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Semiconductors, A Biggest Economic Choke-Point of the 21st Century

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Abstract:
Semiconductors are the soul of all electronic devices and a key player in the global economy. They became a basic necessity of human life and were utilised in every corner of the globe. They are used to design, build, and modernise the technology systems that the world depends on every day. But the production of semiconductors and related electronic products in India is grossly insufficient in comparison to its demand. Even though electronic products are manufactured in India, the domestic value addition to the product is low (source: The Ministry of Electronics and Information Technology, MeitY), which results in lower consumer acceptance. Because of this, India's electronic imports far exceed its exports. Hence this paper explores the growth of electronic sectors that use semiconductors and the impacts of exports and imports of semiconductors and electronics in India. The research process involved the study of various factors that impact the semiconductor industry, including government policy, market environment, competitive landscape, present trends in the market, technological development, and the rise in the demand for basic electronic devices.

Keywords: semiconductors, import, export, shortage, policy, electronic production

Introduction:
Semiconductors are crucial for the Indian economy, technological advancement, and national security. According to the Semiconductor Industry Association (SIA), semiconductors are the major building blocks of electronic devices, and they provide smaller, cheaper, faster, and more reliable electronic devices; smarter and safer transportation; greater network connectivity; enhanced renewable energy; and an improved energy grid, whilst providing high-paying employment to the citizens of the country and hardening the core strength of the manufacturing base. During this pandemic, technologies powered by semiconductors have aided researchers and scientists in developing life-saving drugs and vaccines (Mihalis Kritikos, 2020) and helped the world to learn and work remotely. Investments in domestic semiconductor production should be made since it is part of the future (Melissa Cyrill and Yashoda Kapur, 2022). Chip technologies are destined to continue to evolve to a greater level of performance, and the demand will be equal to or even greater than the supply (Sam Shed, 2021). With the rising demand for semiconductors, the conflict between the U.S. and China over the Taiwan Semiconductor Manufacturing Company Ltd. (TSMC) has made things even worse (A Special Report by FP Analytics, 2021). So the biggest economic chokepoint of the 20th century may have been oil passing through the Strait of Hormuz (Justine Barden, 2019), but now it's microscopic silicon transistors that are manufactured in Taiwan. But while the US and China fight for control of the technology, they still depend on each other for the most part (Lieberthal, K., and Jisi, W., 2012). Their relationships are arguably the most complex in the world, just like the flesh and bones that seamlessly adhere to each other. From a market perspective, China has the largest vehicle and consumer electronic device market where all related corporations are dying to sell their products (Daxue Consulting, 2020); on the other hand, China is eager to deliver on its goal of self-reliance in the technology sector, especially chip making, which the U.S. strictly banned (Akinori Kahata, 2021). This ban will affect the Indian economy as the electronic and automobile sectors of India depend more on China. India is just watching this tech war, fantasising about having a chip plant, and starting to invest more in it since this is an area of industrial revolution that will only prevail with constant investment into the future. The need for research into this field and other linked fields is absolutely essential for global economic progress. We do need to develop alternative manufacturing capabilities for global safety and security.

Research Methodology:
The study involved the extensive use of secondary data from sources such as the National Sample Survey Organization (NSSO), the Ministry of Commerce and Industry (MEITY), and the Directorate General of Commercial Intelligence and Statistics. This study analysed the importance given to the electronic and manufacturing sectors in India and further

analysed the production of electronics in India, which depends on semiconductors and the growth of import and export of electronics in India.

Research Design:

Analysis of historical data from 2013-2021

The analysis of historical data for electronic production in India contains extensive analysis of products that uses semiconductors.

Identification and analysis of influencing factors:

An analysis of the importance given to electronic production in India through various government schemes as well as the detection of shortages and threats in semiconductor production

Trade Forecast (2022-2026):

Analysis of exports and imports of electronics and forecasting the growth rate up to the financial year 2025–2026.

Research Tools:

The compound annual growth rate (CAGR) is used to predict the growth of imports and exports from India until the financial year 2025–2026. Quantitative tools were used to analyse the production of various electronics.

Objectives:

- To understand the schemes put forth by the government to boost semiconductor production.
- To analyze production of electronics in India that uses semiconductors.
- To establish the reasons for shortage and threat in semiconductor production.
- To analyze countries percentage shares in India's trade of semiconductor devices.
- To analyze growth of electronic import and export in India.
- To suggest the strategies to overcome semiconductor shortage

Government Schemes:

To establish India as a global centre for electronic production, the government has announced various schemes to boost domestic electronic manufacturing.

- Production Linked Incentive Scheme (PLI)
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- Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS)
- Modified Electronics Manufacturing Clusters Scheme

Production Linked Incentive Scheme (PLI) for Large Scale Electronics Manufacturing

The PLI scheme for large-scale electronics manufacturing aims to boost domestic electronics production and attract more investments in the electronics value chain, including mobile phones and specified electronic components such as discrete semiconductor devices, passive components including resistors, capacitors, etc. for electronic applications, printed circuit boards (PCB), photopolymer films, assembly, testing, marking, and packaging (ATMP) units, and micro- and nano-electronic components. Under this scheme, incentives of up to Rs 40,951 crore will be sanctioned over a period of five years. (Notification PLI Scheme for Large-Scale Electronics Manufacturing, MEITY, 2021)

