compliance programs, Regular audits, Training requirements, Record keeping	Risk assessment, Compliance systems, Documentation, Regular reporting	Internal control system, Classification procedures, Record keeping, Training	Internal compliance, Regular audits, Training programs, Documentation	Internal control system, Regular audits, Training requirements, Documentation

Table 2: A global comparison of measures to protect dual-use technologies that existed before ISM

Country	Regulatory Framework	Key Focus of Controls	Multilateral Regime Membership	Recent Actions/Updates
India	SCOMET List (DGFT), IT Act, WMD Act	Dual-use tech, fab equipment, AI chips, military-use semiconductors	Wassenaar Arrangement, (Missile Technology Control Regime) MTCR, NSG (aspiring)	Added gallium & germanium (2023); reviewing advanced chip & AI controls under Quad tech cooperation
United States	EAR, CHIPS Act, ECRA	≤14nm chips, EUV tools, AI/GPU chips, China-targeted tech	Wassenaar, MTCR, Australia Group, NSG	Broad AI chip export bans to China (Oct 2022, 2023 updates); strict licensing for Nvidia, AMD, ASML
China	Export Control Law (2020), MOFCOM	Gallium, germanium, rare earths, chipmaking tools	Not part of Wassenaar or NSG	Retaliatory raw material controls; ramping domestic production (SMIC)
European Union	Dual-Use Regulation (EU 2021/821), national systems	Lithography tools, AI processors, military-grade chips	Wassenaar, MTCR, NSG	Netherlands restricted ASML exports (2023); Germany exploring outbound investment screening
Japan	Foreign Exchange and Foreign Trade Act (FEFTA)	Lithography, deposition, 23 critical chipmaking items	Wassenaar, MTCR, NSG	Joined US curbs on China (2023); controls on fab tools
South Korea	Strategic Goods Control System (SGCS)	DRAM, NAND, fab equipment, AI chips	Wassenaar, MTCR, NSG	Balancing US-China interests; cautious about compliance to protect Samsung/Hynix China operations
Taiwan	Foreign Trade Act, NSC Coordination	Advanced nodes (TSMC), AI chip IP, defense-grade semiconductors	Wassenaar; not in NSG	Bans on advanced chip exports to China/Russia; tight IP transfer regulations
Singapore	Strategic Goods (Control) Act	Re-exports, AI hardware, data center equipment	Wassenaar, MTCR	Acts as neutral compliance hub; attracting chip investment while observing US rules
Netherlands	National security-based export licensing (ASML oversight)	EUV & DUV lithography tools (ASML monopoly)	Wassenaar, NSG	Formalized China export curbs (2023); crucial to global chip supply chain
Israel	Defense Export Control Law (DECL)	Military-use AI chips, specialized defense semiconductors	Wassenaar, MTCR, NSG	High-end innovation in AI hardware; aligned with US controls

India on par with global regulations of IC design and manufacturing major countries The AI diffusion framework:

A mechanism initiated during Biden administration to control access to AI chips has now been upended in favour of market access but still restricting access to rogue usage leading to security risks. However, the reversal of the AI Diffusion Framework by the Trump administration (May 2025) has important implications for countries like India, which was previously classified as Tier 2 under the original framework. With the relaxation, a snapshot below of features

Before the Reversal:

- India was capped at around 1,700 advanced GPUs per company annually.
- Large-scale AI model training and deployment (especially LLMs, defense-grade AI, and autonomous systems) would have been severely constrained.
- Indian cloud/data centre companies (like Yotta, Hiranandani, Reliance Jio, and government projects under Digital India) feared hardware shortages.
- US chip suppliers (e.g., NVIDIA, AMD, Intel) would face export license delays, affecting private and government-backed AI infrastructure projects.

After the Reversal:

- **Unrestricted access** to advanced AI chips (H100s, MI300s, etc.) is restored.
- Indian AI start-ups, hyperscalers, and defense R&D can continue scaling.
- Strengthens India's ambitions to become a global AI hub and enhance its semiconductor and defense-tech ecosystems.
- Helps India retain sovereignty over its AI development and reduce dependence on open-access Western models or China-influenced alternatives.

India Critical Mineral Mission 2025

The India Critical Minerals Mission was announced in the last budget (2023-24) but expected to be fully launched and functional in the new year to secure India's strategic mineral resources and hopefully, much-needed details on the scope, vision, and milestones. The main aim is to help secure supply of precious minerals like Germanium, Gallium and other Rare Earths which China controls nearly 70% of the supply, 90% of the processing of critical minerals. According to the International Energy Agency, by 2040 76% of the oil demand will be reduced if nations successfully transition to lesser carbon-emitting fuel sources—Renewable energy and battery-led mobility. [16] With semiconductors (China imports more silicon chips than oil) in the mix, we have a heady cocktail of geopolitics, technology, and security.

China controls a substantial supply of rare earths and critical minerals—the Indian Ministry of Mines has finalized list of about 30 elements that are crucial for economic growth and short in supply pivotal to progress and national security—India imports 40% from China. The impending convergence of digital and green technologies that requires critical minerals and rare earths can deliver more fuel with fewer emissions. However, the race for resources has new implications even as we transition from oil and gas—ironically, we will need 400 new mines to supply critical minerals to fuel this new green world!

Poised to be the 3rd largest economy, India is in real need to transition basis Paris Accord but also to sustain leadership in advance technologies like AI and increasingly the Space race with added responsibility as a champion of the Global South.[17]

The Indian Critical Mineral Mission is coalesced with various government departments and ministries to source minerals that are of national strategic importance and in limited supply, in addition to the growing clamor to hedge against China, which has recently in a tit for tat move has banned outright exports of Gallium, Germanium and Antimony to the USA with all the noise around Trump Tariffs being hiked to 60% of Chinese goods. US and India depend majorly on China for these critical minerals, however, the Mineral Security Partnerships (MSP) and the overall bonhomie between the two countries should augur well to support mutual growth plus with cooperation of other anxious nations equally to task. The situation is dynamic and export controls might vanish with respect to China as eagerness of Nvidia to advocate diffusion of American technology as opposed to Huawei for example.

As India sets out to build its semiconductor industry and the EV sector, we need huge quantities of Cobalt, Lithium, Gallium, Germanium, Graphite and Silicon. Other than, Copper and Aluminum, India needs to import most other minerals in large quantities. With KABIL—Kanij Bidesh India Ltd. (the overseas arm of exploration and sourcing of minerals for the government of India), strong ties with resource-rich South American countries like Argentina, Chile, Brazil, and Colombia is essential alongside African countries like DRC that have huge deposits of cobalt. In an era where countries are going beyond mines of earth to the oceans and outer space, India can't afford to lag in the critical infrastructure race.

India's challenges domestically in a federal competitive structure is all too well known. For example, the Tungsten deposit fiasco in Tamil Nadu is a glaring example—mainly, the environmental impact of mining and regional politics. Also, the inability of Sterlite Copper Ltd. to kickstart its operations in Tuticorin area of the state is a painful lesson in real politick.[18]

[16] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, Brent Wanner, Laszlo Varro, Davide D'Ambrosio, and Thomas Spencer, "Net zero by 2050: A roadmap for the global energy sector," International Energy Agency, 2021.

[17] OBSERVER RESEARCH FOUNDATION, "What Made India's G20 Presidency so Successful? —A Deep Dive into the New Delhi Leaders' Declaration," Orfonline.Org, https://www.orfonline.org/expert-speak/what-made-india-s-g20-presidency-so-successful-a-deep-dive-into-the-new-delhi-leaders-declaration.

[18] Utkarsh Anand, "Sterlite Plant in Tamil Nadu to Remain Shut, SC Dismisses Vedanta Plea," *Hindustan Times*, March 1, 2024, https://www.hindustantimes.com/cities/bengaluru-news/sterlite-plant-in-tamil-nadu-to-remain-shut-sc-dismisses-vedanta-plea-101709235221122.html.

It remains to be seen the impact of the India Critical Minerals Mission, as balancing strategic resource needs for economic development weighs heavily against ESG risks of operating smelter and polluting mines. But as India develops manufacturing capabilities for domestic and export of electronics, as nearly $20 billion worth of semiconductor investments announced in 2024—stronger is the impact on the international market economy and in strengthening the rupee.

Of course, India has key strategic partnerships with the Quad and the MSP, ensuring overall national development is not hindered by regional hegemony. However, this strategic initiative must secure new mining rights, salvage from end of use materials, recycle and most importantly increase local production/process capabilities, it is indeed a critical mission to accomplish requiring astute geopolitical moves and flexible trade pacts.

Policy Recommendations:

1. **Strategic Bilateral Coordination between India and the US and a new Trilateral with Taiwan**
    - Establishing a Joint Semiconductor Supply Chain Risk Council under the US-India Initiative building upon the TRUST initiative and further G2G transactions under COMPACT terms.
    - Aligning export controls & investment screening (e.g., India aligning selectively with the US's CHIPS Act guardrails and Wassenaar norms).
    - Harmonizing standards for secure and trusted IC design, packaging, and fab operations.
2. **Resilient Supply Chain Architecture**
    - Mapping end-to-end IC value chains with stress testing for choke points (e.g., EDA tools, specialty gases, photomasks). And a suitable mechanism to update SCOMET regularly.
    - Co-investing in "trusted nodes" (India as a secure back-end packaging & testing hub; US for advanced node R&D and design).
    - Diversifying sources of critical materials (e.g., rare earths, photoresists) through coordinated sourcing and joint stockpiling.
3. **Trusted Design and IP Collaboration**
    - Joint R&D centers for secure chips (especially in defense, AI/ML accelerators, and telecom hardware)—building more success stories from the INDUS-X initiative.
    - Bilateral licensing of EDA tools/IP to reduce overdependence on third countries.
    - Promoting open-source chip design (e.g., RISC-V collaboration via Shakti and US-based institutions).
4. **Investment and Talent Mobility**
    - Facilitating cross-border investments in strategic semiconductor sectors, including PLI-linked investments; a Joint Innovation Investment fund that sponsors a full stack innovation program across R&D, start-ups, and a joint collaboration technology transfers initiative.
    - Fast-tracking STEM talent mobility: special visa pathways and research fellowships in semiconductors.
    - Joint workforce development programs to build IC design/testing talent in India with US academic/industry support.
5. **Cybersecurity and Dual-Use Controls**
    - Setting up a joint "Secure Chip" certification program for dual-use ICs (defense/telecom/automotive).
    - Collaborating on secure foundry services for sensitive government and defense IC needs.
    - Enhancing threat intelligence sharing on supply chain malware/trojan risks.
6. **Resilient Infrastructure and Logistics**
    - Developing India–US semiconductor logistics corridors (e.g., fast-track customs, airfreight lanes for wafers and equipment).
    - Building joint disaster recovery protocols (e.g., Taiwan contingency scenarios, shipping choke point disruptions).
7. **Global Norm-Shaping and Coalition Building**
    - Promoting plurilateral cooperation (e.g., India-US-Japan-Korea chip alliance) or India-US-Taiwan tripartite to reduce dependency on China-dominated nodes.
    - Co-leading multilateral funding efforts via World Bank/IMF/Quad initiatives for chip infra in Global South.

