European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 9, Issue 7, Summer 2022

Trade Policies for Facilitating the Growth of Semiconductor Industry: Evidence from Developing Country

0Mini jain, Hari Prapan Sharama
Assistant Professor, Institute of Business Management GLA University, Mathura

Abstract
A semiconductor is a material that is used in electronic equipment and devices to manage and control the flow of electricity. The collective of businesses involved in the design and production of semiconductors and semiconductor devices, such as transistors and integrated circuits, makes up the semiconductor industry. it was founded around 1960. Now the manufacture of semiconductor devices became a profitable industry. *The semiconductor* industry is a hugely important sector for world economies. The paper is divided into five parts. The first part underlines the importance of trade policies and technology transfer agreements, and offers examples of their utilization by states to build industrial capacity. In the second section, the paper delves further into India's semiconductor industry and its comparative advantages. An overview of recent policy announcements follows, as well as an examination of why the approach might not suffice in the long run. The fourth section highlights the challenges and barriers facing India when formulating favourable trade and technology transfer policies. The paper ends with policy recommendations.

Keywords: semiconductor, technology, policy, industries, trade

1. Introduction

The first national initiative aimed at the key industry, the Indian government authorised a "comprehensive programme for the establishment of a sustainable semiconductor and display ecosystem" in December 2021. [1] New Delhi made it obvious that industrial policies are its preferred tools by announcing an allocation of US$9.78 billion towards creating a full-stack semiconductor ecosystem. In reality, though, sectoral growth is not necessarily the consequence of state support for industry through industrial policy.

The functions of trade regulations and technology transfers are also crucial, but unappreciated, for the development of effective semiconductor ecosystems.[2]

When compared to single-nation value chains, semiconductor supply chains that gain from advantageous trade policies and technology transfer have accelerated technological innovation and increased efficiency. [3,4] This research focus on role of trade policy specifies in context of Semiconductor.

Currently, India has a large domestic market and is highly dependent on imports for semiconductors. Despite a vibrant workforce known for tech engineering and semiconductor design, the country has only a few semiconductor manufacturing facilities. There is ample room for developing the domestic ecosystem and improving India's global positioning.[5]

1.1 Why trade and technology transfers' matter:

The global chip shortage is not abating. The semiconductor industry is not able to meet increasing sectoral demand, from automobiles to consumer electronics, prompting techno-nationalist calls for building self-sufficiency in the semiconductor supply chain Trade and technology transfers play an integral role in building domestic industries and improving the global ecosystem for semiconductors. The industry's giants, such as Taiwan and Japan, reached their stature because of more liberalised and open market policies.[6] The free movement of labour, capital, and goods across markets has helped these countries build a robust infrastructure and excel in a part of the value chain.[7]

2 Key Driver:

Techno-nationalism in the semiconductor industry is not a new phenomenon. Indeed, the calls began in the 1980s with the US-Japan trade war.[8] Manufacturers in the United States alleged that Japanese imports – memory chips, transistors – were priced lower and hurt their businesses.[9] At the time, Japan had completely insulated its semiconductor industry from global competition; during the 1960s and 1970s, no international semiconductor company were allowed to set up shop in the country.[10] In response, the United States enacted anti-dumping legislation to prevent future Japanese imports. The intent was to help the US firms capture the market for low-cost memory chips away from Japan, but the goal never materialised. [11] Firms moved to other products capable of generating more revenue. The experience taught the semiconductor industry that interconnectedness and global value chains are helpful, due to the following reasons.[12]

First, differentiation in human and financial resource requirements across various stages of semiconductor production has highlighted the role of comparative advantage and geographic dispersion of the production process has added diversity in the supply chain. [13] While technologically advanced countries such as the United States, the Netherlands, and Japan are strong in the manufacturing of equipment, countries like Taiwan have a stranglehold over the manufacturing process, due to their pure-play foundry business model.[14] The foundry model focuses only on the manufacturing or fabrication process of semiconductor chips without taking up other processes of the value chain.[15] Similarly, post-fabrication processes such as assembly, testing, and packaging (known in the industry as ATMP) are highly labour-intensive processes that allow less technical expertise. Here, countries like India, Vietnam, and China have a distinct advantage due to the availability of a large workforce. Free movements of labour and trade are essential for functional value chains and enabled comparative advantages to expand geographically across the entire sector. [16] Second, a competitive global value chain has elevated the standards of semiconductor production in terms of quality and specifications [17], increasing exports from Taiwan, China, and South Korea. Trade-friendly policies have promoted the manufacturing of small and large-scale electronics.

Multilateral trade agreements have also solidified the industry's dependence on trade and free movement of goods. The Information Technology Agreement (ITA) of 1996 remains a landmark agreement that led to the promotion of trade in information and communication technology (ICT). In 2015, the agreement expanded and tariffs on approximately US$3 trillion of ICT goods were banned, as were imposing duties on semiconductor chips traded internationally. Semiconductors remain the largest ITA product category, contributing a total of 32% of global trade in ITA products in 2015. The tariff savings have lowered the costs of products.[18]

The expansion of the ITA also resolved the non-uniform tariff classification of advanced semiconductors called multi-component integrated circuits (MCOs), used in a plethora of consumer electronic products. Smartphones, tablets, gaming consoles, and computer monitors have all benefitted from the tariff restructuring.[19]

