# Focus

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## Abstract

*In the ongoing chip war, tensions between the United States and China have intensified, causing a ripple effect with far-reaching regional implications. The United States, in its pursuit to diminish China's dominance as a semiconductor powerhouse, is forging technological alliances with like-minded countries, prominently India. However, this strategic alignment with India in semiconductor capabilities has placed Pakistan at a crossroads, carrying potential implications for its national security. This paper aims to investigate the escalating cooperation between the United States and India while elucidating the pivotal role of semiconductors in modern technology. Furthermore, it highlights India's aspirations under the Modi regime to strengthen its indigenous semiconductor sector, while examining the associated opportunities and challenges. Concurrently, the paper examines Pakistan's current semiconductor landscape, highlighting the manifold challenges it confronts in keeping pace with global developments. Finally, the paper discusses opportunities in the expanding semiconductor industry for Pakistan to*

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*strengthen its domestic capabilities while safeguarding its national security objectives.*

***Keywords:*** *Semiconductors, Chip War, US, India, Pakistan, Design, Manufacturing.*

## Introduction

Within the global semiconductor supply chain, the United States is resolute to explore alternative means as China accounts for a significant share of semiconductor manufacture, assembly, and consumption. Recent developments, such as the COVID-19 pandemic, the China-Taiwan dispute, and the Russia-Ukraine war, have further highlighted the US and its allies the risks of supply shortages induced by over-dependence on a single state for semiconductors. To this end, extensive negotiations have taken place between the US and India over the past few years, with the aim of positioning India as a strategic competitor to China in chip technology.

Moreover, as a strategic move to limit China's burgeoning semiconductor ecosystem, the United States enacted the 'Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act' on 9 August 2022.[1] The legislation placed restrictions on international semiconductor manufacturers, preventing them from selling chips, designs, and software to China. Simultaneously, it provided foreign firms with financial incentives of roughly $280 billion to invest in US facilities.[2] In addition, in a supply chain assessment report released by the White House in June 2021, two commodities, gallium and germanium, were identified for their pivotal roles in the semiconductor industry, with a notable concentration in China.[3] Correspondingly, China experienced a 15 per cent decrease in its imports of semiconductor manufacturing equipment in 2022 and

a substantial 27 per cent decline in imports during the period spanning from January to February 2023.[4]

As the US seeks to limit China's semiconductor capabilities by equipping India for potential chip-related challenges, these dynamics are adding to national security concerns for Pakistan. The expanding cooperation has the potential to provide India with substantial leverage and influence, both regionally and globally, particularly in the area of semiconductor technology. As India builds ties with the United States, the prospect of increased access to cutting-edge technology looms, signalling that Pakistan will face increased competition in the technology sector. In light of these developments, the paper provides a comprehensive roadmap for Pakistan to navigate this dynamic landscape and protect its technological aspirations within the global tech arena.

## Comprehending the Significance of Semiconductors

Semiconductors, also known as chips, are materials with conductivity levels that fall between those of conductors and insulators. They can be pure elements like silicon and germanium, as well as compounds like gallium arsenide and cadmium selenide.[5] In the age of digital transformation, semiconductors serve as the building blocks of modern electronics and information and communications technology. They have become integral components of quantum computers and data centres all over the world because of their fast processing, storage and transmission capabilities. The significance of the semiconductors has elevated them to a matter of national security concern for countries across the globe.

Furthermore, the manufacturing process of semiconductors can be categorized into various stages: design, fabrication, Assembly, Testing, and Packaging (ATP). Different countries dominate each of these stages, providing specialized services. These services include raw materials, electronic design automation (EDA) tools, semiconductor manufacturing equipment (SME), and core intellectual property (IP).[6] This complexity in semiconductor supply chains results in geographic dispersion. The demand shocks are becoming increasingly evident, leading semiconductor supply-side actors to transition from global collaboration to alliances or self-sufficiency.