A Policy Brief:

Advancing the India–US–Taiwan Semiconductor Alliance—Strategic Scope and Benefits

In an era of increasing geopolitical and technological competition, a trilateral India–US–Taiwan semiconductor alliance offers a unique opportunity to build a secure, resilient, and innovation-led integrated circuit (IC) supply chain. This policy brief outlines the strategic scope of this alliance and its multifaceted benefits to each partner, positioning it as a cornerstone for regional security and global tech competitiveness.

I. Strategic Scope

1. **Design–Manufacturing–Packaging Integration:**
   - Taiwan: World leader in advanced chip manufacturing (TSMC)
   - United States: Hub of fabless design, EDA tools, and advanced R&D
   - India: Growing base for semiconductor design, OSAT (outsourced semiconductor assembly and test), and engineering talent
2. **Technology Transfer & Joint R&D**:
   - Collaborate on next-gen technologies such as 3D chip stacking, RISC-V architecture, and AI-integrated ICs.
   - Joint R&D initiatives involving top Indian institutes (IITs), US national labs, and Taiwanese universities.
3. **Supply Chain Resilience:**
   - Diversify beyond China-centric production hubs.
   - Establish redundant manufacturing and packaging capabilities across geographies.
   - Shared early warning systems for managing disruptions.
4. **Trusted Ecosystem Development:**
   - Launch a trilateral "Trusted Semiconductor Certification" system.
   - Promote IP security, transparency, and traceability throughout the value chain.

II. Benefits to Each Partner

1. India
   - Gains from Taiwan's manufacturing expertise and US design ecosystem
   - Attracts FDI in fabs, OSAT, and chip design.
   - Enhances workforce capabilities via joint training and knowledge transfer.
   - Advances toward secure digital sovereignty
2. United States
   - Gains cost-effective design and backend capacity via India
   - Reduces strategic dependence on East Asian choke points
   - Strengthens its Indo-Pacific semiconductor security corridor
3. Taiwan
   - Secures alternate production and packaging hubs to mitigate geopolitical risk
   - Access to Indian cost-effective talent and markets
   - Strategic diplomatic leverage via trusted partnerships

III. Policy Recommendations

1. Establishing a Trilateral Semiconductor Council to coordinate strategies, investments, and research agendas.
2. Creating a Joint Innovation Fund focused on critical and emerging semiconductor technologies.
3. Aligning Export Control and IP Standards to ensure seamless, secure collaboration.
4. Supporting Talent Mobility and Joint Education Programs between Indian, US, and Taiwanese institutions.
5. Developing a Resilient Semiconductor Logistics Network with fast-tracked trade routes and trusted suppliers.

The India–US–Taiwan alliance is more than a strategic convenience; it is a timely imperative. By harnessing complementary strengths across design, manufacturing, and packaging, this partnership can anchor a resilient, secure, and future-ready global semiconductor ecosystem.

Conclusion

To sustain the early momentum of India's semiconductor mission, the government has launched complementary initiatives such as the National Research Foundation, the National Quantum and AI Missions, and the Critical Minerals Mission. These frameworks aim to strengthen R&D, accelerate innovation, and build robust institutional capacity across the technology value chain.

Recognizing that cutting-edge applications (≤7nm nodes) will drive demand for GPUs, while legacy nodes (e.g., 28nm) will continue to serve the bulk of electronics sector needs, India has earmarked an additional $5 billion in incentives to expand component manufacturing. These measures go beyond existing schemes like the Production Linked Incentives (PLI) and Design Linked Incentives (DLI), and are intended to deepen India's position in the global electronics value chain.

The Chips-to-Start-ups program plays a pivotal role in nurturing India's Electronic Systems Design and

Manufacturing (ESDM), Very Large-Scale Integration (VLSI), and embedded design ecosystems. It seeks to catalyse collaboration among academia, R&D institutions, industry, and private capital—laying the groundwork for indigenous intellectual property creation while complying with evolving export control frameworks.

Both demand- and supply-side policies are reinforcing India's Atmanirbhar Bharat (self-reliant India) strategy. Yet, policy continuity and international strategic alignment remain vital. As global tensions reshape semiconductor geopolitics, deeper partnerships with trusted, like-minded nations are now more critical than ever. The US "Liberation Day Tariffs" and concerns over China's growing dominance in legacy nodes—even as it narrows the gap in advanced chips—underscore the urgent need for the US to diversify its sourcing. India, with its maturing fabrication ecosystem, is well-positioned to serve as a reliable alternative for legacy node production. However, current limitations—such as India's classification as a Tier-2 partner with capped access to AI GPUs (50,000 per year)—contrast sharply with deals like the UAE-US AI city initiative. The evolving US trade and tech strategy must prioritize long-term democratic and technological alignment over short-term transactionalism. Export controls should not only restrict adversarial access but also proactively empower allies like India in key domains such as AI, quantum, and semiconductor manufacturing—critically in workforce mobility and technology transfer.

To expand the scope and depth of such partnerships, building enduring trust is essential—rooted in mutual respect for markets, shared democratic values, acknowledgment of security imperatives, and support for IP creation and dual-use technology governance. These principles are foundational for advancing peace, resilience, and technological leadership in the Indo-Pacific.

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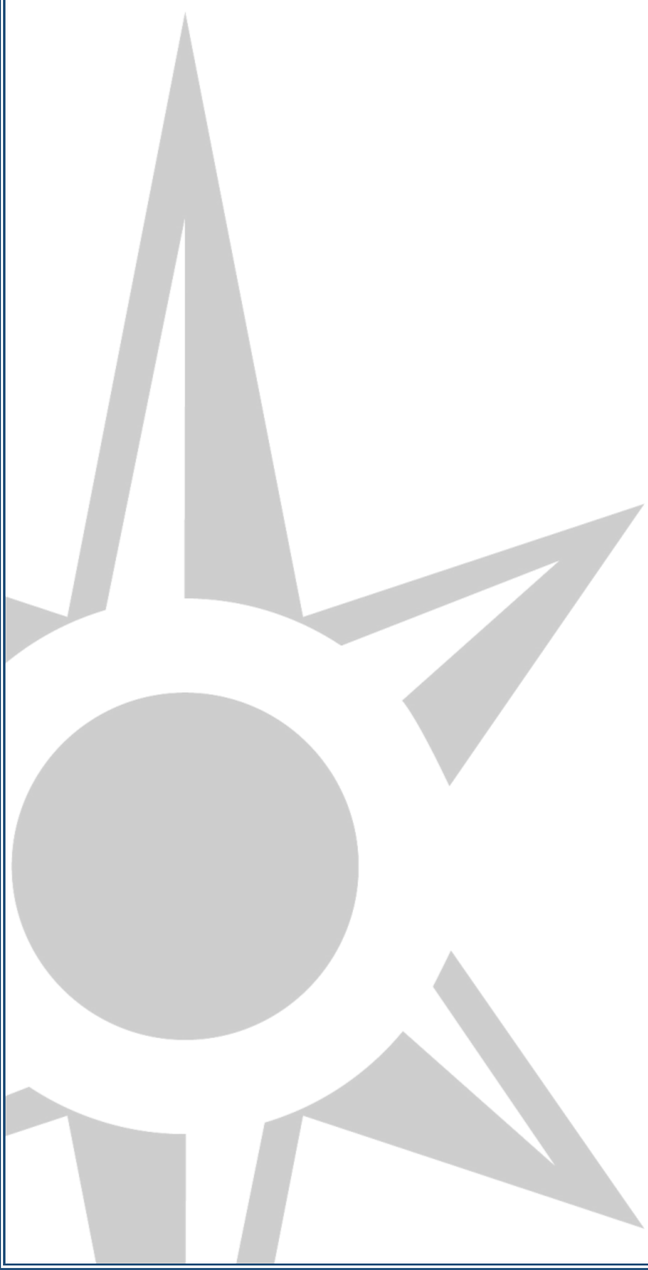
Indian Semiconductor Industry—An Analysis of Law & Policy

By
Nandimath Omprakash V



Executive Summary

Nandimath Omprakash V

All global studies predict the Indian economic growth rate to be stable at around 6.8%—probably the highest growth rate in the world.[1] The latest Deloitte study indicates the growth rate of India will be on the high burner, particularly due to increasing consumer spending in rural India.[2] Private consumption growth, due to an expanding middle class (3.5% year-on-year) and private investments (10.6% year-on-year) are at an all-time high. These credentials indicate that India is heading to the status of the third-largest economy in the world from the current fifth. PwC's report estimates that the Indian economy will attain this status by 2030.

This growth is the result of past careful planning and policy refinement. India realizes that to sustain this growth rate and to further bloom its economy, robust and resilient semiconductor industry is an imperative. The disrupted semiconductor supply chain, and changing geo-political equations, demanded global level planning and quest for effective alternatives, which indicates that there can't be a better opportunity for India to press for it candidature to be the global alternative. The Indian Semiconductor Mission (ISM) aims to just do that. Prime Minister Narendra Modi has said, "the day is not far when we will see made-in-India chips in America; this small thing will take India to the next level."

With this background, this paper builds its arguments for further policy refinement, upon the hypothesis that, unless India recalibrates its overall ease of doing business parameters, the high R&D intensive semiconductor industry will not be a quickly realizable goal.

[1] Indian gross domestic product grew 6.7% in April-to-June quarter, which was slower than in the previous last five quarters. Despite this, India remains one of the world's fastest-growing economies.
[2]Deloitte Insights, *India Economic Outlook, October 2024*, accessed [Nov. 10, 2025], https://www2.deloitte.com/us/en/insights/economy/asia-pacific/india-economic-outlook.html.