These devices were classified as parts of other equipment and subjected to 25% tariffs, which were also eliminated. Recent trade policies allowing access to cheaper equipment and promoting the exports of finished goods have made the semiconductor industry more robust.[9]

Third, the positive business environment created by select countries has attracted semiconductor giants, as the savings accrued from no import duties and low tax rates enabled more spending on research and development. Such was the case of Fairchild Semiconductor, which moved its assembly line process to Hong Kong in 1961, citing low tax rates and duties, technological cooperation, and the proximity to consumer markets for the move. The company subsequently improved its growth. [21]

Fourth, sound legal frameworks that protect intellectual property (IP) rights through multilateral trade agreements have strengthened the sector. IP is critical in the semiconductor industry, and the IP licensing mechanism is used in many parts of the supply chain.[22] For instance, licenses are issued to design firms for using specific processor architectures in their computers or mobile phones. Electronic Design Automation (EDA) tools – specialised software used for chip design – are also sold on a per license basis. Such mechanisms work because of the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement in 1995, signed by all WTO member states, which clearly defined multilateral IP rules and mandated a minimum set of procedures for national IP enforcement. The TRIPS agreement covered three areas specific to the semiconductor industry:

– Protection of trade secrets
– Protection of integrated circuit layout designs (after which the United States also passed similar legislation)
– Safeguards against any compulsory licensing of semiconductor-related IP

By enabling semiconductor firms to focus on developing new technologies with legal protection, the TRIPS agreement was transformational. The licensing that followed required an adherence to international standards in development and manufacturing, which subsequently improved export opportunities.

Finally, it is useful to look at the ecosystem which dominates today's semiconductor fabrication. Indeed, the story of Taiwan exemplifies how smart policy can change the course of history. [23]

One single agreement for technology transfer laid the groundwork for the development of Taiwan's semiconductor industry. In the 1970s, when Taiwan was still primarily an agricultural economy, the Ministry of Economic Affairs made a critical choice: it decided to develop a domestic semiconductor ecosystem. To learn more about semiconductors, the government struck a technology transfer deal with the Radio Corporation of America (RCA), worth millions of dollars.[24] A stream of Taiwanese engineers travelled to the United States to learn the 7-micron, metal-gate CMOS process. By 1975, with the help of RCA's technology, Taiwan was able to build a 3-inch wafer fabrication facility, or 'fab', officially kickstarting the semiconductor industry. Within five years, Taiwanese engineers had become highly skilled, technically adept, and proficient at developing their own technology. The example of Taiwan shows that multilateral trade agreements, favourable trade policies, and technology transfer deals have been key to the industry's growth and development.[25]

Today, with its large workforce for semiconductor design services and the availability of low-cost labour to work in fabrication or OSAT facilities, India faces an opportunity to climb the semiconductor value chain. But can India address its vulnerability gaps and fulfil its potential?[26]

3 Mapping India's semiconductor ecosystem

According to a collaborative research by the 'Indian Electronics and Semiconductor Association' (IESA) and Counterpoint Research, India's semiconductor market, estimated at $119 billion in 2021, will increase at a compound annual rate of 19% to $ 300 billion by 2026. [27] The country is already a powerhouse for semiconductor design, with eight of the world's top semiconductor companies by revenue having Indian design centres. Moreover, home-grown firms have become pioneers in providing quality design services to international semiconductor giants – at lower costs. [28,29] This is critical for the Indian semiconductor industry as it enlarges the domestic workforce and exposes them to the latest developments in semiconductor design.[30]

Forecasted market value of semiconductor design services in India from 2014 to 2020(in billion U.S. dollars)

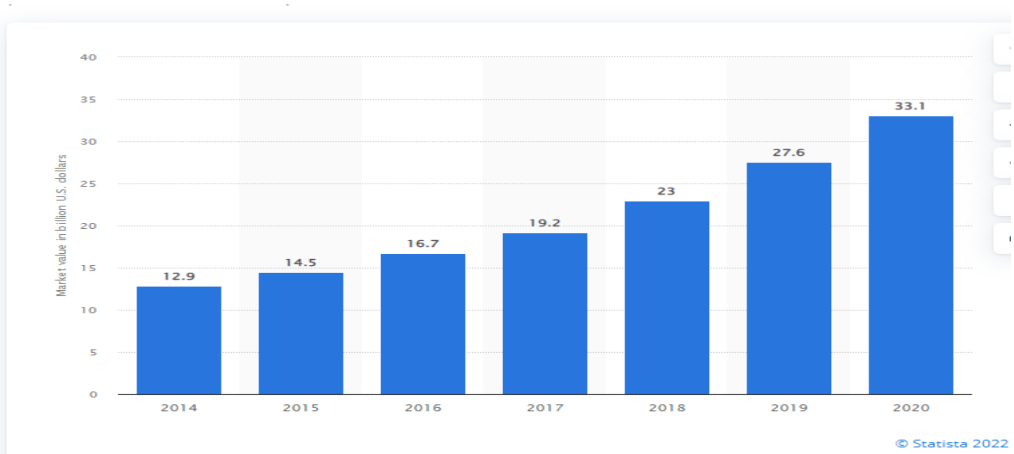

Fig. 1

Until recently, the country's manufacturing capabilities have been restricted to a few government labs. India has three semiconductor fabrication facilities, and they are led by the state. The SITAR facility in Bengaluru and the 'Gallium Arsenide Enabling Technology Centre' (GAETEC) in Hyderabad are both under India's Defence Research and Development Organisation.

