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MAY 2022

Harnessing trade policy to build India's semiconductor industry

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Contents

Introduction

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.

In December 2021, the government of India approved a 'comprehensive programme for the development of a sustainable semiconductor and display ecosystem' – the first national program targeting the strategic industry. By announcing an allocation of US$9.78 billion towards developing a full-stack semiconductor ecosystem, New Delhi made clear that industrial policies are its instruments of choice.

In practice, however, state support through industrial policies can be problematic and does not always result in sectoral growth. Equally important – but underappreciated – to successful semiconductor ecosystems are the roles of trade policies and technology transfers. When compared with single-nation value chains, semiconductor supply chains benefiting from favourable trade policies and technology transfer have led to greater efficiency, higher productivity, lower consumer prices, and faster technological advancement.[1]

This paper outlines the role of trade policies in India's current context. 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.

The paper is divided into five parts. The first section 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

Despite a vibrant workforce known for tech engineering and semiconductor design, India has only a few semiconductor manufacturing facilities.

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.

Why trade and technology transfers matter

Trade and technology transfers play an integral role in building domestic industries and improving the global ecosystem for semiconductors.[4] The industry's giants, such as Taiwan and Japan, reached their stature because of more liberalised and open market policies.

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.[2]

The aim to remove chokepoints in production is understandable. However, this narrative can be problematic for the semiconductor industry. A sector that has burgeoned globally and thrives on international cooperation cannot be restructured quickly. The industry's current structure has also improved efficiency and productivity, as countries and companies focus on specific areas in which they excel, thus reducing risks of overcapacity and oversupply.[3] In addition, the sector's global nature has broadened access to large and growing markets, resulting in lower consumer prices. Global production has contributed to technological innovation, enhanced economic growth, and helped countries move up the value chain.

Trade and technology transfers play an integral role in building domestic industries and improving the global ecosystem for semiconductors.[4] The industry's giants, such as Taiwan and Japan, reached their stature because of more liberalised and open market policies. 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.[5]

The chip industry's global nature has resulted in lower consumer prices.

The key drivers

Techno-nationalism in the semiconductor industry is not a new phenomenon. Indeed, the calls began in the 1980s with the US-Japan trade war. Manufacturers in the United States alleged that Japanese imports – memory chips, transistors – were priced lower and hurt their businesses.[6] 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. 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. Firms moved to other products capable of generating more revenue.[7]

Japan's industry also realized – perhaps too late – that isolationist and protectionist policies had weakened the ability of domestic firms to compete on the global stage.[8]

The experience taught the semiconductor industry that interconnectedness and global value chains are helpful, due to the following reasons.

First, differentiation in human and financial resource requirements across various stages of semiconductor production has highlighted the role of comparative advantage.[9] And geographic dispersion of the production process has added diversity in the supply chain. 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

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process, due to their pure-play foundry business model.[10] The foundry model focuses only on the manufacturing or fabrication process of semiconductor chips without taking up other processes of the value chain.

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.[11] Free movement of labour and trade are essential for functional value chains and enabled comparative advantages to expand geographically across the entire sector.

Second, a competitive global value chain has elevated the standards of semiconductor production in terms of quality and specifications, increasing exports from Taiwan, China, and South Korea.[12] Trade-friendly policies have promoted the manufacturing of small and large-scale electronics.[13]

The Information Technology Agreement (ITA) of 1996 remains a landmark agreement that led to the promotion of trade in information and communication technology (ICT). Semiconductors remain the largest ITA product category, contributing a total of 32% of global trade in ITA products in 2015.

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.[14] 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.[15]

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.

In 2015, the Information Technology Agreement expanded and tariffs on approximately US$3 trillion of ICT goods traded globally were banned, as were imposing duties on semiconductor chips traded internationally.

These devices were classified as parts of other equipment and subjected to 25% tariffs, which were also eliminated.[16] Recent trade policies allowing access to cheaper equipment and promoting the exports of finished goods have made the semiconductor industry more robust.

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.[17]

Countries looking to join the semiconductor industry – including India – revamped their industrial policies to incentivise foreign investment.[19] With a growing engineering workforce and lower wages per capita, India offered incentives for semiconductor producers seeking to outsource manual design and verification work.