Introduction

It's no exaggeration that creating a semiconductor is perhaps the most complex manufacturing activity humanity has undertaken. The design and operation of semiconductor fabs is so nuanced and sophisticated that it considers details as minute and granular as the gravitation effects of the moon on assembly lines. Everything around us, from modern smartphones to old conventional doorbells, are driven by a semiconductor in it. Chips represent the heartbeat of the modern global digital economy and the brain of advancements in science. Today they are the most traded goods in the world. Today semiconductors are indispensable, permeating every aspect of our lives and have brought global interdependency like fossil fuels did in the past. Any disruption in the semiconductor supply chain can have a remarkable impact on the global economy.

The semiconductor industry is projected to double its market size in revenue by 2030, with some sectors such as electric vehicles, projected to grow relatively faster than others. The semiconductor industry will grow to a $600 billion (51,46,200 crores) industry by the end of 2025 and will grow from there to become one of the country's biggest sectors. The PricewaterhouseCoopers (PWC) report estimates the industry to surpass $1 trillion by 2030. The key driver for this growth is going to be the government focus and spending on developing and reshaping their semiconductor industry.

More than $400 billion in government spending is estimated over the next five to 10 years. In July in the US alone, $30 billion in grants has been awarded, and more than $25 billion in loans have been approved to the semiconductor industries. South Korea draws $50 billion in investment via its 20% tax credit and has claimed to support investments equivalent to $90 billion. China has continued to dominate the scene and through its National Integrated Circuit Investment Fund has allocated $41 billion to the industry (which includes tax breaks and loans). According to the study China's investment is estimated to exceed $190 billion. India has plans to spend around $10 billion on semiconductor initiatives in its immediate future.

Geographically the semiconductor industry is still dominated by the US, Taiwan, South Korea, and Japan. Since its inception this industry has achieved 13% growth but has also witnessed high cyclical volatility. Such volatility is highest impact compared to other industries, making companies think about and invest in stabilizing the industry globally. Until the 1980s the industry was vertically integrated. Without any exception semiconductor companies designed, manufactured, and tested their products themselves. The scenario changed thereafter. Today all these functions are done by separate entities, making the intra industry supply chain itself complicated. Furthermore, this reflects further upon overall supply-chain of semiconductors.

In mid-1980s TSMC, UMC etc., emerged as dominant foundries, specializing solely in the manufacture of other companies' designs. For instance, in 2020 TSMC accounted for more than 60% of the total global foundry revenue. During these times it supplies nearly half of semiconductors to the globe. Today TSMC has the capacities (along with Samsung) of manufacturing the advanced 5-nanometer chips, and it is aiming to go for 3nm chips now.

Furthermore, the COVID pandemic brought to light vulnerabilities of this industry. Especially when the global supply chains are disrupted. The COVID scenario led in acute shortage of supply to many key industries, from automotive to consumer electronics. This made artificial entities too suffer along with humans. The current focus of the industry across globe is to address these supply chain challenges and that continues to be crucial for the industry's sustainability and stability.

As technology has progressed, the critical nature of semiconductors has increased and the geopolitics surrounding semiconductor invention, innovation, and production has also changed drastically. National security issues, aspirations for technological supremacy, growing trade wars between nations (particularly between the US and China), the war in Ukraine etc., have forced the industry to "re-shore" and pull-back the production locally. Undoubtedly semiconductors have become an inevitable aspect for state existence and means of progress. The cold trade war between China and the US testifies this statement.

The Indian Semiconductor Industry—An Overview

The ideal way to understand the Indian semiconductor space, is from two basic perspectives. The first is as a consumer; the second one as the producer of semiconductors.

The Indian semiconductor marketplace is growing exponentially, as its consumption will reach $64 billion by 2026. This is threefold more than its consumption in 2019. Indian semiconductor consumption growth is at a 16% compound annual growth rate (CAGR), which is in comparison to other emerging nations is still very high. This will soar further to $110 billion by 2030, or approximately 10% of total global semiconductor consumption.

Invest India predicts by 2030 wireless communications ($26.5 billion), consumer goods ($26 billion), and automotives ($22 billion) will be the largest components' consumers of India's semiconductor market. However, simple math would reveal that Indian consumption would certainly be more than these moderate predictions. For instance, Indian electronic production, was valued at $101 billion in 2022, and is expected to triple to $300 billion by 2026. Mobile production will rise from $44 billion in 2023 to $110 billion by 2026. Already India has become the second-largest mobile phone manufacturer in the world. Indian exports of electronics will be around $120 billion in 2026, if not more.[1] India is the most populous country with over 1.4 billion people. She was, as noted by the International Monetary Fund, the fastest-growing major economy in 2023 and will continue to be so for some time to come. The recent economic survey predicts that by 2027 Indian household spending will increase by 29%, making the demand for electronic goods increase further; this will in turn increase its demand for semiconductors.

The BMI research indicates that, in 2027 one-third of India's population will be between the age group of 20 to 33 years, which is an age group inclined to spend more on electronic gadgets and telecommunication products. This "technology-literate" demographic group will undoubtedly fire the demand. The Telecom Centers of Excellence India (TCOE) calculates the number of Indians owning a smartphone will double from 600 million today to 1.2 billion by 2027. According to the Automotive Research Association of India (ARAI) Indian automotive production will grow to reach $300 billion by 2030 (from the present $222 billion). It also records that India's is one of the world's fastest-growing Electric Vehicle (EV) markets, who devour semiconductors.

Dr. Alexander Thomas, past president of Association Health Providers India (AHPI), in his interview reveled that India's medical device market (which is the fifth-largest in Asia) will grow from the current $12 billion to around $60 billion by 2030, or perhaps more. This is owing to the polices of government to promote "medical tourism" in India. In a nut shell the Indian terrain will grow rapidly on all fronts and dramatically expand demand for semiconductors in the coming years, making her potentially more attractive to semiconductor producers. All these northward trends indicate that India's craving for semiconductors will be even more than is predicted. In 2023 the Indian semiconductor industry was worth $4.3 billion. This is expected to grow to $100.2 billion with CAGR of 20% by 2032. Nearly 9% of India's consumption is met by local sourcing. According to the Observatory of Economic Complexity's data, India exported semiconductor devices worth $ 516 million but imported worth $4.55 billion in 2022.

Current policies in India aim to raise the local sourcing by 17% by 2026. This is highly ambitious, but possible considering positive government initiatives and policies. The geo-political shift and reshaped reshoring policies of the industry have made India a favorite destination.[2]

India noticed a steep 130% increase into the investments in semiconductor space. Till now INR1.5 trillion is invested in semiconductor investments from major companies such as Micron, Tata Electronics, CG Power and Keynes Technology. Precisely for this reason, India wants to be self-reliant in the semiconductor space, which means saving tremendous foreign currency for itself. While multinational corporations dominate India's semiconductor design landscape, the domestic ecosystem is slowly maturing.

It is to be noted that, not just in India, but the global demand for semiconductors will steeply rise as technologies like artificial intelligence, machine learning, big data and IoTs go further. Therefore, more and more investments will flow into the sector,

[1] Various industry experts during the interview expressed that the official figures are too modest and the real figures are far greater.

[2] In a survey released by the American Chamber of Commerce in Shanghai in September 2023, it was revealed that 40% of companies are actively planning to move their investments from their existing countries to diversify their production, and particularly from China. This phenomenon is described as "China-plus-one" or "China-plus-two" strategy. A UBS Evidence Lab study stated on record that, 71% of US companies having their manufacturing in China were either in the process of or planning to shift operations to other countries. The strained political relations of the US with China also has had a telling impact. This opens a huge door of opportunity to India.

with more fabs will be established. McKinsey Global Institute predicts over 70 new semiconductor fabs are expected to be added to the current global capacity by 2030 and many will be in India due to its promising consumption pattern. Most of the studies mention with a greater degree of confidence that India, Cambodia, Thailand, and Vietnam are the favorite destinations for semiconductor industry expansion.

Early trends show greatest advantage to India; and obviously the most attractive element in that is its growing local demand for semiconductors. [3] The Economic Intelligence Unit's report observes a steep rise of FDI into India, signaling that many companies have already diversified their supply chains and established production hubs in the country. This can be evidenced from increased export levels. More and more MNCs are relying on India's manufacturing capabilities, in comparison to its closest competitors. This summarizes that the current geopolitical movement offers a tremendous opportunity for India to attract increased investment in globally mobile high-tech industries.[4]

A top executive of Bharat Electronics Limited (BEL) states that integrated circuit (IC) design is undoubtedly India's greatest semiconductor industry strength, as India employs approximately 21% of world's semiconductor design engineers (roughly 125,000). About 3,000 ICs are designed in India each year. Who and who like Intel, Texas Instruments, Qualcomm, Samsung etc., have their semiconductor design companies in India; and majority of them are in Bengaluru. The All-India Council for Technical Education (AICTE), University Grants Commission who are tasked to implement the new Education Policy are forcing the Indian universities and technical institutes to establish active ties with the industry. This push has established a link between over 1,000 engineering colleges across India with these R&D centers. This facilitates industry-ready graduates, readily available for taking up niche jobs in the semiconductor space.

Prof. Yadati Narahari, deputy director of the Indian Institute of Science (IISc), stated (in an interview with the author) that they have executed MoUs with many industry leaders like Qualcomm and Synopsys and are undertaking research in developing apt educational curriculums as well as faculty development programs—so that teaching and training in the engineering colleges will be more focused to cater to industry needs, particularly to semiconductor design and manufacturing.

The Skill India Mission is also driving the industry readiness programs, beyond the boundaries of institutes of higher education and universities. Lam Research has announced its plan to train up to 60,000 engineers through its semi-verse solutions virtual fabrication platform, or applied materials, heralding plans to invest $400 million over four years to launch a new engineering center in India, indicative of greater skills to be developed, honing Indian youth to man the expanding semiconductor space.

Another area deserving of our attention is the Indian start-ups. Thanks to the Indian governments multiple initiatives of supporting startups, Indian startups have entered the field of semiconductors as well.

Compared to other fields, investors are reluctant to invest in semiconductors. Despite this many startups have taken up the challenge, said the Chennai-based owner of one of the startups, who explained in 2024 that there are more than 60 startups in India at work, ranging from semiconductor design to manufacturing. He is confident that this number would further rise multiple times over in the days to come.