The following details the landscape of India's semiconductor industry.

3.1 Design

Texas Instruments opened their first R&D centre in India in 1985. Today, India houses design centres for all the major semiconductor firms. This demand for semiconductor design engineers has created a virtuous circle which boosts India's comparative advantage. There are nearly around 30,000 engineers in the country, designing an average of 3,000 chips per year.[31] Each year, a new batch of electronics and electrical engineers graduates from technical educational institutions across the country, creating a thriving market for semiconductor design services. However, the domestic industry needs to bolster the capacity for creating indigenous semiconductor design IP.

3.2 Manufacturing

Despite many attempts to set up a fabrication facility in the country, India is home to only a few state-owned manufacturing units (as mentioned above) catering to the needs of the defence and space industries.[32] With help and investment from Israel's Tower Semiconductor, the SCL facility has upgraded to manufacturing the 8" wafer fab to produce 180nm chips.[33] However, the absence of private capital to set up a semiconductor manufacturing plant indicates that incentivising policies have not worked.[34]Even with the new package of policies for the semiconductor industry, doubts linger about whether a foreign semiconductor foundry would be willing to invest in a fab in the country. [35]

Indeed, roadblocks remain in the way of India's ambitions; for example, the need for significant capital investment, high skilled labour meant for handling complex semiconductor manufacturing equipment, import of manufacturing equipment, and easy access to raw materials.[36] There have been reports that government officials from both India and Taiwan are engaged in talks to build a manufacturing hub in the country as well as finalise a free trade agreement (FTA). This would help India to gain easier access to the critical manufacturing equipment and foundry technology in which Taiwan is specialised. It remains to be seen, however, if talks with Taiwan would result in India finally getting a domestic manufacturing unit.

3.3 Outsourced assembly and testing (OSAT)

Compared to fabs, the Outsourced Assembly and Testing (OSAT) facilities require relatively less investment to set up and run. With low-skilled labour sufficing for OSAT operations, the only costs associated with these facilities are the imports of semiconductor devices, which have enjoyed government incentives and subsidies in recent years.[37] The abundance of low-cost labour in the country is an added advantage. With the sector dominated by a few players, India has the potential to assert its presence through conducive policies and tie-ups with existing foreign companies.[38] Furthermore, the potential of fabs and OSAT facilities in India is intertwined with trade – both need favourable import policies.[39] To build a strong domestic industry, free trade agreements, tariff restructuring, and easier access to important markets (such as for semiconductor raw materials and manufacturing equipment) must be on the government's radar.

4. New Delhi's semiconductor push

Before pandemic-induced supply chain disruptions, New Delhi had taken a mellow approach to building the country's industrial capacity.[40] Incentives such as the Scheme for Production of Special Electronics and Semiconductors and the Modified Special Incentive Scheme were rolled out to attract potential investors. The Production Linked Incentive (PLI) scheme also specifically targeted the country's manufacturing. Following New Delhi's announcement of the semiconductor package, the Ministry of Electronics & Information Technology explained the four specific schemes to incentivise domestic production of semiconductors.[41] In addition to having definitive timelines and outcomes, the schemes focused on all stages of semiconductor production: design, manufacturing, and OSAT. It also addressed the procedures for setting up different types of fabs: semiconductor fabs, display fabs, and specialised fabs for compound semiconductors, silicon photonics, and sensors. Understanding each of the four schemes would provide a holistic view of the government's vision.[42]

The aim of the Design Linked Incentive (DLI) scheme is to build India's comparative advantage in semiconductor design and support domestic design firms.[43] The scheme provides financial incentives for up-and-coming design firms to spend on Electronic Design Automation (EDA) tools licensing and IP rights. It also aims to nurture a hundred domestic design companies and help at least twenty firms to achieve an annual turnover of US$193 million in the next five years.[44]

One scheme specifically targets specialised fabs for compound semiconductors, silicon photonics, and sensors, and the development of ATMP/OSAT facilities. Companies with experience have been asked to commit a minimum capital investment threshold of US$12.86 million to set up specialised fabs over a capacity of 500 wafer starts per month with a 150/200mm wafer size. With regard to ATMP, the minimum capital requirement is set at US$6.43 million. Under this scheme, the government will reimburse 30 percent of capital expenditure to the selected firms.[45,46] Nurture a hundred domestic design companies and help at least twenty firms to achieve an annual turnover of US$193 million in the next five years.[47]

One scheme specifically targets specialised fabs for compound semiconductors, silicon photonics, and sensors, and the development of ATMP/OSAT facilities.37 Companies with experience have been asked to commit a minimum capital investment threshold of US$12.86 million to set up specialised fabs over a capacity of 500 wafer starts per month with a 150/200mm wafer size. With regard to ATMP, the minimum capital requirement is set at US$6.43 million. Under this scheme, the government will reimburse 30 percent of capital expenditure to the selected firms.[48,49]

Third, the government has proposed a scheme specifically to establish display fabs in India. New Delhi has already proposed funding 50% of the total project cost of two experienced companies.38 The only caveat: the firms applying under this scheme must invest a minimum capital of US$12.87 billion for manufacturing Active-Matrix Organic Light Emitting Diode or Thin-Film Transistor display screens in India.[50]