Ensuring the seamless global distribution of semiconductors and related products is a difficult task. The fragility of the semiconductor supply chain to even minor disruptions highlight the possibility that countries would become vulnerable targets for cyberattacks. As semiconductors form the core of critical infrastructure systems, developing a robust domestic semiconductor sector is critical to ensuring the integrity of any country's cyber defences. Countries have recognized the intricate relationship between semiconductors and national security, prompting them to prioritize collaborative efforts over solitary pursuits to strengthen their technological resilience. In this regard, both the US and India consider semiconductor research, development, and production to be a strategic imperative.

## US- India Chip Collaboration: Joint Ventures and Research Initiatives

In an effort to reduce their dependence on China and strengthen their indigenous capabilities, the United States and

India are engaging in several semiconductor initiatives. During the QUAD Summit in Tokyo, Japan, in May 2022, US President Biden and Indian Prime Minister Modi unveiled a landmark joint initiative known as 'Initiative on Critical and Emerging Technology (iCET),' which aims to strengthen the technological partnership between the governments, businesses, and academia of both countries.[7] Within the framework of iCET, both countries have emphasized building 'Resilient Semiconductor Supply Chains,' by supporting the semiconductor ecosystem in India, nurturing a skilled semiconductor workforce within India, and facilitating joint efforts in the domains of mature technology nodes and packaging in India.

On 12 April 2022, the US Semiconductor Industry Association (SIA) entered into a Memorandum of Understanding (MoU) with the India Electronics and Semiconductor Association (IESA).[8] This collaboration intends to explore possible opportunities for the US and India within the global semiconductor value chain, as well as to help IESA in assisting local service companies in creating semiconductors and associated goods for the domestic market. Following that, the 'US-India CEO Forum' was soft-launched on November 9, 2022, during a virtual meeting between Gina Raimondo, US Secretary of Commerce, and Shri Piyush Goyal, Indian Union Minister of Commerce and Industry.[9] During the discussion, both officials mentioned strengthening supply chain resilience, bolstering energy security, working to reduce greenhouse gas emissions, and developing inclusive digital trade as top priorities.

In January 2023, the US Semiconductor Industry Association (SIA) and the India Electronics and Semiconductor Association (IESA) took a significant step by forming a private-

sector task force and deepening public-private partnership for chip cooperation.[10] This collaborative effort is part of many bilateral initiatives established under the iCET. This task force will offer recommendations to the Department of Commerce and the India Semiconductor Mission on opportunities and challenges in the global semiconductor supply chain, as well as facilitate both countries to create complementary chip ecosystems.

From 7th to 10th March 2023, Gina Raimondo, the US Secretary of Commerce, visited India at the invitation of Shri Piyush Goyal, the Indian Union Minister of Commerce and Industry.[11] Following a meeting with the Union Minister, Secretary Gina Raimondo signed an MoU to strengthen US-India cooperation focused on semiconductor supply chain development and innovation. The MoU was announced during the relaunch of the 'US-India 5th Commercial Dialogue' in 2023.[12] According to a joint statement, both countries have agreed to establish a semiconductor subcommittee led by the US Department of Commerce on one side and the Indian Ministry of Electronics and Information Technology (MeitY) and the Ministry of Commerce and Industry on the other.[13] Its primary objective will be to evaluate the recommendations made by the task force established under the iCET.

Later that week, US Secretary Raimondo met with Indian Prime Minister Modi, during which they discussed the two countries' deep technological partnership, which operates within the frameworks of the US-India CEO Forum, the US-India Commercial Dialogue, the newly established Strategic Trade Dialogue, and the US-India MoU on Semiconductor Supply Chain and Innovation Partnership.[14] Throughout her visit, the US Secretary had bilateral meetings with Indian ministers, focusing

on critical subjects such as semiconductors and supply chain resilience.

Moreover, Indian Prime Minister Modi's state visit to the United States in June 2023 holds significant importance for both countries, particularly in terms of semiconductor agreements.[15] Additionally, academic institutions in India have intensified their research on sophisticated semiconductor technology in recent years. This has resulted in notable initiatives such as 'SHAKTI,' an open-source project launched by the Indian Institute of Technology, Madras (IITM), with the aim of developing the first domestically produced industrial-grade processor.[16]

Against this backdrop, Mung Chiang, President of Purdue University, participated in the inaugural 'USA-India Semiconductor Collaborative' on 23 June 2023, alongside government officials and technocrats from both the United States and India. This event, co-hosted by Purdue University and the semiconductor industry organization SEMI, took place in Washington, D.C., and was dedicated to advancing workforce development, and research and development efforts in the domain of semiconductors.[17] Notably, this roundtable session coincided with Modi's visit to the US.