In the 1970s, many US semiconductor firms began to move their labour-intensive operations overseas to Southeast Asia, abundant with human capital.[18] Countries looking to join the semiconductor industry – including India – revamped their industrial policies to incentivise foreign investment.[19] With a growing engineering workforce and lower wages per capita, India offered incentives for semiconductor producers seeking to outsource manual design and verification work. The expansion of the value chain into multiple continents, with each process specialised for specific locations, set the foundation for the industry's immense growth.[20]

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. 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.[21]

The TRIPS agreement covered three areas specific to the semiconductor industry:[22]
- 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.

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.

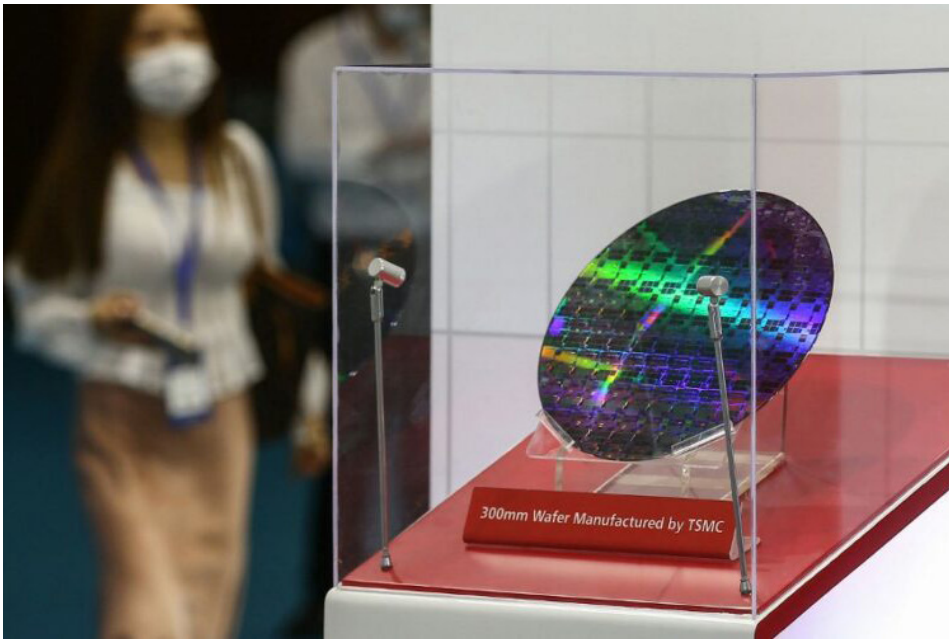
Finally, it is useful to look at the ecosystem which dominates today's semiconductor fabrication. Indeed, the story of Taiwan exemplifies how smart policy can change the course of history.

One single agreement for technology transfer laid the groundwork for the development of Taiwan's semiconductor industry.[23] 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

A stream of Taiwanese engineers traveled 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.

deal with the Radio Corporation of America (RCA), worth millions of dollars.[24] A stream of Taiwanese engineers traveled 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.

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?



The success story of Taiwan's semiconductor ecosystem exemplifies how smart policy can change the course of history.