Finally, the package includes a program to set up the long-pending semiconductor fab. The government has ensured different levels of financial support, depending on the manufacturing nodes by the firm. To set up a fab, the firm must invest a minimum capital of US$25.72 billion and have a manufacturing capacity of a minimum 40,000 wafers per month. For companies producing transistors with a size of 28 nm or less, 40% for those with a size of 28 nm to 45 nm, and 30% for those with a size of 45 nm to 65 nm, the government will reimburse 50% of the entire project cost. This scheme will also provide long-term support over a period of 6 years for at least two companies. [51,52,53]

The package makes clear the government's long-term strategy for building its domestic semiconductor industry, with its prioritizing of capital investment and financial support.[54] However, a more holistic approach requires better multilateral engagement and a stronger presence in the global supply chain. While the recent package is catered towards industrial policies, a broader view is needed – one which addresses the need to integrate the Indian industry with the global semiconductor ecosystem. Trade policy and technology transfer frameworks remain crucial for developing semiconductor ecosystems.[54]

5. The impact of geopolitics on collaboration

The development of semiconductor technology is greatly aided by increased international trade and national cooperation. However, states may encounter challenges when attempting to enhance trade.[55] Globalization has increased the likelihood of restrictions, which can hamper technology dissemination. These restrictions, which challenge the industry's growth, are as follows.

5.1 Restrictions on human capital movement

The cross-border movement of commodities and services in a supply chain is made easier by effective trade policy. Both highly skilled and low-skilled personnel are needed at various points throughout the value chain in the labor- and capital-intensive semiconductor sector. [56,57]

Semiconductor foundries and fabrication facilities need highly skilled workers to handle crucial manufacturing equipment, and OSAT facilities require low-skilled labour to complete the assembly, testing and marking processes. Semiconductor design services require technical expertise with competent engineering skills.40 With different levels of expertise needed, free exchange of labour across countries and borders becomes critical.[58]

Again, Taiwan provides excellent lessons. Because Taiwan faced a shortage of manpower for the nascent industry, the government promoted "science parks" to house advanced semiconductor firms and their research centres. The result was Hsinchu Science Park, for which the government provided upfront capital, including tax deductions to the companies willing to relocate.[59]

Today, it is difficult for workers to move freely across nations. A lack of qualified workers willing to relocate to a nation like India exists as many emerging economies struggle economically as a result of the Covid-19 pandemic.[60] India's per capita income continues to be lower than that of semiconductor superpowers like the US and Taiwan. It will take more financial assistance from the government, as well as a favourable investment climate, to entice skilled employees from these nations. [61]

Geopolitical tensions between the US and China have also increased the scrutiny towards Chinese researchers working in critical and strategic technology areas. Semiconductors and their supply chain are at the top of the list. As a result, collaboration between the two countries, especially in the scientific and academic realms, is declining. The growth of India's semiconductor industry is thus constrained by increasing techno-nationalism beyond its borders. As more countries ringfence their semiconductor sector under the auspices of national security, barriers for transferring key technologies to other countries will increase.[61]

5.2 Fears of weaponization

Geopolitical and geoeconomic worries over semiconductor supply chains have been sparked by recent events such as the Covid-19 epidemic and the conflict between Russia and Ukraine. [62,15] Concerns have also been expressed about the militarization of semiconductor technology by the opposing militaries.[63] Regional techno-nationalist impulses may rise as a result of these changes.[64]

5.3 Export control mechanisms

According to multilateral agreements like the Wassenaar Agreement, dual-use applications, which might result in export rules and limitations, apply when semiconductor technology is employed to create defence and military equipment. This attaches a component or threat of proliferation, similar to nuclear technology, making the technology subject to certain export rules. [9]

The US, Japan, Netherlands, and South Korea are among the signatories of the Wassenaar Agreement, which was established to restrict the excessive export of dual-use technologies.[65]

Taiwan cannot join the agreement because of its legal status but the government of Taiwan has curated its own export control list on semiconductors, similar to that of the agreement.[66]

5.4 Import restrictions

Many economies, including India, still impose import limitations. The Indian Cellular and Electronics Association, a business organisation made up of the heads of significant domestic companies, reminded the public after the government announced the semiconductor package that import tariffs for semiconductors continue to be high and that there are still some restrictions in the form of sensitive technologies and high tariffs. The statement also emphasised how the advantages of the fiscal support package would be negated. [67]

Thus, emerging semiconductor producers face the challenge of balancing domestic firms and acquiring state-of-the-art equipment and technologies by facilitating imports.[68] Again, Taiwan serves as a powerful example. Its success is generally attributed to a policy shift toward trade and investment liberalisation, especially for industrial inputs, and away from import substitution. Flexibility in the labour market, macroeconomic stability, infrastructural development, and secondary education are government priorities., and favourable trade policies, helped Taiwan scale new heights in the semiconductor industry. Import restrictions were eliminated, helping Taiwan gain access to the necessary materials and equipment to build its industry. [69,70]

6. A roadmap for the path ahead

India faces daunting challenges: demonstrating its dedication to developing the semiconductor industry. Capital-intensive industrial policies may entice bids and investments, but advantageous trade policies and a supportive business environment can ensure that the projects are completed and produce the desired results.[71] This strategy may eventually draw additional foreign semiconductor companies. Adopting the following policy suggestions will help India get closer to its objectives:

6.1 Overhaul of trade policies

India has to adjust its international trade strategy and make it more tolerant of the technology sector. The government can then concentrate on creating a thorough trade policy tailored to the semiconductor industry specifically. It is necessary to end current mercantilist and unfair trade practises that jeopardise the principles of industry-wide, competitive markets. This may involve lavish domestic sector subsidies that deter foreign businesses from making investments in the nation. [72,73] Furthermore, participation in international forums and multilateral trade organisations that might promote the expansion of the semiconductor industry requires government involvement. These businesses consist of:

6.1.1 The World Semiconductor Council (WSC)

The WSC is a global conference that brings together leaders in the semiconductor industry and technical specialists to discuss topics that affect the sector globally. The organisation currently consists of the associations for the semiconductor industries in Japan, South Korea, the US, Europe, China, and Taiwan. The WSC, which was founded in 1996, encourages international collaboration in the semiconductor sector to support long-term industry growth. [74,75]

To be heard among the world's leading manufacturers of semiconductors, India should join the Council. The Council strongly supports free trade and is governed by the values of justice, adherence to market norms, and conformity to WTO regulations.[76] The WSC also acknowledges the significance of open markets free from discrimination and holds that the main determinant of business success and global commerce should be the competitiveness of firms and their products.[77]

One of the two requirements for tariff removal must be satisfied by any prospective member (a nation or area where the association is located). The first is the complete abolition of tariffs. Second, a commitment has been made to swiftly eliminate all tariffs on semiconductors or to suspend such levies until they are formally eliminated.[78] India's dedication may inspire confidence in investors and potential collaborators to develop the domestic ecosystem. Additionally, this would increase India's access to free trade in the semiconductor sector.

6.1.2 The 2015 ITA Expansion

The World Trade Organization's ITA, which reduced tariffs on high-tech and information technology items, was the main one in place in 1996. The WTO has had to reconsider the agreement's entire scope in light of the quickly developing digital revolution. This served as the catalyst for the ITA-II negotiations in 2015, which added more than 200 technology goods. It is in India's best advantage to formally sign the extended ITA. By doing this, the domestic sector would have access to products with zero tariffs that are relevant to the semiconductor sector. Additionally, it would aid new businesses and domestic producers in increasing their export volume. Strategic industries like semiconductors might be in the leading position of India's international trade, thanks to the large range of technology items offered by the ITA. Due to the necessity to safeguard its domestic economic sectors, India has historically refrained from joining trading blocs and agreements like the 'Regional Comprehensive Economic Partnership' (RCEP) and the 'Comprehensive and Progressive Agreement for Trans-Pacific Partnership' (CPTPP). [79] However, multilateral cooperation in the technology sector is necessary for supply chains to operate effectively. In the semiconductor and high-tech industries, free trade of goods and services is essential. If India joins these multilateral organisations that generate benefits particular to the industry, it will gain advantages domestically and will be able to contribute more to the global value chain.

6.2 Promote a tech transfer and IP protection regime

India should lead the global semiconductor sector in establishing a mechanism for the protection of 'intellectual property' (IP) related to the semiconductor industry and support a close-knit framework for the promotion of technology transfer agreements in the semiconductor domain. For potential investors and global semiconductor juggernauts interested in India, this would guarantee appropriate protection.[79]

In the end, persuading global marketplaces to recognise India's potential as a semiconductor powerhouse depends on open knowledge transfer and a functional high-tech sector structure. India can get things going by establishing tough IP theft laws and other standards for the semiconductor industry, and making sure they are enforced.[80] Any company breaking the rules and regulations may be prohibited from participating in the markets as part of enforcement. Long-term innovation-based competition will be ensured by banning exports, limiting domestic operations, and levying fines or penalties against individual businesses who violate IP theft rules.[81]

6.3 Foster multilateralism as a necessity for resilience

The Indian government should have a single area of attention, potentially through creating technical partnerships targeted at the industry, to facilitate a smooth transfer of semiconductor technology. Through a multilateral or plurilateral approach, a "bubble of trust" strategy can aid India in engaging with like-minded states. In particular, high-tech industries, such as semiconductors, this can aid improve information-sharing methods. Through already-existing groups like the Quad, these technology-sharing agreements can take place between alliance partners. For instance, the 'Quad Supply Chain Initiative', unveiled at the inaugural in-person summit of the organisation, can be expanded to incorporate trade secret protections that will make technology transfer agreements simpler.[80] Technology alliances may shape diplomacy's future in the digital era. Technology transfer agreements can help disseminate semiconductor technology across many states, reducing current vulnerabilities in supply chains that are experiencing bottlenecks. In order to strengthen flexibility in the global value chain and its own ecosystem, India can contribute by allowing technology transfers to its domestic industry.[80]

7. Conclusion

The semiconductor industry has evolved into an intricate and globalised value chain, with critical dependencies on a handful of production centers. One reason for this transformation is certainly the complicated production process itself. But another integral factor is the role of trade and technology transfers in developing semiconductor ecosystems. Trade has significantly shaped the semiconductor industry's worldwide value chain, from the multilateral trade accords that facilitated industrial growth through the development of competitive advantages. From creating a business-friendly environment through zero-tariff structures for semiconductor goods to helping several countries increase export volumes, trade is critical for sustaining domestic industries and the international supply chain.

