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FOSTERING SEMICONDUCTOR GROWTH IN INDIA THROUGH COLLABORATIVE INITIATIVES WITH SOUTH KOREA, JAPAN, AND TAIWAN

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"Our people have tremendous abilities, be it in research or design. India has all the prerequisites to achieve success in the field of semiconductors. For this, we are focused on the right mix of policies, incentives and skilling. We have taken giant leaps in our semiconductor manufacturing mission. Our focus is now on bringing in the entire ecosystem of electronics manufacturing to India, which includes the entire value chain. We are working towards creating a favorable and enabling environment for this,"

-**Prime Minister Narendra Modi**[1]

Abstract

This paper analyses the necessity of fostering semiconductor growth in India through collaborative initiatives with established semiconductor hubs such as Taiwan, Japan, and South Korea. Acknowledging India's substantial reliance on imported semiconductors, intensified by disruptions in the global supply chain, the paper illustrates the pressing necessity for India to diminish its dependency on foreign nations for vital components across multiple sectors. Drawing parallels with the semiconductor industrial development of Taiwan, South Korea, and Japan, the paper elucidates the policy frameworks and strategic initiatives that propelled these nations to become global semiconductor leaders. These include targeted industrial policies, government incentives, and investment in research and development. The paper also discusses

various collaborative avenues with Taiwan, Japan, and South Korea, including joint ventures, technology transfer agreements, and research partnerships. Moreover, the paper highlights the critical areas for improvement in India's semiconductor ecosystem, including the development of indigenous technologies, sustainable manufacturing practices, and water management strategies. It also emphasizes the importance of diversifying the semiconductor supply chain to mitigate supply chain risks and enhance national security.

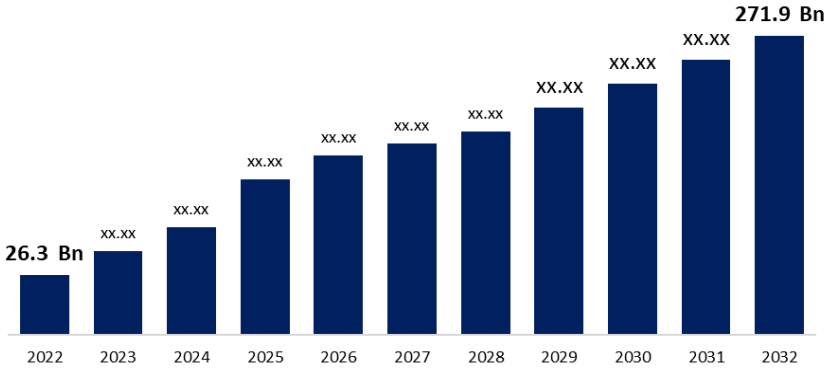
Introduction

Our reliance on electronic devices underscores the vital importance of semiconductors which serve as foundational elements in their fabrication and are being used in healthcare to defense sectors all around the globe. The materials which have a conductivity between conductors and insulators are called semiconductors. The semiconductor industry, which relies on materials like silicon, germanium, and compounds such as gallium arsenide, plays a pivotal role in modern technology. China, as the largest producer of gallium and germanium,[2] supplies these crucial materials globally. This industry operates through four primary phases: raw materials, foundry, fabless design, and packaging, encompassing six manufacturing stages: wafer fabrication, photoresist coating, lithography, etching, ion implantation, and assembly and packaging.

Recently on 13th March 2024 it has been announced that Tata Electronics Private Limited (TEPL) is investing significantly in this sector, with plans for a Semiconductor fabrication facility in Dholera Special Investment Region (DSIR) and an Outsourced Semiconductor Assembly and Test (OSAT) facility in Morigaon, Assam.[3] These initiatives not only signify a leap forward for India's semiconductor ecosystem but also promise to create substantial employment opportunities. The ripple effects are expected to extend across related sectors such as electronics and telecommunications, driving economic growth and advancement. Study shows that the consumption of semiconductor in India will grow at the rate of 19% annually till 2026[4] and India's Semiconductor Market Size is expected to reach USD 271.9 Billion by 2032 as seen in Figure 1.[5]

FIGURE 1

India Semiconductor Market



Source- India Semiconductor Market Size, Share, Forecast Report - 2032 (sphericalinsights.com)