Mapping India's semiconductor ecosystem

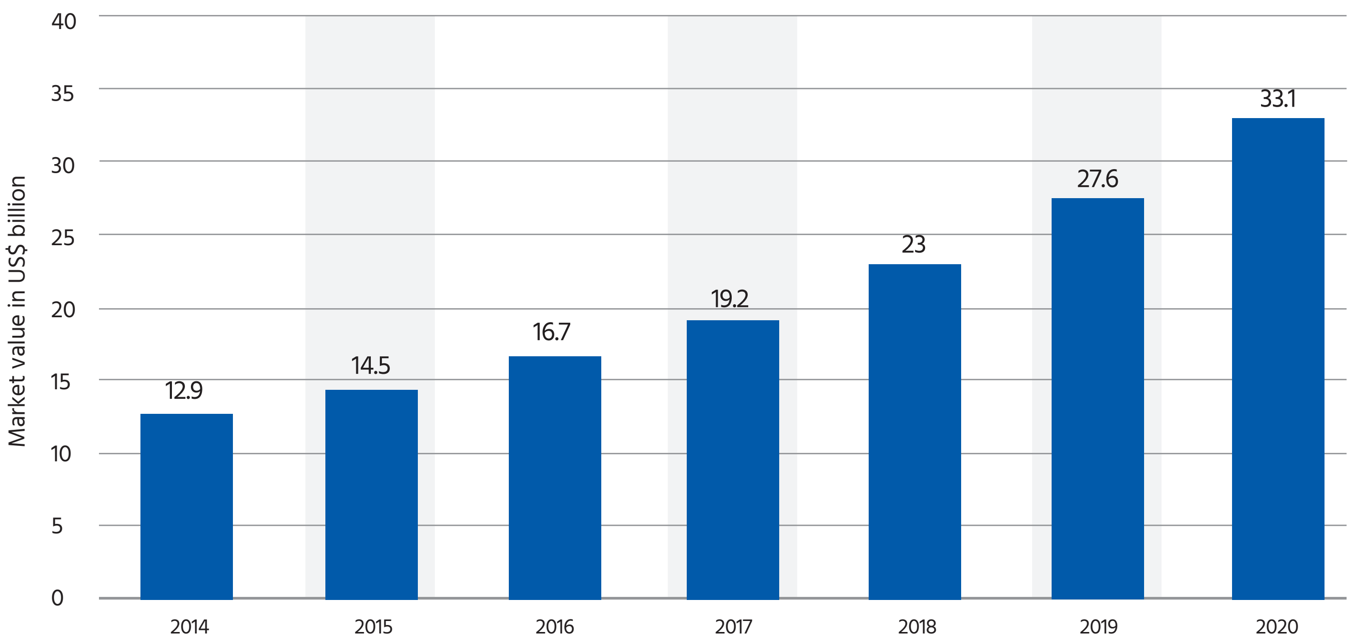
Consuming an estimated US$52.58 billion worth of semiconductors in 2020, India offers large market potential and technological competency.[25] The country is already a powerhouse for semiconductor design, with eight of the world's top semiconductor companies by revenue having Indian design centres. Moreover, home-grown firms have become pioneers in providing quality design services to international semiconductor giants – at lower costs. This is critical for the Indian semiconductor industry as it enlarges the domestic workforce and exposes them to the latest developments in semiconductor design.

However, more than 90% of India's semiconductor consumption relies on products imported from the United States, Japan, and Taiwan.[26]

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.

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 Semi-Conductor Laboratory (SCL) in Chandigarh is managed by the Department of Space. The government has also supported a Gallium Nitride facility at the Indian Institute of Science in Bangalore. Currently, there is no commercial semiconductor manufacturing plant operated either by the government or any private sector entity. With regard to

Figure 1 – Market value of semiconductor design services in India (2014-2020)



Source: Statista

assembly, testing, marking, and packaging, India has a limited presence, with few domestic firms such as SPEL Semiconductor Limited and SemIndia Private Limited.

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

Design

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.

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.[27] And 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.[28]

Table 1 – India's previous attempts at semiconductor fabrication and manufacturing

When?	With whom?	What happened?
1960s	Fairchild Semiconductors	Sought to setup manufacturing factory but was discouraged by the existing bureaucratic restrictions. Invested in Malaysia and Phillipines instead.
1980s (specifically 1984)	Semiconductor Complex Limited (SCL) setup with 100% stake of Indian government	US$40-70 million nvestment by government to setup plant in Mohali. 1984 – Licensed 5 micron process tech from AMI and had two other deals with Rockwell Automation and Hitachi, respectively. Assembled the BBC Acorn computer. Also acquired 800nm technology. 1989 – Major fire at SCL.. Production resuming only in 1997 (lost progress to TSMC and Samsung). Government could not sell the fab to private investors. Retooled from making chips for telecom exchanges to smartcards. 2005 – Company was restructured due to huge losses as 'Semiconductor Lab', a R&D facility within Department of Space.
2006	AMD wanted to setup assembly and test facilities	'FabCity' project with US$3 billion in investment. Poor industry conditions shut down the project (SemIndia).
2014	Proposal from two investor groups approved to build fabs worth US$10 billion. – First group – Jaypee Group, TowerJazz (Israel) and IBM – Second group – HSMC, STMicroElectronics (Europe) and Silterra (Malaysia)	First group – In 2016, Jaypee group pulled out due to debt and said the plant was not commercially viable. Project suspended. Second group – Government cancelled HSMC's 2-year-old letter of intent. The group did not submit any docs for "demonstration of commitment". No update. Project in Noida.
2015	Cricket Semiconductor with the Madhya Pradesh government	Investment of US$1 billion for an analog IC and power supply specific IC fab in the works. Fab policy released by the government in 2015. Progress not known and project most likely suspended.