During this visit, Micron Technology, a renowned global semiconductor manufacturer, announced a $825 million investment in a semiconductor assembly and testing factory in Gujarat, India, which is expected to rise to $2.75 billion with Indian contribution.[18] This initiative is expected to generate around 5,000 new job opportunities within Micron. Similarly, Applied Materials, a US-based semiconductor manufacturing company, announced the establishment of a 'Semiconductor Centre for Commercialization and Innovation' in Bangalore, India, focusing

on the development and commercialization of semiconductor production equipment.[19]

Additionally, Lam Research, a US supplier of wafer-fabrication equipment and related services, has committed to training 60,000 Indian engineers through its 'Semiverse Solution' to help India meet its goals in semiconductor education and workforce development.[20] While the US is optimistic about India's potential as a competitor to China in the semiconductor industry, there is still a significant gap between verbal guarantees and tangible commitments from the Indian side. This imbalance is forcing India to struggle to provide the necessary capital to support the semiconductor industry, resulting in a multitude of challenges.

## Chip Nationalism in India and Related Challenges

By 2022, the Indian semiconductor business had grown to $27 billion, with 90 per cent of its chips imported, indicating a heavy dependence on external sources for chips.[21] Despite its early stages, global consulting firm Deloitte reported that the Indian semiconductor market will reach $55 billion by 2026.[22] Chip nationalism in India peaked in 2014 when Indian Prime Minister Narendra Modi launched the 'Make in India' campaign. The objective was clear: to transform India into a global manufacturing hub for semiconductors. Since then, India has been actively working to create a more competitive policy environment, aiming to foster deeper integration into global semiconductor value chains.

In November 2020, India introduced the 'Production Linked Incentive (PLI) Scheme,' earmarking a substantial

investment of $963 million to boost semiconductor manufacturing in the country.[23] Following closely in January 2021, the 'Semiconductor Fabless Accelerator Lab (SFAL)' initiative was announced, to foster domestic capabilities in chip design and manufacture.[24] In December 2021, India's Union Cabinet gave its approval for the 'Semicon India Programme' with a significant budget of Rs 760 billion.[25] It was then relaunched as the 'Modified Semicon India Programme' in September 2022, with additional subsidies for the semiconductor sector's robust development.[26]

On 6 April 2022, India took a significant step forward by forming the 17-member 'India Semiconductor Mission (ISM)' to nurture a dynamic semiconductor display ecosystem within the country.[27] The primary responsibilities of this committee include generating finance mechanisms, strengthening global engagements, and encouraging semiconductor research and development. These national developments, coupled with growing cooperation with the US, have ushered in a significant shift in India's national security considerations regarding semiconductors. However, India is confronted with several challenges that must be addressed.

Firstly, the semiconductor industry is undeniably complex, with stages ranging from raw silicon wafers to wafer fabrication, chip design, assembly, testing, and packaging. The Indian government is meticulously analyzing the proposals for semiconductor-related initiatives. Another challenge that India faces is the absence of a semiconductor fabrication facility (commonly known as a fab). However, Ashwini Vaishnav, Indian Minister of Information Technology, announced in March 2023 that India is set to unveil its semiconductor fab facility, with the decision hinged on one of three international bidders, including

a Vedanta-Foxconn joint venture, the International Semiconductor Consortium (ISMC), and Singapore's IGSS Ventures.[28] If any proposal is approved, India might export fabricated wafers to consumers in three or four years.

Furthermore, establishing a commercial fab demands substantial capital investments, long gestation periods, and patience for payback. While India possesses a commendable pool of design expertise, it has failed to create its own fabrication capacity. The Indian Space Research Organisation (ISRO) and the Defence Research and Development Organisation (DRDO) each run their own fab foundries, largely to meet their specific needs.[29] Mohali currently houses India's sole existing semiconductor fabrication facility.[30] In addition, chip production facilities are resource-intensive entities that require clean water, a stable power supply, enormous land, and a highly qualified workforce to function properly.