India, which is being led by democratic advantages, significant youth population, increment in skilled workers, incorporating high technology, foreign direct investment, and addressing fiscal deficit, is poised to leverage these strengths to propel its semiconductor industry forward. India's semiconductor market is driven by increasing demand for smaller electronic devices, the growing technology and the emergence of advanced consumer products.[6] In this growing era of 5G technology, semiconductors being the center stage in global politics poses a huge question on the lack of research and development centers in India as currently India relies heavily on countries such as China, Singapore, Japan, US, Taiwan and South Korea for imported chips. In such a rapidly evolving world, 90% dependency on other countries for chip manufacturing is hindering India's growing economy and poses a question on its self - reliance capacity. Moreover, China's rise in the field of semiconductor industries constitutes a threat on India's national security as the Chinese official news outlet Xinhua said in a commentary: "As the 'chip war' fever catches the imagination of India's politicians, diplomats and industry leaders, the age-old problem of talent, infrastructure, and fast-transforming technology ecosystem will plague the India's vision." The Xinhua commentary clearly asks Taiwanese companies to stop obsessing about business opportunities in India.[7]

In this issue brief we will delve into various indigenous prospects of semiconductor development by looking upon the examples of Taiwan, South Korea and Japan. Moreover, this issue brief will scrutinize possible opportunities in the semiconductor

industry by collaborating with these influential giants. The 21st century has seen a rise in geopolitical concern prompting competition and attention among various nations. With AI and 5G technology gaining attention from all over the world, the role of semiconductors has heightened. Needless to say, the military and defense system have a vast array of uses of semiconductors. Some of the examples include unmanned aerial vehicles, GPS systems, advanced radar systems, electronic warfare equipment, missile guidance systems, microprocessors in drones and satellite communications. In the last few years, the world has been suffering from the global COVID-19 pandemic, shutdown of chip production facilities, US-China tensions over Taiwan, Russia - Ukraine war, Israel - Hamas war, impact of climate change, cybersecurity threats and the UN World Water Development Report 2023 cautions about the looming threat of a worldwide water crisis.[8] In such a crucial time of unprecedented challenges, it is essential to advocate for self-sufficiency and minimize our dependence on international partners to foster growth in the semiconductor sector and flow of supply chains. The deteriorating US-China trade war has also forced Apple to shift its manufacturing hub to India[9] to restructure the company's production strategy with India at the center and shift away from China. To retain the advantage in this industry, the chipmakers are persistently working towards strengthening semiconductor performance by packing more transistors into chip bodies. It will make end- devices more sustainable and eco-friendlier.[10]

Comparative Analysis

In order to understand the economic growth of Taiwan, South Korea and Japan we need to shed light upon its various policies which have helped them to become global industrial players in the semiconductor industry. Of utmost significance is that these nations have been transitioned from agrarian societies to economic powerhouses which can also be seen in the case of India.

Japan

Over the years, Japan's economy has transitioned through various phases, starting with rapid growth and expansion in the post-World War II era, extending to the economic miracle of the 1970s and 1980s, during which it emerged as a global economic powerhouse, and persisting through to the present day. Japan's

semiconductor industry was thriving in the 1970s-1980s as they saw the sudden rise in the domestic demand of chip design, materials and manufacturing. Over the course of this era, the significant surge of electronic goods in Japan surpassed the leading semiconductor giant- USA. The Japanese government restricted foreign entry into its domestic market by imposing high import tariffs and also limited the percentage of ownership of foreign companies in the Japanese semiconductor firms. By 1974, Texas Instruments stood as the sole foreign company with a wholly owned manufacturing subsidiary in Japan.[11] In the midst of these events, the funding for Research and Development (R&D) in semiconductor manufacturing equipment also increased which led to the strengthening of innovation and development.

Another significant step taken by the Japanese ministry of international trade and industry which brought technological revolution was the obligation that any licenses brought by foreign firms be made available to all the Japanese firms upon request. These government policies catalyzed the economic progress of Japan. However, the US- Japan semiconductor agreement of 1986 mandated an increase in the foreign share of Japan's semiconductor market from 10 percent to 20 percent which weakened Japan's competitiveness in the market and it boosted South Korea and Taiwan’s global share in the semiconductor market. Yet in the 2000's, Japan revived it's economy by its semiconductor strategy for 2023 focusing on bolstering domestic manufacturing capabilities and promoting research and development (R&D) for next-generation semiconductor technology through global partnerships. This comprehensive approach aims to revitalize Japan's semiconductor industry, showcasing the government's commitment to rejuvenate its semiconductor ecosystem.[12]One of the world's top producers of photoresists which are used in the process of making circuits on silicon wafers is JSR Corporation. JSR and four other Japanese manufacturers account for roughly 90% of the global market for photoresists.[13]

South Korea

The journey of South Korea's semiconductor industry has evolved from a small start and emerged as a top contender globally. The technological revolution sparked in South Korea in 1955 when the three semiconductor firms - Samsung, Hyundai and LG Electronics were ranked amongst the world's top fifteen semiconductor producers. Another significant step taken by the Electronics Industry Promotion law was the

creation of an Kumi electronics industrial complex in 1970's. The complex was granted numerous privileges and government support in the form of infrastructure and facilities development.[14] To attract the foreign investment in South Korea, the government emphasized the collaborative establishment of Masan Free Export Zone (MAFEZ) and Kumi Industrial Complex. As envisioned by the government, Japanese capital predominated in MAFEZ, comprised over 90% of both the number of foreign companies and the total investment size in 1974. (Lee Chang Rok 1974).