Source: Author's compilation

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. With help and investment from Israel's Tower Semiconductor, the SCL facility has upgraded to manufacturing the 8″ wafer fab to produce 180nm chips.[29] However, the absence of private capital to set up a semiconductor manufacturing plant indicates that incentivising policies have not worked. 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.

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).

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.[30]

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).[31] 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.

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. The abundance of low-cost labour in the country is an added advantage.[32] 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.

With respect to indigenous IP design, India has suffered from a lack of technology transfer agreements with more experienced manufacturers such as the United States.

In general, however, India faces hurdles in reaching its potential. With respect to indigenous IP design, India has suffered from a lack of technology transfer agreements with more experienced manufacturers such as the United States. Access to critical semiconductor technology infrastructure can help India build its own IP pool.

Furthermore, the potential of fabs and OSAT facilities in India is intertwined with trade – both need favourable import policies. 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.

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. 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.[33] The Production Linked Incentive (PLI) scheme also specifically targeted the country's manufacturing.[34]

Following New Delhi's announcement of the semiconductor package, the Ministry of Electronics & Information Technology explained that the schemes focused on all stages of semiconductor production: design, manufacturing, and OSAT.

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. 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.

The scheme clarified the governance structure too. The Indian Semiconductor Mission will act as the nodal agency, composed of industry experts and government officials, and be responsible for the schemes' efficient and smooth implementation.[35]

Understanding each of the four schemes would provide a holistic view of the government's vision.

The aim of the Design Linked Incentive (DLI) scheme is to build India's comparative advantage in semiconductor design and support domestic design firms.[36] 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

Table 2 – Revisiting India's semiconductor manufacturing incentives

	Pre-2019	2019 to 2021
Capital expenditure	20% financial incentive of total capital expenditure	25% financial incentive of total capital expenditure (includes R&D)
Basic Custom Duties (BCDs)	Exemption of BCDs for non-covered capital goods	Exemption of BCDs for all capital goods used for setting up fabs
Tax deductions	Investment-linked deduction under Section 35AD and deduction on R&D under Section 35(2AB) of the IT Act	Investment-linked deduction under Section 35AD and deduction on R&D under Section 35(2AB) of the IT Act
Loans	Interest-free loan capped at 20% of capital expenditure	-
Tax exemptions (if fab starts operation before March 31, 2023)	-	Reduced corporate tax of 15% with no Minimum Alternate Tax (MAT) applicable

Source: Author's compilation

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.

Companies with experience have been asked to commit a minimum capital investment threshold of US$12.86 million to set up specialised fabs.

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.

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.

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.[39] 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. The government will cover 50% of the

Table 3 – India's 2021 semiconductor package

<table>
<tr><th>GoI's Semiconductor Schemes</th><th>GoI's Semiconductor Schemes</th></tr>
<tr><td>Design Linked Incentive (DLI) Scheme</td><td>Product Design Linked Incentive – Reimbursement of 50% of the eligible expenditure subject to a ceiling of US$1.93 million incentive per application.</td></tr>
<tr><td>Semiconductor Fab Scheme</td><td>Minimum Capital Investment – US$2.57 billion

Fiscal support from Government of India
<table>
<tr><th>Node size</th><th>Percentage of project cost</th></tr>
<tr><td>28nm or lower</td><td>Up to 50%</td></tr>
<tr><td>29nm to 45 nm</td><td>Up to 40 %</td></tr>
<tr><td>46nm to 65 nm</td><td>Up to 30%</td></tr>
</table></td></tr>
<tr><td>Display Fab Scheme</td><td>Minimum Capital Investment – US$1.29 million