Interestingly, some of these startups have found initial success, encouraging others to join the bandwagon. Mindgrove Technologies, a Chennai-based systems-on-a-chip (SoC) startup deserves a special mention for finding success in designing 28 nm chips which can fuel automobiles, medical devices, wearables, smart electricity, water meters, and of course home appliances. The representative of Mindgrove, during an interview reveled that they estimate the chip-based biometrics solutions alone will count for $500 million market in India.

There are news reports that Saankhya Labs and Signalchip, another startup, established in 2006, have come out with finished products useful in broadband, satellite, and broadcast applications. The Chennai-based startup owner felt that the Indian startup policy, if fine-tuned to include a minority of startups

[3] Following the iPhone, Google is scouting for suppliers in India to assemble its Pixel smartphones.

[4] Information Technology & Innovation Foundation, "Information Technology & Innovation Foundation Report, February 2024," ITIF, February 2024.

in the semiconductor space, would go a long way and he was confident that this would happen as the Indian government's focus is upon this industry.

External Affairs Minister S. Jaishankar recently said the next world war will be fought on chips and emphasized the need for India to invest its resources in building a good semiconductor industry. He said, "We need to figure out, are we a bystander and a victim or are we a player. If we must be a player we must weigh into it, make investments, train people, and we have to bring something to the table and we are doing that." [5] This only reinforces the Indian government's resolve to establish its semiconductor industry.

Indian Legal System

The Indian legal system is based on common law, with a written constitution balancing the power between its three constituent organs. The Constitution divides legislative powers through three lists: union, state and concurrent lists. The union and state lists provide exclusivity of power vesting in the Center and the States, respectively; the concurrent list provides an opportunity to both. Any conflict between a central and state legislation would be resolved in favor of central law. However, one can expect some friction between Center and State regards their jurisdictions. This point distinguishes the federal structure in India from the US.

The unified judiciary undertakes judicial functions, including the task of interpretating the Constitution and resolves any plausible disputes between center and state or among the states. The Judiciary is also responsible for ensuring that the rights of citizens are protected, and powers of the government do not cross the limits prescribed. The Supreme Court at the apex level and High Courts at the provincial state level are constitutional courts. All subordinate courts and tribunals function under the control of High Courts; and the High Courts are being supervised by the Supreme Court.

The element of judicial review is strongest in the Indian legal system, making the judiciary fiercely independent. The organization and functions of the subordinate courts throughout the country are uniform, except with minor variations. In every district there are civil and criminal courts.

The Constitution of India, the basic document on which the entire systems of governance depend, provides in Chapter III for fundamental rights. These are in one sense, limitations upon the state while exercising its executive powers.

The Executive is expected to work according to the powers conferred to them by the respective legislation. Wherever found that either the executive or legislature has gone beyond the prescribed constitutional powers and have touched negatively the fundamental rights of its citizens—such state acts are held to be *ultra vires* and rendered inoperable.

This ensures greater safeguard to the fundamental rights; and particularly in our situation ensures certainty of business interests. Article 19(1)(g) of the Indian Constitution ensures a fundamental right to carry on any trade and profession. This would not only mean to provide protection but also ensure that the state has a positive obligation to support and protect the commercial interest of citizen when they are conducting their trade and business.

There are two dimensions from which Indian courts have developed the right of trade and profession. The first being when the executive acts without clear authority of law.[6] And the second one is where the exercised authority by the executive is "arbitrary" or "unreasonable." These approaches have resulted in greater protection to the business enterprises in their operations. This also renders greater stability to the working environment to the enterprises. State of Bombay v R M D Chamarbugwala[7] was first among the milestone judgements, where the Supreme Court had to examine the ambit of Art. 19(1)(g). Using the opportunity, it defined the limits of fundamental rights to trade under our Constitution. The State of Bombay enacted Bombay Lotteries and Prize Competitions Control and Tax Act, 1948 and the Bombay Prize Competitions Tax Act, 1952. By these the government imposed strict controls and heavy taxes on such activities, effectively making it impossible to run the business. The Respondents,

[5] *Times of India*, "Next World War Will be fought on chips: External Affairs Minister S. Jaishankar," Times of India, Nov. 24, 2024, https://timesofindia.indiatimes.com/city/bengaluru/jaishankar-warns-that-the-next-world-war-will-be-fought-over-semiconductors/articleshow/115606638.cms, accessed Dec. 29, 2024."

[6] See generally, Excel wear v Union of India, 1979 AIR 25; Maneka Gandhi v Union of India, 1978 AIR 597; Krishna Kumar v State of Bihar, Civil Appeal No. 5875 of 1994; Hamdard Dawakhana v Union of India, 1060 AIR 554; State of Tamil Nadu v Sanjeetha Trading Company, AIR 1993 SC 237.

[7] AIR 1957 SC 699.

who were conducting the "prize competitions" through newspapers and crosswords, were affected by these laws. Therefore, they in their challenge, contended that their fundamental right to carry on trade or business under Art. 19(1)(g) is violated. In this context the apex court observed that:
"The phrase 'reasonable restriction' connotes that the limitation imposed on a person in enjoyment of the right should not be arbitrary or of an excessive nature, beyond what is required in the interests of public. The Court must examine the propriety of the restrictions…The test of reasonableness should be applied to each individual statute impugned."

Further to it an additional dimension was added while deciding (another milestone decision) Maneka Gandhi v Union of India.[8] In this case the Petitioner's passport was impounded by the government of India. The State justified its stance by quoting the broader heading of "public interest" under the Passport Act, 1967. She was even not granted any opportunity to be heard before this action was taken. While providing the relief to the Petitioner the court observed that:
The principle of reasonableness must permeate the entire law. It is not enough that the restrictions are for a legitimate aim under Art. 19(6); the procedure prescribed by law for imposing those restrictions must also be fair, just and reasonable. An arbitrary procedure is not procedure at all."

In one of its recent judgments in the case of Kshetriya Kisan Gramin Bank v D B Sharma,[9] the Supreme Court summed up that the "right under [Article] 19(1)(g) is not an absolute right but is subject to reasonable restrictions under clause (6). The onus to prove that a restriction is reasonable is on the State. The test of reasonableness involves: (i) it is for the court to determine reasonableness; (ii) the restriction must not be arbitrary or excessive; (iii) It must be in the interest of the general public; (iv) the nature of the right, the purpose of the restriction, and the conditions prevailing must be considered; and (v) a restriction placed to give effect to Directive principles can be reasonable." Building upon the existing foundation, the Supreme Court in this case provided a clear, concise, and authoritative summary of the principles governing Art. 19(1)(g) of the constitution. Therefore, State power is highly regulated. It must be shown that the state action to regulate the business, complies with the standards of fair, just and reasonableness. Otherwise, such state actions are held to be invalid. Not just to semiconductor industry, this well-founded approach to the Indian legal system renders assurance and security from unreasonable interference to the entire business community.

All citizens have the right to carry on any trade or profession/occupation, provided the same is not illegal, immoral or opposed to public policy. None of the fundamental rights, including the right to carry on trade and profession, are absolute. They can be limited reasonably. Reasonability of limitation is the key, which provides greatest assurance to the commercial operations, that none of the business regulations and policies can change drastically to their detriment; and any change being unreasonable and arbitrary can be struck down.

Semiconductor Legal Framework

Business law, commercial law, mercantile law, or trade law are different expressions used by lawyers and businessmen alike. However, it must be noted that these are generic, undefined, and non-technical expressions. The conglomerate of laws frequently used by the men of commerce or applied while resolving commercial disputes are placed together as business laws. Except the Semiconductor Integrated Circuits Layout Desing Act 2000, all are generic business laws applicable to the semiconductor space.[10]

Any industry, particularly the semiconductor industry seeks stability, certainty and predictability from any legal system. The MNCs for their offshoring of business *inter alia* look into (among about 500 discrete pointers) state support, available talent, labor and industrial laws, tax structure etc. The Indian legal system is robust enough to answer all these requirements.

The paper, without going into mundane issues of law, focuses on and examines how the Indian legal system attempts cater to these requirements in its subsequent portions.

[8] AIR 1978 SC 597. This case established the doctrine of procedural due process and interconnection of fundamental rights, which became a powerful tool to check arbitrary state action affecting business.

[9] 2001 (1) SCC 353.

[10] The Semiconductor Integrated Circuits Layout Designs Act aims to protect intellectual property rights in the semiconductor industry.

Regulatory Refinement

The overarching legal framework ensures the rolling out of any programs of the government. In this regard the government of India has undertaken multiple initiatives. Ease of doing Business or reducing compliance burden is probably the paramount Indian initiative. This is to benefit the overall industry sectors and will certainly benefit the semiconductor industry.

Following are the key focus areas of this initiative, which has already started yielding results:

1. Simplification of procedures relating to applications, renewals, inspections, filing records etc., by the enterprises.
2. Rationalization by repealing, amending, or subsuming redundant laws.
3. Digitization by creating online interfaces eliminating manual forms and records; and
4. Decriminalization of minor technical or procedural defaults.

An often-quoted, but generalized, statement is "the more corrupt the State, the more numerous the laws." To establish the "rule of law society" we probably need numerous laws. Although it is impossible to quantify how many laws are ideal, the central government undertook the exercise of eliminating the redundant laws, 125 already repealed, and another 758 laws waiting to go off the books.[11] Across 42 legislations 183 provisions imposing criminal liability on delinquents were completely removed. The decriminalizing will help entrepreneurs to undertake their activities with relief of the threat of consequences resulting in their imprisonment.[12]

The central government and all the state governments have scanned through their compliance procedures to eliminate duplicating and cumbersome procedures. This was undertaken in consultation with the industry. Multiple procedures have been simplified. For instance, tax return reporting was simplified. The online application form for FDI into the country was brought down to 7 pages from 15 pages. Capturing the essence of this initiative, Piyush Goyal, the minister for commerce and industry said that the outdated laws "have contributed to a trust deficit" and repealing them as part of government's efforts to improve "the ease of living as well as ease of doing business" in India.

Governments at all levels have now introduced a "single window" clearance system. This provides a single interaction point for the entrepreneur to seek necessary permits, licenses, no-objection certificates etc., from multiple state agencies. This has resulted in reduced duplicity of information submission, reduced time in seeking state leave; and overall gestation period of establishing a business.

This initiative of Department for Promotion of Industry and Internal Trade (DPIIT) started in 2021 and up to last year National Single Window System has cleared 75,000 applications out of 12,30,000 applications received. Following the suit, many provincial governments have also started and implemented the single window approach. The state of Tamil Nadu claimed to have cleared 21,380 applications (out of 23,548 received) in a record time; and further claims to clear all investment project proposal decisions within 30 days of submission. The Karnataka's single window clearance is also working efficiently.