A clearer comprehension of the significance of trade and technology transfer would be beneficial for India. in building semiconductor industries. The technology transfer agreement with the US was a starting point for the Taiwanese semiconductor industry. With Taiwanese engineers gaining technical competency through the deal, Taiwan’s liberal and open trade policies during the 1960s allowed state- funded foundries like ‘United Microelectronics Corporation’ (UMC) and ‘Taiwan Semiconductor Manufacturing Company’ (TSMC) to grow. Gradual increase in private investment and easier access to foundry components and equipment helped Taiwan become a semiconductor superpower. Emulating Taiwan’s semiconductor industry in the field of trade and technology transfer can help India and other growing semiconductor powers scale new heights.

Industrial policies in the high-tech sector can only reap certain dividends while an unfavourable trade ecosystem can negate the positives of such industrial policies. It is of paramount importance to focus on formulating policies that improve India’s position in high-tech industries and specifically the semiconductor ecosystem.

References

1. Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. Process Safety and Environmental Protection, 118, 254-267.
2. Kleinhans, J. P. (2022). US–China Economic and Security Review Commission.
3. Teece, D. J. (2020). Fundamental issues in strategy: Time to reassess. Strategic Management Review, 1(1), 103-144.
4. Buckley, P. J. (2022). Corporate reactions to the fracturing of the global economy. International Business Review, 102014.
5. Majid, M. A. (2020). Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. Energy, Sustainability and Society, 10(1), 1-36.
6. Wang, H., & Lim, G. (2021). Catching-up in the semiconductor industry: comparing the Chinese and Malaysian experience. Asian Journal of Technology Innovation, 1-23.
7. Tarkar, P., Dhamija, S., & Singh, P. (2019). A mediation effect of job satisfaction and affective commitment in relationship between passion and work intentions after retirement. Vision, 23(2), 197-207.
8. Lacey, S. (2022). Trade, Technology and Security: Exploring the Linkages. Technology and Security: Exploring the Linkages (September 13, 2022).
9. Bown, C. P. (2020). How the United States marched the semiconductor industry into its trade war with China. East Asian Economic Review, 24(4), 349-388.
10. Kenney, R. F. M., & Florida, R. (2000). Silicon Valley and Route 128 won't save us. California Management Review, 33(1), 68-88.

11. Matura, T. A. (2021). Trade, Investment and Politics between China and Central and Eastern Europe Economic Necessity or a Trojan Horse? (Doctoral dissertation, Budapesti Corvinus Egyetem).
12. Panwar, R., Pinkse, J., & De Marchi, V. (2022). The future of global supply chains in a post-Covid-19 world. California Management Review, 64(2), 5-23.
13. Avelar-Sosa, L., García-Alcaraz, J. L., & Maldonado-Macías, A. A. (2019). Evaluation of Supply Chain Performance. Management and Industrial Engineering. Cham: Springer International Publishing.
14. Pandey, S. (2022). Augmentation of a State's power in Kautilya's Arthashastra, The case of India.
15. Grimes, S., & Du, D. (2020). China's emerging role in the global semiconductor value chain. Telecommunications Policy, 101959.
16. Khan, W., Khan, S., Dhamija, A., Haseeb, M., & Ansari, S. A. (2022). Risk assessment in livestock supply chain using the MCDM method: a case of emerging economy. Environmental Science and Pollution Research, 1-16.
17. Khan, S., Haleem, A., & Khan, M. I. (2022). A grey-based framework for circular supply chain management: a forward step towards sustainability. Management of Environmental Quality: An International Journal, (ahead-of-print).
18. Ballard, C. L., Shoven, J. B., & Whalley, J. (1985). General equilibrium computations of the marginal welfare costs of taxes in the United States. The American Economic Review, 75(1), 128-138.
19. Sharma, H. P., & Chaturvedi, A. (2021, October). Adoption of Smart Technologies: An Indian Perspective. In 2021 5th International Conference on Information Systems and Computer Networks (ISCON) (pp. 1-4). IEEE.
20. Bown, C. P. (2020). How the United States marched the semiconductor industry into its trade war with China. East Asian Economic Review, 24(4), 349-388.
21. Varadarajan, P"Rajan, and Daniel Rajaratnam. "Symbiotic marketing revisited." Journal of Marketing 50, no. 1 (1986): 7-17.
22. Hickey, P., & Kozlovski, E. (2020). E-strategies for aftermarket facilitation in the global semiconductor manufacturing industry. Journal of Enterprise Information Management.
23. Chen, L. Y., Hsieh, W. Z., & Chou, R. J. (2021). The Impact of the Construction of Large Reservoirs on the Cultural Landscape: A Case Study of the Shimen Reservoir, Taiwan. Land, 10(11), 1161.
24. Khan, H. N., Hounshell, D. A., & Fuchs, E. R. (2018). Science and research policy at the end of Moore's law. Nature Electronics, 1(1), 14-21.
25. Castillo, V. M., & Acosta, R. D. J. R. (2021). Restructuring Manufacturing: Mexican maquiladoras and East Asian EPZs in the Presence of The North American Free Trade Agreement. In What is in a Rim? (pp. 69-88). Routledge.
26. Althaf, S., & Babbitt, C. W. (2021). Disruption risks to material supply chains in the electronics sector. Resources, Conservation and Recycling, 167, 105248.
27. Biberman, J. (2022). Manufacturing the Digital Revolution: Building a Sustainable Supply Chain for ICT-Driven Development in India (No. 67). ICT India Working Paper.
28. Mazzucato, M. (2021). Public Purpose: Industrial Policy's Comeback and Government's Role in Shared Prosperity. MIT Press.
29. Mao, Y. (2022). Empirical Study on Overall Industrial Upgrading. In The Restructuring of Global Value Chains (pp. 187-238). Springer, Singapore.
30. Nikolic, M. V., Milovanovic, V., Vasiljevic, Z. Z., & Stamenkovic, Z. (2020). Semiconductor gas sensors: Materials, technology, design, and application. Sensors, 20(22), 6694.
31. Biberman, J. (2022). Manufacturing the Digital Revolution: Building a Sustainable Supply Chain for ICT-Driven Development in India (No. 67). ICT India Working Paper.