Fiscal support from Government of India –
Up to 50% of project cost or a maximum sum of US$1.55 billion</td></tr>
<tr><td>ATMP/OSAT Facility Scheme</td><td>Minimum Capital Investment – US$6.43 million

Fiscal support from Government of India –
30% of Capital Expenditure</td></tr>
</table>

Source: Government of India's Semiconductor Ecosystem Schemes Notifications total project cost for firms covering 28 or lower nanometers (size of transistors produced), 40% for 28 nm to 45 nm, and 30% for 45 nm to 65 nm. This scheme will also provide long-term support over a period of 6 years for at least two companies.

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. However, a more holistic approach requires better multilateral engagement and a stronger presence in the global supply chain.

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. 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.

Following New Delhi's announcement of the semiconductor package, the Ministry of Electronics & Information Technology explained the four specific schemes to reduce India's dependency on imports and incentivise domestic production of semiconductors.

The impact of geopolitics on collaboration

Global trade and stronger collaboration between countries play a major role in advancing semiconductor technology. But states may face impediments when trying to improve trade. Globalisation has heightened the potential for restrictions, which can hamper technology dissemination. These restrictions, which challenge the industry's growth, are as follows.

Restrictions on human capital movement

Taiwan faced a shortage of manpower for the nascent industry, so 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.

Efficient trade policies facilitate the cross-border movement of goods and services in a supply chain. In the capital and labour-intensive semiconductor industry, both high-skilled and low-skilled workers are required in different areas of the value chain.

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.

Again, Taiwan provides excellent lessons.[41] 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.

When semiconductor technology is used to build defence and military systems, dual-use application applies and can trigger export regulations and restrictions

The project hoped to attract people with high-tech knowledge, to improve the efficiency of R&D operations. Skilled labour from the United States was recruited. The engineers and their families were provided housing and schools for children were established inside the park. Workers were also provided upskilling opportunities while locals were provided on-the-job training. Over time, this seamless transfer of labour built an industrial cluster now worth billions of dollars.[42]

The per capita income of India remains on the lower end of the spectrum compared to semiconductor powerhouses like the US and Taiwan. Attracting skilled workers from these countries will require additional financial support from the government as well as a favourable investment climate.

Today, easy movement of labour across countries is a challenge. With many emerging economies facing dire economic situations due to the Covid-19 pandemic, there is a shortage of skilled workers ready to relocate to a country like India. The per capita income of India remains on the lower end of the spectrum compared to semiconductor powerhouses like the US and Taiwan. Attracting skilled workers from these countries will require additional financial support from the government as well as a favourable investment climate.

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.

There may also be increased poaching of employees working in the high-tech sector. Industrial espionage and surveillance mechanisms being used to cover for the paucity of human resources in the semiconductor domain is a threat and key challenge that needs to be addressed.[43]

With increased economic protectionism around the world, the trade of skilled labour for the semiconductor sector will face constraints.

The growth of India's semiconductor industry is constrained by increasing techno-nationalism beyond its borders.

Fears of weaponization

Recent events, including the Covid-19 pandemic and the Russia-Ukraine conflict, have raised geopolitical and geo-economic concerns about semiconductor supply chains. They have also raised fears about the use of semiconductor technology to weaponize respective militaries.[44] These developments can lead to an increase in techno-nationalist tendencies across regions.

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Export control mechanisms

When semiconductor technology is used to build defence and military systems, dual-use application applies and can trigger export regulations and restrictions, as per multilateral conventions such as the Wassenaar Agreement. Like nuclear technology, this attaches a component or threat of proliferation, which makes the technology liable to certain export controls. Put in place to prevent the excessive exports of dual-use technologies,[45] the Wassenaar Agreement's 42 signatories includes the US, Japan, Netherlands, and South Korea. 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.

As per the list, export controls on specific technologies have been divided into five categories: materials, software, technical data, and two covering physical commodities. The list of products specifies more than 150 semiconductor products and more than 20 types of semiconductor manufacturing equipment.
There is also the possibility of unilateral controls on the export of emerging technologies by countries. The best example is the United States' Export Control Reform Act (ECRA 2018), which identifies export controls essential for technologies directly related to the country's national security.[46] According to this Act, the Department of Commerce's Bureau of Industry and Security has the authority to update the Export Administration Regulations. Unilateral controls by a semiconductor giant such as the US can hamper the chances of other countries to access critical materials and equipment.