Cost of Regulations

The Ministry of Commerce has undertaken last year, and expects to implement by 2027, the "cost of regulations" project. This activity of the DPIIT aims to create a framework, which would assess the cost of regulations in each State regarding various facets of business, like starting, closure, filing returns, having inspections done etc., and assigning cost in terms of money for crossing over these compliance stages. A more complex system would mean more cost involved. This initiative will bring parity as well as competitiveness among the states and lead to further ease of doing business at the state level.

This initiative transforms the game by reducing time and tangible expense. For enterprises this means unprecedented transparency. A 2023 industry survey by the Centre for Civil Society found that MSMEs spend an average of INR 1.1 lakh annually and over 500 hours navigating state-level compliance.[13] By benchmarking these costs, the project relates a powerful competitive dynamic among states, incentivizing them to streamline processes and slash

[11] Lok Sabha has passed the bill and it is waiting to be passed by the Rajya Sabha.

[12] Otherwise even inadvertent omissions, like filing some returns would have attracted imprisonment or hefty fine as consequences.

[13] See generally, Ministry of Micro, Small & Medium Enterprises, Government of India, "Annual Report 2022-23," at https://msme.gov.in/sites/default/files/AR_English_2022-23.pdf.

bureaucratic hurdles to attract investment. This move directly empowers businesses to make smarter, cost-informed location decisions, turning regulatory efficiency into a measurable competitive advantage and solidifying India's commitment to become a premier global destination for enterprise.

Tax Reforms

India's taxation framework has undergone a transformative evolution, moving from a complex, multi-layered system to a more streamlined, efficient, and investment-friendly regime. This strategic shift is anchored in two pillars: the revolutionary overhaul of indirect taxation through the Goods and Services Tax (GST) and a series of targeted reforms in direct corporate taxation. Together, they aim to formalize the economy, boost revenue, enhance ease of doing business, and position India as a premier global investment destination.

Implementation of Goods and Service Tax (GST) regime in 2017 was one of the major tax reforms in the recent past. Some authors opine that, after land reforms in early 1950s, this can undoubtedly be a major reform undertaken by the government.[14] In its initial phase it has simplified trade by removing duplicated multitude of indirect taxes. This regime fundamentally changed the consumption-based to origin-based indirect tax system, which had conferred myriad benefits to the economy. These include increased revenues, uniformity in taxation, elimination of cascading taxes, reduced compliance burdens, and an online system of taxation. The reform has undoubtedly led to the boosting of Indian economic growth.[15] The introduction of a sampled online portal and single returns replaced the need to file multiple returns for different taxes, streamlining trade and logistics across state borders.

Parallel to the GST, the government has aggressively reformed corporate taxation to boost private investment and manufacturing, a policy often termed the "big bang" corporate tax cut of 2009. There is array of reform in the space of corporate tax as well. Standard corporate tax rate was slashed from 30% to 25%, while offering a lower 22% opt-in tax, which is from earlier 30%. The tax rate was reduced to 15% for such companies who make investments in manufacturing and started production before 2024. A significant point to note here is that this lowered corporate tax of 25% is lower than in Philippines (30%). To cater to the certainty aspect of taxation and promote predictability India changed "retrospective" taxation regime. "This would encourage the flow of foreign investment in India and create a transparent and reliable tax regime for global investors," said one of the chartered accountants working in FDI facilitation. It has to be mentioned that, in the special economic zones spread across Indian states there is complete exemption from taxes for a period of five to 10 years, making it attractive for new investors and also for new initiatives.

While not yet implemented, the ongoing discussion around the new Direct Tax Code aims further simplify and modernize the direct tax laws in the days to come. The expansion of faceless, automated tax assessment and appeal mechanisms reduces human interface, minimizes discretion, and enhance transparency and efficiency. The reforms are being debated to revamp the SEZ policy to make it compatible with global trade norms, ensuring these zones remain attractive for export-oriented manufacturing and services.

India's tax reform journey, through the structural unification of GST and the strategic corporate tax cuts, represents a deliberate and data-backed shift from a complex, penalty-oriented system to a simpler incentivized, and trust-based framework. By bolstering revenues, enhancing competitiveness, and assuring predictability, these reforms are foundational to the government's vision of achieving sustainable, high economic growth, and attracting global capital.

Labor & Industrial Regulations

India's labor and industrial legal framework is a legacy of its post-independence socialist philosophy. Designed to protect workers from exploitation in a nascent industrial economy, these laws were highly protective but eventually became notoriously complex and rigid. A 2013 World Bank report famously lamented this stating that, "Indian's 51 central and 170 state labor statutes, some of which pre-date independence, make it hard for firms to fire

[14] Refers to redistribution of land from rich to poor. After independence, considering the unequal distribution of land, coupled with the large mass of the rural population below the poverty line, the government undertook this program. This meant antagonizing the entire rich strata of our feudal society but with varied degrees of success this program was implemented, paving the way for building the modern India.

[15] The National Council of Applied Economic Research (NCAER) has estimated that the GST had led to an increase in the India's economy up to 3%.

underperforming workers." An employer needed the leave of government to even lay off a worker. This regulatory labyrinth, often called the "inspector raj," created a significant disincentive for large-scale formal hiring and hampering business flexibility.

However, the situation has changed to balance the enterprises' interest. Major reforms undertaken from 2019-2020 amalgamated 29 pieces of labor legislation into four comprehensive labor codes. The Code on Wages, 2019; The Industrial Relations Code, 2020; The Occupational Safety, Health & Working Conditions Code, 2020; and The Code on Social Security are the four comprehensive codes. These codes represent a paradigm shift aimed at balancing robust worker protection with the operational interests of enterprises. Particularly these reforms will enable companies to adjust their labor requirements in line with changes in market demand, facilitating the ability of gig and platform workers to attain benefits, ensuring better compliance of labor laws through online tools, and shifting labor inspection regimes from a negative regulatory regime based on do's and don'ts to more positive inspector and facilitator approach.

These codes are however, waiting to be implemented in their full potential, as their implementation is pending as states must finalize and notify their respective rules. This delay would to some extent mean the full impact of the reforms is yet to be realized on the ground. This is only time but once these codes are implemented will provided the following leverages:

Easing hiring and firing—The introduction of fixed-term employment contracts allows companies to hire workers for specific periods based on project needs, providing them flexibility to adjust workforce size in line with the market demand. The threshold for government approval for layoffs, retrenchment, and closure has been significantly raised for establishments with up to 300 workers making it easier for most SMEs to manage their workforce.

Formalizing the informal sector—This would mean inclusion of gig and platform workers (Uber, Swiggy, Zomato, etc.) within the social security net. The new codes mandate that platform companies contribute to social security fund for these workers, enabling access to benefits like insurance and pensions.

Ease of compliance—the new regime shifts from punitive "inspector raj" to a facilitator-based model. The introduction of a centralized online portal for registrations, returns, and compliance (often under a single form) drastically reduces the bureaucratic burden on businesses. Risk-based inspection system and computerized random allotment of inspector minimize human discretion and potential harassment.

The correlation to the ease of doing business in India is direct and significant. By replacing a fragmented, archaic system with a consolidated, transparent, and flexible framework, these reforms address one of the biggest historical pain points for investors and domestic businesses alike. They reduce compliance costs, mitigate regulatory uncertainty, and formally acknowledge the realities of the modern economy, including its platform-based workforce.

The beauty of law is in its implementation. While the final implementation is key, these labor codes mark a decisive move away from a purely protective philosophy towards productivity-linked and enabling one. This rebalancing is crucial for attracting investment, encouraging formal job creation, and ultimately fostering a more competitive and business-friendly environment in India, all while aiming to extend welfare benefits to a larger section of the workforce.

Import & Export Policies

India's engagement with the global trading system, particularly in technology, is a story of evolving strategy shaped by economic history. As an original signatory to the 1996 World Trade Organization (WTO) Information Technology Agreement (ITA-1), India embraced tariff elimination on a wide range of ICT products. This move was instrumental in integrating the country into global tech supply chains, primarily fuelling its now-world-leading software services and IT enabled services exports. However the experience also revealed a vulnerability. A surging import bill for hardware and electronics that contributed to a worrying trade deficit in the sector, which stood at over $60 billion as recently as 2022.

This historical context explains India's subsequent strategic caution. A pivotal shift occurred in 2015 when India, citing an imbalanced product coverage that failed to include key items like cellphones while demanding concessions on components, decided not to participate in the expended ITA-2 negotiations. This decision marked a clear policy turn from pure integration towards protecting its nascent electronics manufacturing ecosystem—a goal that would later become central to the Production Linked Incentive (PIL) scheme, which has committed over $2 billion in incentives to boost domestic production of mobile phones and other components.

This divergence from its multilateral commitments culminated in a significant legal challenge. In April 2023, a WTO dispute settlement panel ruled against India in a case brought by the European Union, Japan and Taiwan. The panel found that India's imposition of import tariffs—ranging from 7.5% to 20% on key ICT products like mobile phones, components, and integrated circuits—violated its binding commitments under ITA-1. India has appealed against the ruling, a move that effectively stalls the process indefinitely due to the ongoing paralysis of the WTO's Appellate Body, a tactic reflecting its strategic prioritization of domestic industry over multilateral compliance.

The government's acute concern for the sector was further underscored in August 2023 when it abruptly announced a mandatory licensing regime for imports of laptops, tablets, and personal computers. Facing severe backlash from industry and trading partners over its potential to disrupt supply chain and increase consumer costs, the government swiftly recalibrated. The policy was softened to an "Import Management System," effective from Nov. 1, 2023. This system requires authorization for imports, but officials have clarified it is not a quota; instead, its stated purpose is to monitor shipments and "provide trust-based and hassle-free import of goods." This incident highlights the constant tension inherent in the *Atmanirbhar Bharat* doctrine: the push for self-reliance versus the immediate need to avoid market disruption and maintain access to critical technology. Since October 2024, the import management system of IT hardware is operational. The government has approved all import applications received thus far, validating its claim that the system is for monitoring rather than restriction. However, industry bodies continue to express concerns about the administrative burden and the potential for delays. The government has simultaneously approved over 110 applications under the PLI scheme for IT hardware, signaling that the monitoring system is intrinsically linked to measuring the success of these domestic manufacturing incentives. Conversely, India has emerged as a proactive leader in trade facilitation for goods that do enter the country. Its ratification of the WTO's Trade Facilitation Agreement (TFA) in 2016 was followed by the establishment of a high-powered National Committee on Trade Facilitation (NCTF), chaired by the Cabinet Secretary. This institutional push delivering measurable results. According to the Commerce Ministry, the average customs clearance time for imported goods has improved dramatically—sea cargo reduced to less than three days in comparison to four days a year prior; and air cargo got reduced to less than a day.