For instance, ISMC kept India waiting for the finalization of a deal to build a fab in Karnataka.[31] Once construction begins, new challenges may arise, such as acquiring high-purity gases and wafers needed for chip fabrication. Although cooperation between the United States and India appears to be a positive move, it falls short of producing substantial outcomes. Before committing to high-volume commercial production, the Indian government must foster interconnectedness among various industries within the country, facilitating the creation of a comprehensive chip manufacturing ecosystem and granting access to prototyping facilities. Amidst unfolding global rivalry, developing states such as India and Pakistan face the tremendous challenge of navigating this chip war while protecting their national interests.

## Semiconductor Landscape in Pakistan: Identifying Key Challenges

Pakistan's semiconductor industry is in its early stages and faces vulnerability, primarily due to the challenging domestic politico-economic conditions and a lack of digital infrastructure. Noteworthy, the regional and global dynamics add another layer of complexity. Neighbouring India is actively attempting to reposition itself within the global technology supply chain, aiming to gain a technological competitive edge over Pakistan. In response to this evolving semiconductor landscape, Pakistan has taken various steps to expand and improve its semiconductor sector.

One notable effort is the initiative launched by the Punjab's Higher Education Department in June 2021 across eight universities in the region. The project aimed to introduce courses at both undergraduate and graduate levels in these universities, with the dual objectives of integrating students into the design industry and enhancing their expertise in micro and nano-electronics design technologies. To oversee this initiative, the Higher Education Department formed a committee, which includes vice chancellors from relevant universities and key government officials, with the Vice Chancellor of the University of Engineering and Technology (UET), Lahore serving as the committee's convener. The province government has also allocated Rs 41.75 million to establish chip design centres at these universities.[32]

In October 2021, Rapid Silicon, a company specializing in Field-Programmable Gate Array (FPGA) with headquarters in San Jose and Shanghai, announced its entry into Pakistan as the country's first chip design firm. Following the acquisition of $15

million in startup capital, the company set up a local office and began operations in Lahore by hiring around 60 engineers.[33] In the semiconductor space, a significant development occurred when Pakistan unveiled the 'Pakistan National Semiconductor Plan (PNSP)' in January 2022.[34] This plan serves as a strategic roadmap designed to enable Pakistan to develop long-term manufacturing capability and secure design supply for crucial components.

Following the COVID-19 pandemic, countries took steps to secure their manufacturing capabilities by relocating production plants. In February 2022, Chaudhry Fawad Hussain, the former Federal Minister for Information and Broadcasting, revealed that former Prime Minister Imran Khan discussed the possibility of relocating the microchip industry to Pakistan during his visit to China for the opening ceremony of the Olympic Winter Games Beijing 2022.[35] This proposal was not entirely new, as discussions about Chinese chip companies interested in semiconductor cooperation with Pakistan had already taken place during the Federal Minister's visit in 2019.[36]

In December 2021, Imran Khan also inaugurated 'Lahore Technopolis,' a special technology zone, and signed an MoU to secure a $300 million investment for the development of three additional technology zones across the country.[37] The government previously granted a 10-year tax exemption to enterprises working within the zone in order to encourage further investment. Companies from the United States, Canada, and Australia, in addition to China, had expressed interest in working with Pakistan in this zone.[38] By 2022, Pakistan has revealed its goal to develop Lahore Technopolis into a semiconductor zone.