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Fear of weaponising semiconductor technology can also result in tighter investment screening mechanisms. Financing that might originate from unverified sources and potential Chinese investors might be viewed with increased scepticism. These developments can impede industry growth.

Import restrictions

Import restrictions also still exist in many economies, including in India. After the government announced the semiconductor package, the Indian Cellular and Electronics Association, an industry body made of the leaders of major domestic firms, reminded that the rates for semiconductor imports remain high and certain restrictions remain in the form of high tariffs and sensitive technologies.[47] The statement also emphasised how this would negate the benefits offered by the fiscal support package.

Thus, emerging semiconductor producers face the challenge of balancing domestic firms and acquiring state-of-the-art equipment and technologies by facilitating imports.

The government's prioritization of labour market flexibility, macroeconomic stability, infrastructure expansion, secondary education, and favourable trade policies, helped Taiwan scale new heights in the semiconductor industry.

Again, Taiwan serves as a powerful example. Its success is generally attributed to a policy shift away from import substitution towards trade and investment liberalisation, particularly for industrial inputs.[48] The government's prioritization of labour market flexibility, macroeconomic stability, infrastructure expansion, secondary education, 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.

Import restrictions can continue to hamper the growth of India's semiconductor industry. The government should prioritize unilaterally reducing import tariffs for electronic and semiconductor components. While there are now financial incentives to set up shop in India, efficient operations require a constant inflow of essential goods at lower prices. Restructuring import rules and regulations to facilitate such an outcome is the first step.

A roadmap for the path ahead

India faces a tough task ahead: to show its commitment in building the semiconductor industry. Industrial policies with capital may attract investments and potential bids, but favourable trade policies and conducive business environment can ensure the completion of said projects and yield results. In the long run, this approach can attract more international semiconductor firms. India can be closer to its goals by adopting the following policy recommendations:

1. Overhaul of trade policies

India's must change its approach with foreign trade policy and make it more accommodating to the technology sector. The government can then focus on developing a comprehensive trade policy suited or catered to the semiconductor industry itself.[49]

Existing mercantilist and distortive trade practices that undermine the tenets of market-based competitiveness in the industry must be eliminated. This can include exorbitant subsidies provided to the domestic sector that might discourage foreign firms from investing in the country.

Existing mercantilist and distortive trade practices that undermine the tenets of market-based competitiveness in the industry must be eliminated. This can include exorbitant subsidies provided to the domestic sector that might discourage foreign firms from investing in the country.

Furthermore, government commitment is necessary for engaging in international forums and multilateral trade groupings that can advance the growth of the semiconductor industry. These organizations include:

The World Semiconductor Council (WSC)

The WSC is an international forum bringing together semiconductor leaders and technical experts to address global issues concerning the industry.[50] Currently, the organisation comprises the semiconductor industry associations of Japan, South Korea, the US, Europe, China, and Taiwan. Established in 1996, the WSC promotes international cooperation in the semiconductor industry to facilitate the industry's long-term growth.

India should join the Council to make its voice heard among the semiconductor powerhouses. The Council is a strong proponent of free trade and is guided by the principles of fairness, respect for market principles, and consistency with WTO rules. The WSC also recognizes the importance of open markets without discrimination and believes that the competitiveness of companies and their products should be the principal determinant of industrial success and international trade.

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Any aspiring member (a country or region where the association is located) must meet one of the two criteria regarding tariff elimination. First, all tariffs have been eliminated. Second, commitment to expeditious elimination of all tariffs on semiconductors or suspension of such tariffs pending their formal elimination has been made. India's commitment can bring about investor confidence and potential partners to build the domestic ecosystem. This would also extend India's access to free trade with respect to the semiconductor industry.

The 2015 ITA Expansion

In 1996, the World Trade Organisation's ITA was the primary tariff-cutting agreement related to high-tech and information technology products. The rapidly evolving digital revolution has made the WTO rethink the overall scope of the agreement itself. This kickstarted the ITA-II negotiations in 2015 and resulted in the addition of over 200 technology products.