Another noteworthy progression was made by the Economic and Scientific Council and Ministry of Trade and Industry which included these points: -

- Adoption of systematic industrial policies including the enactment of the
- Electronics Industry Promotion Law;
- Various tax incentives;
- Export promotion;
- Long-term policies for the education of technical personnel;
- Encouraging the chaebol to enter the electronics sector;
- The establishment of the Electronics Industry Promotion Fund. (EIAK 1989, 56-61)

The escalation of foreign ventures led the semiconductor chaebols (Samsung, Hyundai and LG) to establish business operations in Silicon Valley in the USA. The main purpose of such investments was the acquisition of modern technology, staff training and coordination of business with overseas partners. (Business Korea, 1985). In the 1990's Korea established its position in the market and saw an increase in the market share of DRAM. The East Asian Financial Crisis of 1997 shook the South Korean semiconductor industry. However South Korea learnt a lesson from it and started its dependence more on domestic production of semiconductors.

Moreover, the K Semiconductor strategy of 2021, the Semiconductor Superpower strategy of 2022, the strategy for strengthening the system semiconductor ecosystem of 2023 and the South Korean government plan of making the biggest chipmaking hub near Seoul envisages South Korea as a world's fastest-growing chipmaking industry.

South Korea's K-Chips act which was passed on March 30, 2023 is expected to boost domestic investment for the local chip industry, especially for Samsung and SK Hynix Inc, which are dominant producers of memory chips globally.[15]

Taiwan

Taiwan has established itself as a top microchip producer and taken the lead in the international market because of its robust OEM wafer production capabilities and full industry supply chain.[16] The dominance of Taiwan in microchip manufacturing has been propelled by a combination of factors. The establishment of Industry Technology Research Institute (ITRI) which ultimately resulted in Taiwan's domination in chip fabrication plants are United Microelectronics Company (UMC) and Taiwan Semiconductor Manufacturing company (TSMC).

The Semiconductor manufacturers in Taiwan have always had adequate land, robust infrastructure, access to water and substantial tax incentives. Undoubtedly, 1978 Economic reforms of China propagated by Deng Xiaoping helped China to revive its economy. Being situated next to China, Taiwan's geographical location has positioned the country as an optimal site for semiconductor manufacturing, making it a strategic focal point for the industry.[17]

The research and development (R&D) efforts of the government and the privatization of semiconductor industries helped them to leverage their efforts and capabilities over the years. TSMC also established its research and development center on July 28, 2023 at its manufacturing hub in Hsinchu, Taiwan. The center has been dedicated to produce increasingly smaller silicon wafers which is highly in demand.

Taiwan’s Ministry of Economic Affairs has outlined three areas of partnership in the semiconductor industry, namely:

(1) Joining Taiwan’s core cluster,
(2) Exploring the growing market for semiconductor equipment and materials, and
(3) Establishing operations and research centers to tap into the fast-growing Asia market.[18]

These policies have helped Taiwanese manufacturing companies to propel towards global technological leadership, ushering in unprecedented achievements.

Policy Frameworks and Semiconductors in India

Embedded within every sector, semiconductors hold a central position in driving economic growth and strategic initiatives of a country. With attention now directed towards India's positioning as a semiconductor hub, it is essential to acknowledge the policies and initiatives taken by the Indian government in this sector. The semiconductor industry became prominent in India after Rajiv Gandhi's government initiative in 1984 of relaxation in licensing requirements, the lifting of import duties on electronic equipment and focusing on foreign investments in the technological sector.
When India was progressing in this field and was just two years behind the latest chip manufacturing technology,[19] there was an unexpected turnaround and India saw a downfall in the semiconductor sector as India's bureaucratic system turned into a stumbling block characterized by fragmented ministry collaboration, delaying in granting allocation, slow policy rollout and inadequate infrastructure resulting in significant developmental delays. Today we are twelve generations behind. In the mid 1980's IISc professor A.R. Vasudeva Murthy in partnership with Bharat Electronics Limited (BHEL) tried to establish Metkem Silicon Limited to produce polysilicon wafers for solar cells and electronics, but fell short in achieving the goal due to lack of government support in providing subsidized electricity.