32. Murti, M. (2020). A Comparison of Defence Sector Innovation Ecosystems in China and India. Strategic Analysis, 44(1), 45-53.
33. Basu, J. (2019). From design to tape-out in SCL 180 nm CMOS integrated circuit fabrication technology. IETE Journal of Education, 60(2), 51-64.
34. Wan, J., & Shin, H. (2022). Predictive vehicle dispatching method for overhead hoist transport systems in semiconductor fabs. International Journal of Production Research, 60(10), 3063-3077.
35. Varas, A., Varadarajan, R., Goodrich, J., & Yinug, F. (2020). Government incentives and US competitiveness in semiconductor manufacturing. Boston Consulting Group.
36. Goodman, S., VerWey, J., & Kim, D. (2019). The South Korea-Japan trade dispute in context: Semiconductor manufacturing, chemicals, and concentrated supply chains. Chemicals, and Concentrated Supply Chains (October 1, 2019).
37. Kumar, K., Prakash, A., & Khan, W. (2020). Integrating the notion of sustainable development in banking: Analysing historical and conceptual framework. Indian Journal of Economics and Development, 16(3), 449-458.
38. Howell, T. R., Noellert, W. A., MacLaughlin, J. H., & Wolff, A. W. (2019). The microelectronics race: The impact of government policy on international competition. Routledge.
39. Raju, S., & Saradhi, V. R. (2020). What ails India's electronic manufacturing industry: an assessment. The Indian Economic Journal, 68(4), 610-632.
40. Puig, X., Ra, K., Boben, M., Li, J., Wang, T., Fidler, S., & Torralba, A. (2018). Virtualhome: Simulating household activities via programs. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (pp. 8494-8502).
41. Shalaby, A. M. H. (2021). Model for the Automated Generation of Optimized Work Packages in Results-Based-Finance Mega Sanitation Projects.
42. Ghilarducci, T., Saad-Lessler, J., & Reznik, G. (2018). Earnings volatility and 401 (k) contributions. Journal of Pension Economics & Finance, 17(4), 554-575.
43. Portes, A., & Guarnizo, L. E. (2019). Tropical capitalists: US-bound immigration and small-enterprise development in the Dominican Republic. In Migration, remittances, and small business development (pp. 101-131). Routledge.
44. Thorgren, S., & Williams, T. A. (2020). Staying alive during an unfolding crisis: How SMEs ward off impending disaster. Journal of Business Venturing Insights, 14, e00187.
45. Choi, S., Kang, C. M., Byun, C. W., Cho, H., Kwon, B. H., Han, J. H., ... & Lee, H. (2020). Thin-film transistor-driven vertically stacked full-color organic light-emitting diodes for high-resolution active-matrix displays. Nature communications, 11(1), 1-9.
46. Kim, H. T., Park, B. S., Song, S. S., Moon, T. S., Kim, S. H., Kim, J. M., ... & Ho, Y. C. (2018). A 28-GHz CMOS Direct Conversion Transceiver With Packaged 2×4 Antenna Array for 5G Cellular System. IEEE Journal of Solid-State Circuits, 53(5), 1245-1259.
47. Wang, Xiaoyan, Linjiang Chen, Samantha Y. Chong, Marc A. Little, Yongzhen Wu, Wei-Hong Zhu, Rob Clowes et al. "Sulfone-containing covalent organic frameworks for photocatalytic hydrogen evolution from water." Nature chemistry 10, no. 12 (2018): 1180-1189.
48. Bezzu, C. G., Carta, M., Ferrari, M. C., Jansen, J. C., Monteleone, M., Esposito, E., ... & McKeown, N. B. (2018). The synthesis, chain-packing simulation and long-term gas permeability of highly selective spirobifluorene-based polymers of intrinsic microporosity. Journal of Materials Chemistry A, 6(22), 10507-10514.
49. Nicotra, M., Romano, M., Del Giudice, M., & Schillaci, C. E. (2018). The causal relation between entrepreneurial ecosystem and productive entrepreneurship: A measurement framework. The Journal of Technology Transfer, 43(3), 640-673.
50. Kumar, K., & Prakash, A. (2021). An Assessment of Mandatory Corporate Social Responsibility Expenditure. Economic & Political Weekly, 56(39), 21.