Subsequently, in September 2022, Pakistan's Technology Upgradation and Skill Development Company (TUSDEC) recognized the need for establishing a 'Center for Acquisition of Semiconductor Technology.'[39] This centre is anticipated to offer expert services for product design and prototyping, as well as sophisticated electronics design and quality assurance laboratory for design purposes. In January 2023, Hamza Saeed Orakzai, Director of Strategic Planning and Regulatory Affairs at the Special Technology Zones Authority (STZA), stated that Chinese companies have displayed significant interest in STZA projects.[40]

Notably, China announced a $400 billion plan to address surging semiconductor demand. China needed 0.5 million semiconductor developers for this project, and it had already acquired 0.2 million chip designers domestically, leaving a need for the remaining 0.3 million chip designers from other countries. Recognizing this opportunity, STZA developed a comprehensive strategy in collaboration with the Pakistani embassy in China to engage with Chinese tech companies and offer chip design services. To facilitate this outreach, the Pakistan embassy issued 200 letters to relevant Chinese companies.[41]

Nonetheless, India's emergence as a dominant player in the semiconductor industry is starting to disrupt the hegemonic balance in South Asia. Given India's rapid progress, Pakistan has begun to understand the untapped potential of semiconductors as a conduit for technological advancement. However, Pakistan's efforts to support its semiconductor sector, while commendable, exhibit limitations in terms of both scope and scale, particularly when juxtaposed with India's more ambitious initiatives.

Presently, India claims an astounding $150 billion in technology-based exports, compared to Pakistan's meagre $1

billion in technological exports.[42] Moreover, India's proactive collaboration with the United States has brought forth a myriad of implications that Pakistan must promptly address. For instance, the US-India engagement under the framework of iCET has the potential to propel India to technological prominence. This could expose new vulnerabilities for Pakistan, which India can exploit, similar to incidents involving Israeli spyware, Pegasus, which targeted Pakistan's government, journalists, and citizens.

Moreover, Pakistan's semiconductor sector is currently underdeveloped, with a notable absence in the semiconductor supply chain. Likewise, Pakistan is highly reliant on semiconductor imports and lacks an indigenous fabrication facility. This shortcoming highlights Pakistan's gap in R&D efforts, which are critical for developing a trained workforce to serve academia and industry alike. It is also caused by a dearth of highly trained faculty and an insufficient allocation of academic resources. Therefore, academic institutions have yet to adapt to the rapidly changing skill sets required by the global market.

In a similar vein, Pakistan lacks a competitive edge when it comes to establishing itself as a dominant competitor in the semiconductor design sector. One glaring issue is the absence of incentive schemes to entice chip design businesses from the United States and China to build centres in the country. They have also expressed legitimate concerns about the availability of high-quality facilities and infrastructure, as well as effective security measures. To mitigate these concerns, Pakistan needs to actively pursue policies aimed at the development of top-tier facilities, potentially making them accessible to overseas design centres.

## Pakistan's Semiconductor Future

In the semiconductor industry, Pakistan can explore several potential avenues to bolster its domestic semiconductor sector while fostering cooperation with countries at the forefront of semiconductor technology. One significant potential lies in semiconductor testing and packaging. It also corresponds to market trends in Pakistan, where cost-effective solutions are important. Notably, firms such as AltaNova have already begun to provide semiconductor testing services in Pakistan.[43] Pakistan could pursue strategic collaboration with prominent international and regional testing and packaging companies to further strengthen its testing capabilities.

Furthermore, Pakistan's willingness to invest in semiconductor manufacturing and establish a fabrication plant remains limited due to the capital-intensive nature of this space. Rather, concentrating on chip design and ATP services appears to be a more practical option. These are labour-intensive segments that complement Pakistan's existing talent pool. A coordinated effort between the government and the private sector could achieve success swiftly. Ideally, the government can play a key role in establishing national semiconductor goals, offering incentives such as leased land, tax grants, a favourable regulatory framework, and assistance in managing design centre operational costs.

However, it is unlikely that the government will solely undertake the direct investment in design centres. This is where the private sector steps in, assuming responsibility for the establishment of training institutions and design facilities. The private sector could also take the lead by meticulously planning, raising funds, collaborating with international design firms, and

working closely with training centres to ensure the development of a skilled workforce. In addition, Pakistan benefits from a surplus of human capital, with a large number of engineers graduating each year. This pool of engineers can actively contribute to improving the chip-designing process by establishing training facilities.

When international corporations consider working with design centres in Pakistan, their initial point of contact is with Pakistani consulates.[44] These companies reach out to learn about the feasibility of operations, the availability of skilled labour, and trade restrictions in cities with a concentration of semiconductor companies. However, dealing with these consulates presents a challenge. They are often understaffed, and their commercial attachés lack knowledge regarding the complexities of the semiconductor sector. A feasible solution might involve developing a specialized role within embassies, delivering expert guidance and promoting semiconductor businesses in Pakistan.