Another tragedy happened in 1989 when the SCL complex in Chandigarh was devastated from fire. India's first semiconductor policy of 2007's objective was to draw INR 24,000 crore ($289.51 million USD) in investments within a span of three years, alongside the creation of three fabrication plants. AMD and Intel were also exploring the idea of establishing fabrication facilities in India during this period and a licensing deal was reached by a group of Indian technologists called SemIndia and AMD Inc. to use AMD's technology to establish a water fabrication plant. Intel, which began operations in India in 1988, declared that it would provide US$ 1 billion to the country in addition to potentially building a fabrication plant. However, circumstances such as including the Semiconductor Policy's stringent minimum investment criteria and the policy's delayed passage, disallowed the industry to take off.[20] A contributing element

was also AMD's decision to divide its fabrication units into a different business, which became GlobalFoundries, as well as problems with financing and production delays.[21]

Now the times have changed thereby, paving the way for new directions in the chip industry. By 2026, the Indian semiconductor market is expected to reach USD 55 billion, with three industries accounting for over 60% of the market's growth: computing and data storage, automotive components, and smartphones and wearables.[22] PM Modi declared that India is turning into a grand conductor for investments in the semiconductor sector during the opening of Semicon India 2023, a national-level conference centered on the semiconductor industry, in Gandhinagar, Gujarat.[23] With the attention now fixed on India's firm initiative of *Aatmanirbhar Bharat*, the Indian government is taking several measures to make itself reliant.

Several Initiatives Taken by Indian Government to Foster Semiconductor Growth In India Are:

- **Semiconductor Fabs and Display Fabs.** The Revised Programs for Establishing Semiconductor Fabs and Display Fabs in India will provide financial assistance of 50% of the project cost on an equal basis to eligible applicants with the necessary technology and capacity to undertake such highly capital and resource-intensive projects. The Indian government will collaborate closely with state governments to develop High-Tech Clusters with essential infrastructure, including land, high-grade water, reliable power supply, logistics, and a research ecosystem, to approve applications for establishing a minimum of two new Semiconductor Fabs and two Display Fabs in the country.[24]
- **Compound Semiconductors / Silicon Photonics / Sensors (including MEMS) Fabs/ Discrete Semiconductor Fabs and Semiconductor ATMP / OSAT Units.** The Updated Scheme for Establishing Compound Semiconductors / Silicon Photonics / Sensors (including MEMS) Fabs / Discrete Semiconductor Fabs and Semiconductor ATMP / OSAT facilities in India will provide 50% fiscal assistance for capital expenditure on an equal basis to eligible applicants possessing the necessary technology to execute these projects. This scheme aims to establish a minimum of 20 units of Compound Semiconductors and Semiconductor Packaging with government support.[25]
- **Semiconductor Design Companies**. Under the Design Linked Incentive (DLI) Scheme, eligible semiconductor design firms will receive incentives of up to 50%

of their expenditure for product design, along with deployment incentives ranging from 6% to 4% on net sales for five years. This support aims to benefit 100 domestic semiconductor design companies engaged in developing Integrated Circuits (ICs), Chipsets, System on Chips (SoCs), Systems & IP Cores, and related semiconductor designs, fostering the growth of at least 20 companies targeting a turnover exceeding Rs. 1500 crore in the next five years.[26]

- **Semiconductor Laboratory (SCL).** The Union Cabinet has approved measures for the modernization and commercialization of the Semi-conductor Laboratory (SCL) in Mohali. The Ministry of Electronics and Information Technology (MeitY) will explore options for a joint venture with a commercial fab partner to upgrade the existing fab facility.[27]
- **India Semiconductor Mission**. To drive sustainable strategies for the development of the semiconductor and display ecosystem, the "India Semiconductor Mission (ISM)" has been established. Led by global experts in the semiconductor and display industry, ISM will serve as the central agency for the efficient implementation of schemes aimed at establishing Semiconductor and Display Fabs.[28]
- **Production Linked Incentive Scheme (PLI).** The Production Linked Incentive Scheme (PLI) for Large Scale Electronics Manufacturing provides incentives linked to production to enhance domestic manufacturing and attract significant investments in mobile phone manufacturing and specific electronic components, including Assembly, Testing, Marking, and Packaging (ATMP) units. This initiative aims to greatly enhance the electronics manufacturing sector and position India as a global player in the electronics industry.[29]
- **The Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS).** (SPECS) aims to mitigate the challenges hindering domestic manufacturing of electronic components and semiconductors, thereby enhancing the electronics manufacturing ecosystem within the country.[30]