This has enabled by a relentless digitization drive, including the Turquoise Customs Initiative and the Single Window System, which have slashed documentation requirements. A well-oiled grievance redressal mechanism further streamlines processes, directly enhancing India's logistics performance. This progress is reflected in its improved rank in the World Bank's Logistics Performance Index (LPI), moving up to 38th in 2023 from 44th in 2018 (as indicated above).

India's trade policy is not one of blanket protectionism but a calculated two-pronged strategy. It represents a strategic retreat from further multilateral tariff liberalization in sensitive, high-value sectors like electronics. Here, it is willing to absorb WTO disputes and partner criticism to create protected market space for its domestic manufacturing ambitions, as evidenced by the PLI scheme and the tariffs on ICT goods. Simultaneously, it is vigorously implementing facilitative measures for the vast majority of goods that cross its borders, understanding that efficient logistics are crucial for export competitiveness and overall economic health. This dual narrative reflects a mature and pragmatic approach to globalisation: leveraging global trade rules where they align with domestic economic goals (with TFA) and selectively resisting them where they are perceived to conflict with core strategic industrial objectives, even at the cost of short-term diplomatic friction. The ultimate gamble is whether protected domestic manufacturing can become efficient and competitive fast enough to justify the departure from multilateral norms.

Contract Enforcement & Dispute Resolution

India took a quantum leap of 79 positions from 142nd (in 2014) position to 63rd position in 2020 in Ease of Doing Business Index.[16] This is owing to several

[16] World Bank, "Doing Business Report, 2020," World Bank, 2020.

policy reforms discussed above. The entire exercise of the state was to promote trust-based governance vis-à-vis enterprises of all nature. However, among all the parameters of this splendid performance, the worst performance was in enforcing contracts (163 out of 190) and registering property (153 out of 190). However, sensing this India had taken remedial measures and implemented an action plan by passing a Commercial Courts Act in 2015. This act establishes commercial courts and has started producing the effect now. The commercial courts aim to provide an efficient mechanism for the resolution of commercial disputes, resonating the nations resolve to provide an efficient legal system to address commercial conflicts. This enactment contemplates for establishment of commercial courts, commercial divisions and commercial appellate division in the High Courts to ensure the speedy disposal of commercial suits.

The establishment of commercial courts was recommended by the law commission in its 2003 report. [17] In addition, the law commission also contemplated commercial courts imbibe hi-technological tools, to work efficiently and cost effectively. The aim was to expeditiously dispose high pecuniary value commercial suits within maximum a year or two.[18] The significant point to note is that since long there was lot of thinking going on to have an efficient dispute resolution system for the nation. Which is imperative for creating an effective and conducive business environment. Recent reduction of pecuniary value to 3 lakhs from 1 crore; a mandatory provision of institutional mediation and settlement, particularly cases that do not require urgent interim relief have been introduced via 2018 amendment to the Commercial Courts Act in 2015. These are game-changing provisions, likely to yield results now on.

The National Judicial Grid (NJDG), a live updating database, provides us the data to evaluate how the establishment of Commercial Courts is delivering the intended results. [19] Over 50.2 million cases are pending across all courts in India (as on Sept. 7, 2025). This can be a reference point for us to understand the importance of specialized courts, who would priorities in resolving the commercial disputes. As per the data the Commercial Courts across India have disposed over 41,000 commercial cases between 2016 to 2023. Notably, the Commercial courts in Delhi and Maharashtra have been among the top performers in terms of case disposal, demonstrating the model's potential for success.[20] Further the same data analysis also indicates how the momentum is accelerating as the Commercial Courts are gaining expertise in the course of their working. Whooping 11,000 commercial disputes were disposed in just three months (between July and September 2023). This surge in disposals can be attributed to the procedural reforms and the push for pre institutional mediation. The Commercial Courts Act was amended in 2018 and "pre-litigation mediation" was added as a mandatory phase, while resolving the commercial disputes. This mechanism has also worked wonders. More than 1.75 lakh commercial cases had been referred to pre-institutional mediation, and out of these over 55,000 cases were successfully settled in the year 2023. This mechanism is definitely \ maturing and will deliver the fruits.

The National Mission for Justice Delivery and Legal Reforms has been pursuing a coordinated approach for phased liquidation of arrears and pendency in judicial administration, which inter alia involves better infrastructure for courts including computerization, increase in strength of subordinate judiciary, policy, and legislative measures in the areas prone to excessive litigation, reengineering of court procedure for quick disposal of cases and emphasis on human resource development. These initiatives are reforming the dispute resolution mechanisms not just for commercial disputes, but the overall reduction in judicial delay.

IPR—Legal Framework and Enforcement

India is comparable to advanced US or European countries in the world when it comes to IPR regime. India has array of IP protection laws. They are

1. Trademarks Act, 1999;
2. The Patents Act, 1970;
3. The Copyright Act, 1957;
4. The Designs Act, 2000;
5. The Geographical Indication of Goods (Registration and Protection) Act, 1999;

[17] Law Commission of India, "188 Law Commission Report," Law commission of India, 2005.

[18] It is estimated that Indian Courts take an average of 1445 days to resolve commercial disputes (which roughly turns out to be 4 years).

[19] https://njdg.ecourts.gov.in . The National Judicial Data Grid (NJDG) is a flagship digital platform under the e-Courts Mission Mode Project, serving as a centralized repository for case data from over 18,000 courts across India. Launched to foster transparency and accountability, it provides real-time, granular information on case pendency, disposal rates, and case duration. NJDG is a cornerstone of India's efforts to modernize its justice delivery system and reduce delays.

[20] This figure was originating from a written reply in the Lok Sabha (Indian Parliament) by the Law Minister, while giving the official government statistics.

6. Semiconductor Integrated Circuits Layout Desing Act, 2000;
7. The Protection of Plant Varieties and Farmers Rights Act, 2001; and
8. The Information Technology Act, 2000.

All these legislations are TRIPS compliant. The entire focus of Indian legal system is to protect, promote and proper enforcement of IP laws.

The National IPR Policy was adopted in 2016, which mainly aims to facilitate the promotion, creation and commercialization of IP assets through a Cell for IPR Promotion and Management (CIPAM) under the control of the Department of Promotion of Industry and Internal Trade (DPIIT). "Creative India: Innovative India" is the popular slogan, heralds the basic intent behind this policy. Following are the seven objectives of the IP Policy:

1. IPR Awareness, promotion and outreach.
2. Generation of IPRs.
3. Legal and Legislative framework.
4. Administration and management.
5. Commercialization of IPRs.
6. Enforcement and adjudication; and
7. Human capital development.

The apex executive body for administrative registration of patents, trademarks, designs and geographical indicators is the office of the Controller General of Patents, Designs & Trademarks (CGPDTM), which is under the Department for Promotion of Industry and Internal Trade, Ministry of Commerce and Industry. There is well-oiled machinery to register the IP rights/innovations. IP Registrars are maintained at the national level. Appeals against the decisions of the IP Registrars (refusal to register a trademark etc.) and to revoke/cancel patents go either before the Commercial Courts or to the High Courts.

IPR dispute resolution and IP enforcement framework is multilayered and slightly complicated one. It involves civil, criminal and administrative mechanisms. For breach of IP both civil and criminal remedies are provided in the statutes.

Petitions are to be filed to seek civil remedies before the District Courts or High Courts (in those High Courts who exercise original jurisdictions) or the newly established Commercial Courts, as the case may be. Permanent injunction,[21] interim injunction,[22] and damages (monetary compensation) for the losses suffered are traditionally know remedies. In addition to that Anton Piller order,[23] John Doe Orders[24] are now possible as our courts have adopted best global practices while enforcing IP rights.

As stated earlier, most of the IP statutes in India provide for criminal penalties, which include imprisonment and fines, for wrongful infringements. For prosecuting these remedies, one must go before the criminal courts established for the purpose. Criminal remedies are particularly availed in cases of counterfeiting and piracy, where raids and seizures can physically stop the illegal activity. Indian laws are so advanced that they provide "customs recordation" as well. IP rights holders can register their IP (trademarks, copyrights, patents, designs, geographical indicators) with the Indian Customs under the Intellectual Property Rights (Imported Goods) enforcement Rules, 2007. Once recorded, the custom authorities have the power to suspend the clearance of, or detail, suspected counterfeit or infringing goods at the border. Subsequently they may inform the rights holder, who can pursue further action legal or otherwise.

Indian judiciary particularly the Delhi High Court, has been very proactive in granting dynamic injunctions, imposing heavy costs and damages, and using technology to combat online infringements. Needless to mention, the establishment of Commercial Courts has further streamlined the process of quicker disposal of cases.

Semiconductor Policy Environment

India Semiconductor Mission (ISM), a specialized and independent business division in the Digital India Corporation, is the biggest and most noteworthy initiative of the central government to build a vibrant semiconductor and display ecosystem to make India a global hub in this space. ISM works

[21] The court order stopping the infringing activity permanently.
[22] These are awarded at the very beginning of a suit to prevent immediate and irreparable harm to the parties. This is a crucial and powerful tool. In the recent part Indian courts have started liberally awarding ex-prate (without hearing the other party) ad-interim injunctions in clear cases of infringement.
[23] It is named after a famous case of Anton Piller KG v Manufacturing Processes Ltd., in UK. It is an order allowing the Plaintiff's representative to enter the defendant's premises to inspect and seize infringing goods and documents to prevent their destruction.
[24] The Indianized version is the Ashok Kumar Order in India. It is an order against unnamed defendants. Used very effectively in copyright cases (like movie piracy) to raid multiple unknown locations where infringement is anticipated.

relentlessly to implement the Semicon India Programme.[25]

This program provides an impetus to semiconductor and display manufacturing by facilitating capital support and technological collaborations. The mission is gaining momentum and has eased the pathway for many significant and impactful beginnings. Semicon India 2024, an initiative of the ISM, attracted nearly 11,000 visitors and 250 companies from 42 countries and was a resounding success.