Moreover, Pakistan has the opportunity to enhance its collaboration with China in response to the increasing partnership between the United States and India. Likewise, China is facing a lack of experienced chip workforce, a critical shortage in its thriving semiconductor industry. To address this, Pakistan's academic institutions can work with their Chinese counterparts to train Pakistan's young engineers for the semiconductor industry. Additionally, Pakistan's diaspora in China possesses the potential to bridge this knowledge gap, bringing technological expertise back to their home country.

Another notable alternative for Pakistan is the establishment of the Pakistan Semiconductor Association (PSA).[45] PSA can act as a unified platform for relevant stakeholders such as

universities, research institutes, design firms, and government officials. Its primary responsibilities would include executing social media campaigns, holding periodic webinars and conferences, enabling international chip company visits to Pakistan, and assisting local semiconductor startups with funds.

Finally, in order to improve its chip ecosystem, Pakistan can invest in expanding research and development capacities in the field. This effort begins at universities, where students can gain critical electronics knowledge and skills. Universities should hire research professors with expertise in specific areas of semiconductors. To complement these efforts, academic institutions should set up well-equipped labs to support rigorous semiconductor research. Pakistan should also prioritize infrastructural development. For semiconductor research centres, stable power supply, transportation networks, and high-speed internet access are very critical. At the same time, Pakistan's cybersecurity measures have to be strengthened in order to secure its semiconductor infrastructure from cyber-attacks.

## Conclusion

The United States and China are both dominant global hubs for semiconductor design, manufacturing and assembling operations. In the semiconductor arena, the United States is actively working to counter China by strengthening ties with India. This strategic alliance intends to build a strong and resilient semiconductor supply chain, with India serving as a regional proxy. The chip race among global tech giants poses socioeconomic and security prospects as well as challenges for developing countries such as India and Pakistan. On the one hand, India is reconsidering its domestic capabilities as it extends

its engagement with the US, progressively reducing its reliance on China. Pakistan, on the other hand, is keen on preserving a safe region in which India does not get a competitive advantage in technical breakthroughs.

The US has made major investments to increase India's self-reliance in the semiconductor industry. If the US follows through on its commitment, India will emerge as a key player in the semiconductor industry. Semiconductors are no longer an aspiration for India; they have become a necessity. Fortunately, the Indian government has taken significant steps in this direction, creating a favourable environment for semiconductor growth. The Indian government's position is unequivocal: it wants to build a thriving indigenous semiconductor industry, eventually freeing itself from reliance on other countries for chip supplies.

Nonetheless, the transfer of cutting-edge technologies is a legitimate concern because it has the potential to destabilize the South Asian region. What is critical at this point is for Pakistan to rethink its approach to semiconductors through the lens of national security. As India's semiconductor capabilities improve as a result of technology transfer, its assertiveness may aggravate Pakistan's situation. Pakistan needs to improve its existing capabilities in semiconductor development in order to keep a competitive position in the technology arena.

Furthermore, the intensifying cooperation between India and the United States has not escaped Pakistan's attention, and its implications for Pakistan cannot be ignored lightly. The growing US-China rivalry can exacerbate the long-standing India-Pakistan rivalry by strengthening both countries' technological capabilities. The US-India partnership could also impose additional strain on Pakistan's fragile economy. However,

building a semiconductor industry from the bottom up is a challenging task.

In such a changing environment, Pakistan needs to prioritize investments in education and workforce development. Pakistan should not rely solely on the backing of major global tech players such as China to maintain its viability in a technologically driven world. Instead, the country has the potential to develop its own technological standards that are perfectly aligned with its national capabilities. Pakistan is still in the early phases of semiconductor design; thus, it needs to construct a comprehensive policy that addresses both the development of semiconductor design talent and the expansion of its indigenous industry. This policy should hinge on a solid public-private partnership. Such a comprehensive approach will place the country strategically in the semiconductor arena, ensuring its competitiveness in the global technological environment.

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