Critical Areas for Improvement

A joint study by the Indian Electronics and Semiconductor Association (IESA) and Counterpoint Research claims that India's semiconductor market, pegged at $119

billion in 2021, will grow at a compounded annual rate of 19 percent to $300 billion by 2026.[31] In the wake of US-based Micron Technology Inc. declaration of its plans to establish an ATMP (Assembly, Testing, Marketing and packaging) unit, there were high hopes within the industry for the emergence of initial initiatives. Semiconductor demands for detailed technological expertise and attention. However, the most vital sectors such as defense, space and railways require fabrication foundries or 'fabs' in its manufacturing but a significant portion of fab processing activities occur within facilities situated in East and Southeast Asia. Therefore, dependence on other countries for such crucial areas leads to the risk of national security and concern. Some of the critical areas include:

- Silicon, which is the most commonly used material in semiconductors, absorbs the sun's energy and converts it into electricity. India has a target of 500 GW of renewable capacity by 2030 and an aim to reach net zero emissions by 2070. Achieving net zero future in the coming years and emerging as a hub of green tech manufacturing will be a catalyst for India's semiconductor industry in South Asia.

- Even in the case of importing silicon, India is still dependent on China, Malaysia and the USA.[32] Achieving self-reliance in silicon production requires a multifaceted strategy encompassing investment in research and development, fostering domestic manufacturing capabilities, incentivizing innovation in renewable energy sources for silicon production, and establishing robust supply chain networks. India must prioritize the development of indigenous technologies for silicon extraction and purification, while also promoting collaborations with global partners to leverage expertise and resources. Moreover, fostering a conducive regulatory environment and providing financial support to domestic players will be pivotal in bolstering India's position in the global silicon market. Embracing sustainability practices and minimizing environmental impact throughout the silicon production process will further enhance India's competitiveness and pave the way towards self-sufficiency in this critical industry.

- Furthermore, another domain that necessitates attention is the manufacturing of semiconductors in which India is still lagging behind. Manufacturing has been happening only in a few selected countries because it requires high skilled work

forces, sound infrastructure, crores of investment and exactitude technology. Undoubtedly, India is making strides in the realm of chip designing.[33] However, depending on other countries for manufacturing is a wakeup call for India's national interest and raises a security concern.

- Currently India is facing a surge in demand for semiconductors which is being driven by its use in smartphones, wearables, computers, automotive parts, building of smart cities, medical and IoT devices. Ultimately the rapid increase in demand of semiconductors contributes to an increase in the demand of water supply. A sharp decline in freshwater resources of about 40% is predicted by the Water Action Decade Initiative 2018-2028 by 2030, which when combined with population growth will drive an international water catastrophe.[34] Water consumption in semiconductor fabrication plants requires millions of gallons of ultra-pure water (UPW) every day. Hence, it is an urgent need for India to adopt sustainable and effective practices to save water to manufacture huge amounts of semiconductors and avoid any disruption from climate. India can adopt several effective practices to save water in semiconductor manufacturing such as implementing water recycling and reuse systems within fabrication plants can significantly reduce freshwater consumption.

- The country has to develop appropriate infrastructure involving various stakeholders to augment this capacity. Furthermore, fostering public-private partnerships and incentivizing industries to invest in sustainable wastewater management practices can facilitate long-term environmental sustainability and mitigate the risk of water scarcity-induced disruptions in semiconductor production.

Potential Collaborative Avenues with Taiwan, South Korea and Japan

Taiwan

(a) Having announced a ₹1.54 trillion ($18.58 billion USD) investment plan with mining company Vedanta through a 40:60 joint venture for the construction of a display fabrication unit, an integrated semiconductor fabrication unit, and an outsourced semiconductor assembly and test (OSAT) facility in Gujarat, Taiwanese electronics giant Foxconn, the largest supplier of iPhones and iPads for Apple, is betting big on the Indian semiconductor market.[35]

(b) The announcement that PSMC (Powerchip Semiconductor Manufacturing Corp) is prepared to assist India in putting up fabs is another step towards realizing India's goal of becoming a semiconductor nation. According to Huang Chongren, the chairman of Taiwan's third-largest foundry, PSMC is prepared to negotiate a cooperation deal with the Indian government. PSMC may help significant local and Indian corporations like Vedanta or Tata with factory setup and talent training for fabs, as they have expertise setting up plants in joint ventures with mainland China.[36]