Allocation of $10 billion in funds by the Central Government as an incentive form the core of this mission. Saliently, the Indian government makes the matching funds available on a *pari passu* basis. The money is made available immediately upfront to the company in semiconductor space. This investment package, offering up to 50% of matching grant, is currently the world's most generous schemes. As per the records by the end of 2024 the government should have received the proposals under this scheme and by the first quarter of 2025 the clear picture of this program would emerge.

It must be noted that this program offers Indian start-ups by way of support towards tools, acquiring of licenses for EDA tools etc. 2.5% of this program funding is earmarked dedicatedly for R&D purposes, especially targeting advanced logic, packaging R&D, compound/power semiconductors, and chip design EDA activities. The Indian government has also proposed to establish the India Semiconductor Research Centre (ISRC), an independent, non-profit initiative, which would attempt to foster R&D activity in this space. Hopefully this initiative will also end India's neglected investments in R&D.

Indian overall spend in R&D is awfully low. National Institution for Transforming India Aayog study itself raised alarm about it. According NITI's figure it stood at 0.7% of GDP in 2022.[26] In comparison with this allocation of nearly 2.5% of the total dedicated amount shows India's shift in R&D, particularly in the space of semiconductors.

Another scheme viz., Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS), offer nearly 25% incentive for eligible capital equipment (including plant, machinery, equipment, R&D and utilities) to develop the supply chain—necessary for the industry. There is also the $20 billion Production Linked Incentive (PLI) scheme which intends to support funding for (i) PLI for mobile phones, components, and hardware; (ii) for components and sub-assemblies; and (iii) development of electronics manufacturing clusters. In addition to support allied sectors another $13 billion funds are earmarked. They are to support (i) advanced chemistry cells; (ii) automobiles and auto components; (iii) telecommunications and networking; (iv) solar photovoltaic cell modules and (v) white goods. The PLI schemes are operational in 14 sectors, including flagship Indian sectors such as vehicles & auto components, pharmaceuticals, steel, and textiles. But this scheme has greater bearing upon the semiconductor space as well.

The Ministry of Electronics and Information Technology (MeitY) has launched the C2C initiative as part of its National Policy of Electronics. The program aims to train 85,000 industry ready engineers over five years to act as catalysts for growth of domestic startups involving fabless chip design.

All Reforms in Context for Semiconductors

Undoubtedly the policy environment looks attractive than ever in India for semiconductor business. However, the most important point to note is the firm resolve and commitment of India to be the global power.

The vibrant modern Indian achievements are illustrations to this ambition. Chandrayaan-3,[27] Aditya-L1,[28] NAVIC (Navigation with Indian Constellation),[29] in space technology; developing

[25] The Union Cabinet had approved the comprehensive Semicon India program with a financial outlay of 76,000 crore for the development of sustainable semiconductor and display ecosystem in 2021.

[26] In contrast China spends 1.2%, Russia spends 1.1%.

[27] Missions developed by the Indian Space Research Organization (ISRO), with which India became the first country to touch down near the lunar south pole, at 69 degrees south, the southernmost lunar landing on Aug. 23, 2023.

[28] "Aditya" in Sanskrit means the Sun, L1 referring to Lagrange Point 1 of the Sun-Earth system, is a location in space where the gravitational forces of two celestial bodies, are in equilibrium. This allows an object placed there to remain relatively stable with respect to both celestial bodies. This mission vide satellite dedicated to the comprehensive study of the Sun. The mission takes the credit of seven distinct payloads developed, all developed indigenously (five by ISRO and two by the Indian academic institutes in collaboration with ISRO).

[29] Indian regional navigation system, providing an alternative to GPS and enhancing navigation capabilities in the region.

Akash,[30] Agni,[31] INS Vikrant[32] and Project 75I (Kalvari-class submarines)[33] series towards achieving self-reliance in defense production sector; Covaxin,[34] Omicron booster mRNA vaccine,[35] qHPV vaccine,[36] ZyCo V-D vaccine,[37] in the biotech and healthcare space; implementing mammoth scale projects like Aadhar,[38] Jan Dhan Yojana,[39] Unified Payments Interface,[40] Account Aggregator[41] —indicate the modern emerging India and its aspirations.

Significantly, India does not just dream of becoming global giant but firmly believes that it can. The earlier pessimism regarding the growing population as burden has now been perceived as its national wealth. The current state agencies are working with gods-speed to achieve this. Indian foreign policy has undergone drastic change, wherein India has started taking independent judgements and decisions, to resonate its realization of being global power.[42] The GOM on National Security (2001) report published by the government of India, suggested that India has no reasonable alternative but to opt for closer relations with the US, demonstrated its shift and strategy. It's growing economic performance has given it a great self-confidence, which was lacking until the 1990s. India's strategic thinker C. Raja Mohan said (2006) "after disappointing itself for decades, India is now on the verge of becoming a great power." This is not just an ambition by a few Indian scholars and political leaders. Even the world is seeing India unleashed every single day in every possible field. *China Daily*'s remark upon India's great power ambitions (when it launched successfully Agni missile); the *Economist* publishing a special issue with a title "India as Great Power"[43]—these are a few testaments to recall.

Ending the era of coalition governments for last few decades (since 1989), BJP was elected to power by winning 282 (out of 543 seats) in the general election in 2014. This heralded a new political agenda. The election slogan of "*shreshha Bharat* ("greatest India"), and high economic growth kindled people's imagination for being global power. The BJP lead government is continuing in power; so, the mandate of making India a world power. S. Jaishankar, when he took over as the external affairs minister said "India's foreign policy dimension is to aspire to be a leading power, rather than just a balancing power," probably captures the essence.[44]

Therefore, undoubtedly underlies a grater aspiration among every Indian to be one among the leading nation. This can certainly be harmonized by the aspiring semiconductor industry which can harness the growing potential of nation. In this large canvass following specific indicators help assessing the opportunities for the semiconductor industry.

Human Resources

It is stated earlier that there are about 1,25,000 engineers working in verity of aspects of chip-design and development. The increase in the sector would call for a greater number of qualified-industry-ready workforce. India has 3,500 engineering colleges (including premier IITs), 3,400 polytechnics—producing nearly 3.0 million engineering graduates with around 7,00,000 engineers with electronics specialization. However, the employability and requisite skill sets is in question, as many reports indicate. The semiconductor employment openings have increased by 7% between 2019 and 2023. If we consider the demand would take quantum leap due to sudden expansion (which is unlikely to happen overnight!) by three times, still India would have immense talent pool to choose from. It must not be forgotten that 5% of these engineering graduates come from IITs alone if we add another 5% from some of the National Institute of Technology (NITs) and others that can certainly cater to the requirement of the sector.

[30] Akash is a surface-to-air missile with an intercept range of 25 Kms, flies with supersonic speed, reaching around Mach 2.5. This was jointly developed by Defence Research and Development Organization, Bharat Electronics Limited, Tata Advanced Systems Limited, National Aeronautical Limited and Larsen & Toubro. This testifies India emerging power of PPP capabilities of emerging India.

[31] Agni, a Sanskrit name for "fire," are long range, nuclear weapons capable, surface-to-surface ballistic missiles. These are developed indigenously under the Integrated Guided Missile Development Programme.

[32] The first Indian-built aircraft carrier which was launched in 2013, the first of two planned for the class, and was commissioned on Sept. 2, 2022.

[33] A program by the Indian Navy to build six conventionally powered attack submarines with advanced air-independent propulsion systems.

[34] Indigenously developed by Bharat Biotech, is one of the successful COVID-19 vaccines.

[35] India's first indigenously developed Omicron booster vaccine.

[36] The maiden indigenous quadrivalent vaccine against cervical cancer.

[37] Again, the first Indian developed DNA-based vaccine.

[38] A unique digital identity platform for Indian residents, enabling access to various government services and financial transactions.

[39] A financial inclusion initiative providing basic bank accounts to unbanked citizens, facilitating electronic payments.

[40] A revolutionary digital payment platform that empowers instant and secure cashless transactions across different banks.

[41] An innovation that allows users to share their financial data securely with authorized entities, simplifying processes like loan applications.

[42] Takenori Horimoto, "Explaining India's Foreign Policy: From Dream to Realization of Major Power," *International Relations of the Asia-Pacific*, Vol. 17, Issue 3, September 2017, pp. 363-497.

[43] "The Economist," *The Economist*, March 30, 2013.

[44] In delivering IISS-Fullerton Lecture at Singapore.

The new NEP emphasizes for industry and academia collaboration, which has already taken roots, and more and more institutions are linking up with industries. AICTE mandates industry internship to the students, which provides a window of opportunity for the industries to scout for right talents, without even hiring any manpower formally. The author of the paper witnessed fantastic collaboration between Cambridge Institute (a mid-level, but progressive) engineering college in Bengaluru having an active collaboration with Samsung, where the students are provided with industry ready knowledge and skills. Prof. Yadati Narahari, of IISc was hopeful that in another few years from now (after IISc's new curriculum is adopted by all engineering colleges) India would be able to cater to the global demand of semiconductor industry. Even the Deloitte report also estimates the same. It states the growing semiconductor industry would be needing around a million skilled workforce; and Indian is poised to fill this gap.

On the contrary, there is a MeitY report which finds that "there will be a requirement of 10,000-13,000 human resources to meet industry (chip manufacturing) requirements, by 2027…and simply does not have such skilled workforce." It is believed that already many premier engineering institutes (like IIT Kanpur) are slowing increasing their electrical and computer engineering course offerings. Particularly IIT, Kanpur offers a course on IC fabrication, and various courses related to electronics device physics and modelling as well as integrated circuits. IIT Madras has launched a four-year online bachelor of science in electronic systems programme. AICTE has also designed a curriculum for BTech in electronics and diploma in IC manufacturing. Many industry experts in their interview revealed that even for US gathering skilled manpower would be a challenge in accomplishing the objectives of the CHIPS Act. This is one area where India and US may collaborate to via skill-India project to benefit mutually.

Power

The semiconductor industry particularly fabs are power hungry. Therefore, ensuring a stable, reliable, and consistent supply of electricity is crucial to supporting the industry. The semiconductor industry uses up to 100 megawatt hours of power for each of its working hours. If the power supply is not stable, then it would result into greater loss to the fabs, as power fluctuations are an anathema for chips. Unstable power supply in India had been a factor in Inda's previous unsuccessful attempts to establish its semiconductor manufacturing. But the situation has improved considerably.