India was a signatory to the original 1996 agreement but opted out of the expansion agreement,[51] which would have mandated duty-free treatment to the expanded list of tech products, including crucial semiconductor products and components. At the time, New Delhi argued that the agreement would impact the domestic electronics manufacturing sector and create an over-reliance on imported electronic goods. The government had introduced the 'Make in India' policy to improve domestic manufacturing across various sectors. This has effectively prevented Indian companies from accessing critical semiconductor products at zero tariff structures.

It is in India's interest to become an official signatory of the expanded ITA. Doing so would enable the domestic sector to access zero-tariff goods related to the semiconductor industry.

It is in India's interest to become an official signatory of the expanded ITA. Doing so would enable the domestic sector to access zero-tariff goods related to the semiconductor industry. It would also help start-ups and domestic manufacturers improve their export volume. The wide range of technology products offered by the ITA can ensure that strategic sectors such as semiconductors would be at the forefront of India's international trade.

India has traditionally stayed away from trading blocs and agreements such as the Regional Comprehensive Economic Partnership (RCEP) and the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), citing the need to protect its domestic economic sectors. But for supply chains to function efficiently, the technology realm requires plurilateral cooperation. It is imperative to have a

The 'Quad Supply Chain Initiative', announced at the first in-person summit of the group, can be expanded to include trade secret protections that will facilitate technology transfer agreements easily.

free flow of goods and services in the semiconductor and high-tech sector. India will benefit domestically and can play a bigger role in the global value chain if they join these multilateral groupings that accrue benefits specific to the industry.

2. Promote a tech transfer and IP protection regime

Ultimately, convincing international markets to view India's potential as a semiconductor powerhouse relies on transparent technology sharing and a functioning system related to high-tech sectors.

It is also in India's interest to advocate for a tight-knit framework for the promotion of technology transfer agreements in the semiconductor domain and lead the global industry in promoting a mechanism for the protection of semiconductor industry-related IP. This would ensure adequate protection for potential investors and semiconductor giants looking toward India. Ultimately, convincing international markets to view India's potential as a semiconductor powerhouse relies on transparent technology sharing and a functioning system related to high-tech sectors.

India can start by introducing and ensuring the enforcement of strict rules against IP theft and other regulations in the semiconductor industry. Enforcement can include restricting any firm in violation of said rules and regulations from participating in the markets. Prevention of exports, restrictions on domestic operations, and levying fines or penalties for specific firms violating IP theft guidelines will ensure innovation-based competition in the long run.

3. Foster multilateralism as a necessity for resilience

A 'bubble of trust' approach can help India engage with like-minded states through a multilateral or plurilateral approach.[52] This can help improve information-sharing mechanisms in specific high-tech industries including semiconductors.

To ensure a seamless transfer of semiconductor technology, there should be a single point of focus for the Indian government, perhaps through the establishing of technology alliances catered to the sector. A 'bubble of trust' approach can help India engage with like-minded states through a multilateral or plurilateral approach.[52] This can help improve information-sharing mechanisms in specific high-tech industries including semiconductors. These technology-sharing agreements can happen between alliance partners through existing groupings like the Quad.[53] For example, the 'Quad Supply Chain Initiative', announced at the first in-person summit of the group, can be expanded to include trade secret protections that will facilitate technology transfer agreements easily.

In the information age, technology alliances can become the future of diplomacy. With supply chains facing bottlenecks, disseminating semiconductor technology across multiple states through technology transfer agreements can reduce existing vulnerabilities. India can play its part in facilitating technology transfers to its domestic sector – to build resilience in the global value chain and its own ecosystem.

Conclusion

From the multilateral trade agreements facilitating industry growth to the creation of comparative advantages, trade has played a major role in shaping the semiconductor global value chain.

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.

From the multilateral trade agreements facilitating industry growth to the creation of comparative advantages, trade has played a major role in shaping the semiconductor global value chain. 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.

Emulating Taiwan's semiconductor industry in the field of trade and technology transfer can help India and other growing semiconductor powers scale new heights.

India would benefit from a deeper understanding of the primacy of trade and technology transfer 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.

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