(c) The two governments could set up Centers of Excellence (CoE) for new design architectures, new technical standards, or composite semiconductors research. With low-skilled labor better available in India, Taiwanese firms like ASE Technology and Powertech Technology can benefit by offshoring these operations to India.[37]

South Korea

(a) A memorandum of understanding (MoU) was inked by SimTech, a South Korean company that makes high-layer printed circuit boards for semiconductors, and the Gujarat government to spend more than Rs 1,250 core ($150.79 million USD) in the state. The company will set up operations to support Micron's semiconductor plant in Gujarat.[38]

(b) According to The Indian Express (IE), South Korean chip maker SK Hynix has considered taking advantage of India's semiconductor manufacturing incentive programme and is in talks with central government representatives about establishing a packaging plant in India.[39]

(c) During his recent visit to Seoul, South Korea, India’s External Affairs Minister S Jaishankar emphasized India's desire to broaden its strategic partnership with South Korea into novel domains such as critical and emerging technologies, semiconductors, and green hydrogen. Jaishankar made these comments while co-chairing the 10th India-South Korea Joint Commission Meeting (JCM) alongside his counterpart Cho Tae-Yul, aiming to modernize and strengthen bilateral ties between the two nations. The outcome of India's efforts to expand its strategic partnership with South Korea into these areas could lead to increased collaboration, technology exchange, and mutual economic growth between the two countries.

Japan

(a) The Union Cabinet, led by Prime Minister Shri Narendra Modi, was briefed about a Memorandum of Cooperation (MoC) inked in July 2023 between the Ministry of Electronics and Information Technology of India and Japan's Ministry of Economy, Trade, and Industry, focusing on the Japan-India Semiconductor Supply Chain Partnership.[40] This partnership will focus on research and development, manufacturing, design and talent development for the country's semiconductor industry.

Conclusion

For the state of fact that currently India is heavily reliant on China for its semiconductors and to reduce this dependency, the government and various companies are putting in their best effort to thrive in this industry. Nonetheless, the global shortage of semiconductor after COVID-19 pandemic has led to the disruption in the supply chain and the shutdown of many factories. To avoid such incidents, diversification of the supply chain has become a necessity for India. Another fact that demands attention is that India needs to evolve more in this industry by taking significant steps and lessening its import from other countries as it becomes a matter of national security. India has a high number of skilled workforce and is proficient in manufacturing semiconductor products. When considering the assembly and packaging of semiconductors, as well as integrating semiconductors into devices such as phones, computers, or servers, India is already actively involved and poised to significantly expand its role in a relatively brief timeframe. This is evident with announcements like Micron's recent unveiling of a sizable new testing and packaging facility.[41] Partnering with established semiconductor hubs like Taiwan, Japan, and South Korea can provide valuable opportunities for collaboration and growth. By working together and embracing innovation, India can move towards semiconductor excellence, benefiting its economy and driving technological progress worldwide.

that the facts and figures quoted are duly referenced, as needed and are believed to be correct.

Endnotes

[1] India Today, December 29, 2023 “Semiconductor Mission Should Have Started 30 Years Ago, Says PM Modi |Exclusive.” *India Today*. https://www.indiatoday.in/business/story/prime-minister-narendra-modi-exclusive-india-semiconductor-mission-delay-30-years-artificial-intelligence-job-creation-2481981-2023-12-29.

[2] Reuters. July 27, 2023.“What Are Gallium and Germanium and Which Countries Are Producers?,” https://www.reuters.com/markets/commodities/where-are-strategic-materials-germanium-gallium-produced-2023-07-04/

[3] Parikh, Niyati, March 13, 2024 “PM Modi Lays the Foundation Stone of India’s First Commercial Semiconductor Fabrication Unit.” *The Times of India*. https://timesofindia.indiatimes.com/technology/tech-news/pm-modi-lays-the-foundation-stone-of-indias-first-commercial-semiconductor-fab/articleshow/108452966.cms.

[4] ———. “Indian Semiconductor Consumption to Grow 19% per Annum to $300 Billion by 2026: Study.” *CNBCTV18*, August 19, 2022. https://www.cnbctv18.com/technology/semiconductors-india-market-size-19-percent-300-billion-dollars-by-2026-14530062.htm#:~:text=India%27s%20semiconductor%20market%2C%20pegged%20at%20%24119%20billion%20in,and%20Semiconductor%20Association%20%28IESA%29%20and%20Counterpoint%20Research%20claims.

[5] Spherical Insights. “India Semiconductor Market Size, Share, Forecast Report - 2032,” n.d. https://www.sphericalinsights.com/reports/semiconductor-market.