India started its power sector reforms in early 1990 resulting into complete privatization of the sector with the Electricity Act. Gross electricity generation in India has increased from 747.07 BU in 2008 to 1624.47 BU in 2022-23. This is at the CAGR of about 5.7%. interestingly as experts indicate the growth in generation is slightly below the capacity. Therefore, without any further investments the production can be increased. The power supply from non-conventional energy sources has increased multifold. Thanks to encouraging governmental policies both at state and central level.

In addition to the state investment (both in terms of economics and policies), national Infrastructure Pipeline, 209-2025 indicates highest share of investments (24% of the total capital expenditure of 11 lakh crores) towards power sector. Total FDI inflows in the power sector reached $18.28 billion between 2000 to 2024 and the power sector is expected to attract an investment worth $205.31 billion till 2029. All these are clear indications that the power generation would further improve, leading to energy independence.

Supply Chain Logistics

Semiconductor industry entails more than 150 chemicals, over 30 gases, and over 30 minerals, including many unique chemicals such as sulfuric acid, hydrochloric acid, ethanol, acetone, and phosphoric acid; minerals including aluminum, antimony, arsenic, beryllium, bismuth, boron, carbon, chlorine, cobalt, copper, fluorine, gallium, and germanium etc. A BEL officer, in his interview explained that India has capabilities and produces many of the chemicals that are required for semiconductor manufacturing already. However, it would need to build refinement capabilities to improve the purity of chemicals to support to the requirement of the semiconductor grade needs. This would mean a further investment of $400 to $500 million and that must be attracted either with government or private funds. However, this must come in tandem with the development of the sector. Asking the chemical industry to invest and start production without consumption is not going to help the cause. This is believed to be one of the critical shortcomings in India's aspiration to build a world class semiconductor industry.

Transportation Infrastructure

India increased its highway construction threefold. India is adding 37 Kms per day to its existing infrastructure. In last 10 years we have added over 2,00,000kms of road infrastructure. Today the Ministry of Road Transport and Highways has consistently been awarding and constructing over 10000 km of national highways per year. This is record breaking and unprecedented.

India has significantly improved its rail infrastructure. The new Vande Bharat trains are the latest focus of Indian initiative. These high-speed trains with all modern amenities. More than 50 Vande Bharat trains are commissioned which connect over 250 cities across India. The Eastern and Western Dedicated Freight Corridors (CFCs) are now largely operational. These are game-changers, freeing up capacity on the existing passenger rail network by moving freight to separate, high-capacity electric lines. PM GatiShakti National Master Plan is a digital platform, which is fundamental to all infrastructure planning. It ensures all ministries (Rail, Road, Ports) plan projects in synergy, avoiding delays and optimizing routes by seeing existing pipelines like gas, water, and fiber optic cables.

India has doubled its number of airports over the period to 150 from mere 74, with another over 100 airports to be added to the list in near future. There is considerable developments and progress in India's ports sector. The World Bank noted this and stated, "since 2015, India has invested in soft and hard infrastructure to connect ports on both coasts to economic poles in the hinterland, including a supply chain visibility platform delivered through a public-private partnership." India has completed a record over 180 port projects over 230 new ones in the pipeline.

State Initiatives

Parallel to the center the various states have also involved in developing the semiconductor industry. They are doing it by providing attractive policies and attracting foreign direct investments. In fact, the Indian states are now fiercely competing (in a positive sense) with each other to attract investments and MNCs in semiconductor space.

As stated, earlier Karnataka is leader in this space. Popularly known as "Silicon Valley" of India, it contributes more than 10% of India's national electronic output. Karnataka has an overarching IT industry worth approximately $64 billion, with a workforce over 5,00,000 employees. Being a leader, the government of Karnataka has provided infrastructure and labor environment needed for larger semiconductor industry with two of its electronics manufacturing clusters in Mysore and Hubballi. According to the industry commissioner it has already received seven to 11 letters of intent from electronics manufacturers to set up operations in Mysuru and Hubballi respectively. He said that Karnataka has also signed an MoU with Keynes Technology for 3,750 crore for a printed circuit board manufacturing plant.

The vibrant western state of Gujarat in India became the first state to have announced a dedicated Gujarat Semiconductor Policy 2022-2027. As a result of this—Micron announced in June 2023 of establishing its plant worth $2.75 billion in Sanand. The state has also announced to develop a "Semicon City" in Dholera Special Investment Region (SIR). In addition to some generous fiscal incentives, the Gujarat policy seeks to provide for land allotments, expedited process approvals, ready access to power, water, gas etc. for instance, for Dholera Special Investment Region, eligible projects will receive 75% subsidy on the procurement of the first 200 acres of land. Another attraction is a fixed water tariff at 12 rupees per cubic meter for five years. The policy also offers a power tariff subsidy of 2 rupees per unit for 10 years.

The leader for manufacturing and automotive sector, Tamil Nadu is willing to catch up with rest of its counterparts. It has the credit of the greatest number of special economic zones in India (50 of them). It houses three out of four Apple's contract manufacturing facilities. Already KLA Tencor, Qualcomm, Applied Materials, Tessolve Semiconductor, Sanmina, Coherent and Mindgrove Technologies are already working out of Tamil Nadu. Through its overall Investment Promotion Subsidy program, it offers one to choose between the following three options: (i) up to 40% flexible capital subsidy; (ii) 10-25% fixed capital subsidy; or (iii) 1.5-2 %turnover subsidy for 10 years. It further provides up to 100% concession on stamp duties and 20 to 50% land subsidy, particularly to support pre-operational setups. Tamil Nadu has also established a state-run skilling and recruitment platform to help industry tap skilled workers and to help students build relevant skills. It is believed that over 3,000 companies and 1.2 million students use the platform, which offers over 300 courses and 20,000 job postings. The eastern State of India, Odisha, in July 2023 unveiled its "Semiconductor and Fabless policy. Further the state government has also launched several initiatives to promote entrepreneurship such as Startup Odisha initiative, which aims to create a conducive ecosystem for start-ups to flourish.

Conclusions & Recommendations

India undoubtedly offers a great hope and opportunity for the semiconductor industry to grow further. This is but a natural progression from its revolution in the space of information technology. The government's resolve and policy programs—all are favorably poised towards this direction. Big ticket investment from States, private players and foreign direct investments will make this happen rapidly and sustainably.

In the light of the above, following are the recommendations to improve the policy paradigm for resilient semiconductor dream of India:

1. R&D investment—In spite of positive indications, Indian spending on R&D still needs to be improved. In the recent interim budget 2024-25, the government announced a corpus of 1 lakh crore to augment research and innovation ecosystem. Even then India's investment in the R&D space is just over 0.64%; which is awfully low in comparison with other developing countries. Particularly in comparison with South Korea (4.8%), the US (3.5%), Germany (3.1%). In a recent study of 34 countries, ITIF found that India ranked 26th in terms of R&D tax subsidies, with a subsidy rate of 8.2% which probably indicates our low priority. In 2023, on an average 247 patent applications were filed daily in India. This is all-time high in comparison to past 20 years. This growth in innovation culture must be sustained by providing proper incentive. Therefore, the need of hour is to increase the allocation and spend on R&D for bolster the high-tech intensive semiconductor industry.

2. Streamlining the "single-window" clearance process—Many industry leaders interviewed by the author (and of course in their other published interviews) indicated that the resolve at the highest political offices alone is insufficient to turn around the ground realities. Specifically, they were referring to the system of "single window" established for grant of clearance to the projects. Lot of refinement is still expected to happen there. Until that the political resolve at the higher levels would not percolate down to transform the reality.

3. Reforms in indirect tax system—As explained earlier implementation of GST, is the biggest reforms to boost overall trade and commerce in the country. Undoubtedly it has eliminated complex and overlapping multitude of indirect taxes. However, the still the tax rates are yet to be rationalized; and auditing procedures are to be further streamlined and simplified. Unless rationalized further, high compliance cost will force enterprises to find dubious ways. Even the dispute resolution mechanisms are to be strengthened. The introduction of faceless assessments and a vendor compliance rating system needs immediate attention, and refinement.

4. Direct tax reforms—"Taxes are what we pay for civilized society," said US Judge Oliver Wendell Homes. But it is imminent that the tax slab shall to optimal. Unfortunately, Indian corporate tax in comparison with other emerging and competition economies is high. For instance, Malaysia (24%), Indonesia (22), Vietnam, and Thailand (both 20) have lower rates than India's imposition of 25%. The correlation between recent refinement in the corporate tax structures and India's plunge from 81st rank (in 2015) to 40th in the Global Innovation Index 2023 must be understood.

5. Rule of law—India ranks 79 (out of 142 countries) in the Rule of Law Index.[45] This naturally raises concern over India's economic prosperity. Mere economic development would not be sustainable over a period, unless rule of law is strengthened. Lack of rule of law will be detrimental to both enterprises and commoner. It is no option for India but to think carefully through in strengthening the rule of law scenario.

6. Commercial courts—There is no doubt that the situation has considerably improved after the establishment of commercial courts. However, the working of the commercial courts must be further improved, particularly by introduction of technological tools. Building the capacity of human resources in understanding the commercial contracts, organizations etc., is the need of hour. Otherwise, mere establishment of commercial courts would not help the cause.

7. The human resources—India produces more than 1.5 million engineering graduates annually. But the quality of the engineering education has always remained a question. New National Education Policy attempts to address this issue by recommending many ways. The skill gap is recognized as the largest cause of our engineers not possessing the requisite industrial readiness. NASSCOM has projected that India's technology sector will require over one million engineers with advanced skills in almost every aspect. This is one area where further impetus must be given for improving the quality of technical education. Moreover, among the engineering aspirants, most of the students are focused on data and computer science or AI as their stream. This might make hiring for the semiconductor industry a challenge.

8. Chemical industries readiness to traction—Semiconductor manufacturing requires nearly 150 chemicals and over 30 gases and minerals, with extreme high purity standards during its processes. This exceptional level of specialization has been met by a very small producers based in Japan, South Korea, the US, and Germany. This concentration has made supply chains vulnerable to disruptions. India has world's sixth-largest chemical industry. However, still Indian chemical industry must gear-up to support with the specialized chemicals and gases required for chip manufacturing. But the key point to note is that Indian chemical industry has the potential to grow and support, if it is honed and encouraged via positive policies. India has produced several bult and specialty chemicals, including acids, solvents and industrial gases. However, these produce currently lack the ultra-high purity standards required for the semiconductor manufacturing. Therefore, the government shall pay attention towards this.

[45] A critical initiative of The World Justice Project.

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