51. Verma, D., Dixit, R. V., & Singh, K. (2018). Green Supply Chain Management: A Necessity for Sustainable Development. IUP Journal of Supply Chain Management, 15(1).
52. Lőrincz, N. S. (2022). Value creation of the automotive manufacturing industry in Hungary within global value chains Analyzing key suppliers [védés előtt] (Doctoral dissertation, Budapesti Corvinus Egyetem).
53. Casalini, F., & González, J. L. (2019). Trade and cross-border data flows.
54. Lecluyse, L., Knockaert, M., & Spithoven, A. (2019). The contribution of science parks: A literature review and future research agenda. The Journal of Technology Transfer, 44(2), 559-595.
55. Kim, Y., & Rhee, D. E. (2019). Do stringent environmental regulations attract foreign direct investment in developing countries? Evidence on the “Race to the Top” from cross-country panel data. Emerging Markets Finance and Trade, 55(12), 2796-2808.
56. Kumar, K., Sharma, H., Khan, W., & Kumar, R. (2022). Factors influencing adoption of green banking practices: Evidence from commercial banks in India. Journal of Asia Entrepreneurship and Sustainability, 18(1), 41-57.
57. D’este, P., & Perkmann, M. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. The journal of technology transfer, 36(3), 316-339.
58. Calabrese, G. (2001). Small-medium suppliers and the new car industry. International Journal of Automotive Technology and Management, 1(4), 471-489.
59. Mariotti, S. (2022). A warning from the Russian–Ukrainian war: avoiding a future that rhymes with the past. Journal of Industrial and Business Economics, 1-22.
60. Tarkar, P. (2020). Impact of COVID-19 pandemic on education system. International Journal of Advanced Science and Technology, 29(9), 3812-3814.
61. Aini, R. Q., & Triantama, F. (2021). The Implementation of South Korea’s Military Technology Reform in The Perspective of Techno-nationalism. Sospol: Jurnal Sosial Politik, 7(1), 63-76.
62. Svoboda, O. (2022). Building Surveillance State in a Digital Age and What Export Control Can (Not) Do About It?
63. Val Sánchez, K. V., & Akyesilmen, N. (2021). Competition for High Politics in Cyberspace: Technological Conflicts Between China and the USA. Polish Pol. Sci. YB, 50, 43.
64. Adhikari, P., Kuruppu, C., Ouda, H., Grossi, G., & Ambalangodage, D. (2021). Unintended consequences in implementing public sector accounting reforms in emerging economies: evidence from Egypt, Nepal and Sri Lanka. International Review of Administrative Sciences, 87(4), 870-887.
65. Lee, J., & Maher, R. (2022). US economic statecraft and great power competition. Business and Politics, 1-16.
66. Hauge, J. (2020). Industrial policy in the era of global value chains: Towards a developmentalist framework drawing on the industrialisation experiences of South Korea and Taiwan. The World Economy, 43(8), 2070-2092.
67. Weldegiorgis, F. S., Dietsche, E., Franks, D. M., Cust, J., & Ahmad, S. (2022). Mining and linkages for economic transformation: Revealing multi-stakeholder perspectives through Q-methodology. The Extractive Industries and Society, 101174.
68. Maulidia, M., Dargusch, P., Ashworth, P., & Ardiansyah, F. (2019). Rethinking renewable energy targets and electricity sector reform in Indonesia: A private sector perspective. Renewable and Sustainable Energy Reviews, 101, 231-247.
69. Lazonick, W., & Hopkins, M. (2021). Why the CHIPS Are Down: Stock Buybacks and Subsidies in the US Semiconductor Industry. Institute for New Economic Thinking Working Paper Series, (165).

70. Suseno, Y., & Standing, C. (2018). The systems perspective of national innovation ecosystems. Systems Research and Behavioral Science, 35(3), 282-307.
71. Asmussen, C. G., Hashai, N., & Delios, A. (2022). The coevolution of international scope and technological knowledge in MNCs. Journal of World Business, 57(1), 101285.
72. Hoekman, B., & Sabel, C. (2019). Open plurilateral agreements, international regulatory cooperation and the WTO. Global Policy, 10(3), 297-312.
73. Ocloo, C. E., Xuhua, H., Akaba, S., Shi, J., & Worwui- Bown, C. P. (2020, D. K. (2020). The determinant factors of business to business (B2B) E-commerce adoption in small-and medium-sized manufacturing enterprises. Journal of global information technology management, 23(3), 191-216.
74. Chen, M., Tworek, J., Jun, H., Yuan, Q., Pinto, H. P. D. O., Kaplan, J., ... & Zaremba, W. (2021). Evaluating large language models trained on code. arXiv preprint arXiv:2107.03374.
75. Rana, P. B., Chia, W. M., & Ji, X. (2022). Managing the Decentralising International Trade Architecture. In From Centralised to Decentralising Global Economic Architecture (pp. 161-195). Palgrave Macmillan, Singapore.
76. Thorbecke, W. (2021). The semiconductor industry in the age of trade wars, Covid-19, and strategic rivalries. Age of Ferment, 21.
77. Cory, N., & Atkinson, R. D. (2020). Why and How to Mount a Strong, Trilateral Response to China's Innovation Mercantilism. Information Technology and Innovation Foundation.
78. Atkinson, R. D. (2021). A US grand strategy for the global digital economy. Policy Report, Information Technology and Innovation Foundation (ITIF).
79. Tiwari, S., & Tiwari, R. (2022). Leveraging bionanotechnology for sustainable and inclusive growth: prospects for Indo-German collaboration in ensuring affordable healthcare.
80. Dilyard, J., Zhao, S., & You, J. J. (2021). Digital innovation and Industry 4.0 for global value chain resilience: Lessons learned and ways forward. Thunderbird International Business Review, 63(5), 577-584.
81. Dreilinger, D. (2021). The secret history of home economics: How trailblazing women harnessed the power of home and changed the way we live. WW Norton & Company.