[6] International Trade Administration | Trade.gov. July 31, 2023 “India - Semiconductor and Electronics Industry,”. https://www.trade.gov/market-intelligence/india-semiconductor-and-electronics-industry.

[7] Ranjit Kumar, August 6, 2023,“India as Semiconductor Hub: Why China Challenge Is a Big Factor,” https://news.abplive.com/, https://news.abplive.com/india-at-2047/india-as-semiconductor-hub-why-china-challenge-is-a-big-factor-semiconductor-race-us-south-korea-germany-1621022.

[8] UNESCO. February 20, 2024 “Imminent Risk of a Global Water Crisis, Warns the UN World Water Development Report 2023. https://www.unesco.org/en/articles/imminent-risk-global-water-crisis-warns-un-world-water-development-report-2023.

[9] Financial Times. “Apple’s Manufacturing Shift to India Hits Stumbling Blocks,” n.d. https://www.ft.com/content/0d70a823-0fba-49ae-a453-2518afcb01f9.

[10] KONARK BHANDARI. , June 30, 2023 ,“The Geopolitics of the Semiconductor Industry and India’s Place in It.” Carnegie India. https://carnegieindia.org/2023/06/30/geopolitics-of-semiconductor-industry-and-india-s-place-in-it-pub-90054.

[11] “Case Study: Managed Trade: The US and Japanese Semiconductor Industries, 1970-2002.” *JGBC* Volume 2, Number 1, 2011 (n.d.). https://jgbc.fiu.edu/index.php/Home/article/download/51/35.

[12] Ministry of Economy, Trade and Industry. June 6, 2023 “‘Semiconductor/Digital Industrial Strategy’ Has Been Revised.,”. https://www.meti.go.jp/press/2023/06/20230606003/20230606003.html.

[13] “JSR Corporation (Japan), Tokyo Ohka Kogyo Co., Ltd (Japan) and Shin-Etsu Chemical Co., Ltd (Japan) Are Leading Players in the Photoresist & Photoresist Ancillaries Market,” n.d. https://www.marketsandmarkets.com/ResearchInsight/photoresist-market.asp.

[14] “The Korean Semiconductor Industry: Historical Overview And Prospects For Future Development.” 2000 MA thesis, School of Public Policy and Management. https://r.search.yahoo.com/_ylt=AwrKAK247PFlU2gYNga7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3Ny/RV=2/RE=1710382392/RO=10/RU=https%3a%2f%2farchives.kdischool.ac.kr%2fbitstream%2f11125%2f29891%2f1%2fThe%2520Korean%2520semiconductor%2520industry.pdf/RK=2/RS=j1wNiEBKij4NbNWuyEFZgJ41SmA-.

[15] The National Bureau of Asian Research. April 13, 2023, “The Role of South Korea in the U.S. Semiconductor Supply Chain Strategy - the National Bureau of Asian Research (NBR).” The National

Bureau of Asian Research (NBR), https://www.nbr.org/publication/the-role-of-south-korea-in-the-u-s-semiconductor-supply-chain-strategy/.

[16] "Emerging Industries," n.d. https://web.archive.org/web/20090915014414/http://taiwan.com.au/Polieco/Industry/Emerge/report01.html.

[17] Singh, Atul. February 27, 2023 ,"What You Need to Know About Taiwan and Semiconductors." *Fair Observer*, https://www.fairobserver.com/world-news/what-you-need-to-know-about-taiwan-and-semiconductors/.

[18] "Taiwan And The Global Semiconductor Supply Chain." Taipei Representative Office in Singapore, August 2023. https://r.search.yahoo.com/_ylt=AwrKCVcyAfJl0jsZFcG7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3Ny/RV=2/RE=1710387634/RO=10/RU=https%3a%2f%2fwww.roc-taiwan.org%2fuploads%2fsites%2f86%2f2023%2f08%2f20230824-TAIWAN-AND-THE-GLOBAL-SEMICONDUCTOR-SUPPLY-CHAIN.pdf/RK=2/RS=Ntozz1UxSQuoO53x5.RGDMCnmpo-.

[19] "India Missed the Bus for Semiconductors Due to Previous Governments' Lack of Political Vision and Strategic Clarity: MoS Rajeev Chandrasekhar," n.d.https://pib.gov.in/PressReleasePage.aspx?PRID=1943218#:~:text=In%201987%2C%20India%20was%20just,semiconductors%2C%E2%80%9D%20the%20Minister%20stated.

[20]Forbes. September 6, 2007, "India Snoozed, Lost Intel Chip Plant,". https://www.forbes.com/2007/09/06/intel-india-china-markets-equity-cx_rd_0906markets1.html?sh=90d96b44bf91.

[21] orfonline.org. "Lessons From India's Past for Its Semiconductor Future," n.d. https://www.orfonline.org/expert-speak/lessons-from-indias-past-for-its-semiconductor-future.

[22] "2023 TMT Predictions: India Chapter," n.d. https://www2.deloitte.com/in/en/pages/technology-media-and-telecommunications/articles/tmt-predictions-2023.html.

[23] NDTV.com. "PM Modi'S Mega '50% Offer' for Firms to Set up Semiconductor Manufacturing," n.d. https://www.ndtv.com/india-news/pm-narendra-modis-mega-50-offer-for-firms-to-set-up-semiconductor-manufacturing-4248177.

[24] "Modified Programme for Semiconductors and Display Fab Ecosystem | Ministry of Electronics and Information Technology, Government of India," n.d. https://www.meity.gov.in/esdm/Semiconductors-and-Display-Fab-Ecosystem.

[25] Ibid.

[26] Ibid.

[27]Ibid.

[28] Ibid.

[29] Ibid.

[30] "Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) | Ministry of Electronics and Information Technology, Government of India," n.d. https://www.meity.gov.in/esdm/SPECS.

[31] Anand, Vijay. August 19, 2022, "Indian Semiconductor Consumption to Grow 19% per Annum to $300 Billion by 2026: Study." *CNBCTV18*, https://www.cnbctv18.com/technology/semiconductors-india-market-size-19-percent-300-billion-dollars-by-2026-14530062.htm.

[32] "Silicon Metal Imports in India - Import Data With Price, Buyer, Supplier, HSN Code," October 31, 2023. https://www.volza.com/p/silicon-metal/import/import-in-india/.

[33] Online, Et. "How India Is Spreading Itself Across the Chip-making Value Chain." *The Economic Times*, March 14, 2024. https://economictimes.indiatimes.com/industry/cons-products/electronics/how-india-is-spreading-itself-across-the-chip-making-value-chain/articleshow/108492622.cms.

[34] Water action decade 2018-2028 was an initiative launched by UN General assembly on 28th March 2018 to tackle water scarcity and manage water usage

[35] Aulakh, Shashank Mattoo and Gulveen. February 7, 2023 ,"Taiwan May Join Foxconn in India to Fuel Chip Skills | Mint." *Mint*. https://www.livemint.com/news/world/taiwan-may-join-foxconn-in-india-to-fuel-chip-skills-11675796210935.html.

[36] Singal, Nidhi. January 12, 2023. "Taiwan's PSMC Might Partner With India to Help Set up Semiconductor Fabs." *Business Today*, https://www.businesstoday.in/latest/economy/story/taiwans-psmc-might-partner-with-india-to-help-set-up-semiconductor-fabs-360000-2023-01-12.

[37] Opinion, Tim Culpan | Bloomberg. "India Wants to Be the Next Taiwan in Chips, but Its Dream Is Misguided." *Www.Business-Standard.Com*, October 4, 2021. https://www.business-standard.com/article/economy-policy/india-wants-to-the-next-taiwan-in-chip-making-but-its-dream-is-misguided-121100400082_1.html.

[38] Outlook Business Desk, and Outlook Business Desk. January 11, 2024. "Simmtech, Gujarat Government Sign MoU, Total Investment Pegged at Over Rs 1,250 Crore." Outlook Business & Money, https://business.outlookindia.com/news/simmtech-gujarat-government-sign-mou-total-investment-pegged-at-over-rs-1250-crore.

[39] Barik, Soumyarendra. July 12, 2023. "South Korea's SK Hynix Looking to Set up Chip Packaging Plant in India." *The Indian Express*, https://indianexpress.com/article/business/semiconductor-manufacturing-in-india-south-korean-chipmaker-sk-hynix-8828128/.

[40] "Cabinet Approves Memorandum of Cooperation Between India and Japan on Japan-India Semiconductor Supply Chain Partnership," n.d. https://www.pmindia.gov.in/en/news_updates/cabinet-approves-memorandum-of-cooperation-between-india-and-japan-on-japan-india-semiconductor-supply-chain-partnership/.

[41] Lele, Sourabh. October 25, 2023. "India-Japan Pact on Semiconductor Supply Chain Gets Cabinet Green Light." *Www.Business-Standard.Com*, https://www.business-standard.com/economy/news/india-japan-partnership-on-semiconductor-supply-chain-gets-cabinet-nod-123102501017_1.html.