Production Linked Incentive Scheme (PLI) for IT Hardware

The PLI scheme for IT hardware aims to boost domestic electronics production and attract more investments in the electronics value chain, including laptops, tablets, all-in-one PCs, and servers. The scheme's total incentive outlay is Rs. 7325 crores. (Notification: Production Linked Incentive Scheme (PLI) for IT Hardware, MEITY, 2021)

Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors:

SPECS aims to strengthen the production of semiconductors and electronic components. This scheme will help fulfil the existing demand for semiconductors and create employment opportunities. Under this scheme, incentives up to Rs 3,285

crore will be sanctioned over a period of eight years. This scheme will play a vital role in making India a self-reliant nation in the production of semiconductors. (Notification: SPECS Scheme, MEITY, 2020)

Description of goods that will get incentives from SPECS:

S.No	Description of goods	Threshold Limit in Crore
1	SMT components including LED Chips	**5**
2	Chip Modules for Smart Cards	**5**
3	Passive components	**5**
4	Electromechanical components	**5**
5	Components for electronic applications	**5**
6	Printed Circuit Boards (PCBs)	**5**
7	Sensors, Transducers, Actuators and Crystals	**5**
8	Image sensors with lens, Vibrator motor	**5**
9	Cables such as USB, HDMI and Data Cables.	**5**
10	Capital goods for all the goods covered under SPECS	**5**
11	Discrete semiconductor and Power semiconductors devices	**15**
12	Pre form of Silica and Optical Fiber	**15**
13	Display Assembly and Cover Glass Assembly	**15**
14	Nano-Electro Mechanical Systems (NEMS) and Micro Electro Mechanical Systems (MEMS)	**25**
15	Assembly, Testing, Marking and Packaging (ATMP) units	**25**
16	Plastic and metal parts for electronic applications	**75**
17	Compound Semiconductors	**250**
18	Semiconductor Wafers	**500**
19	Display fabrication units	**500**
20	Semiconductor Integrated Chips (ICs)	**500**

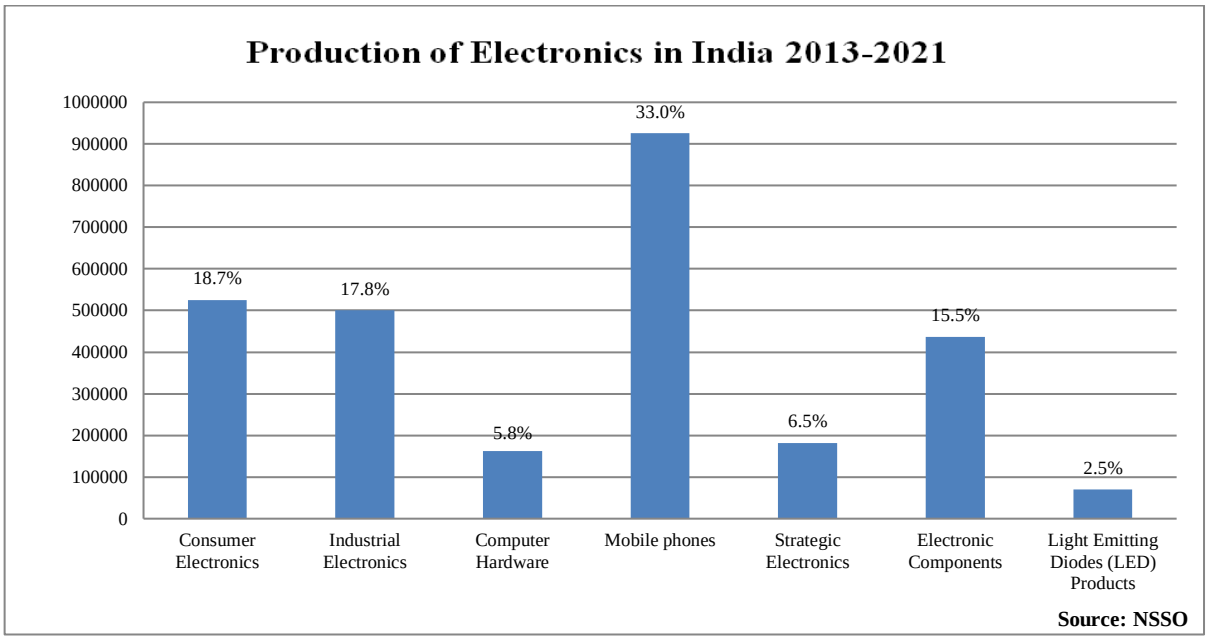
Source: MeitY **Table: 1**

Modified Electronics Manufacturing Clusters Scheme (EMC 2.0):

This scheme aims to establish electronics manufacturing clusters to enhance infrastructure with required facilities for EMC projects and upgrade the infrastructure in industrial areas as Common Facility Centers (CFCs) to attract investment in electronics manufacturing. Creating a common facility centre will strengthen the supply chain while also lowering logistics costs. This scheme supports services like e-waste management, warehousing, water recycling, recreational facilities, effluent treatment plants, centres of excellence (R&D, incubation, and consulting services), skill development centres, banking and financial services, etc. It also provides manufacturing support for various electronic activities. Under this scheme, incentives of up to Rs 3,762 crore will be sanctioned over a period of eight years. (Notification: EMC 2.0 Scheme, MeitY, 2020)

Production of Electronics In India Which Uses Semiconductors (2013-2021):

The domestic production of electronics in India has increased substantially since 2013. Especially in the sectors of consumer electronics, mobile phones, strategic electronics, industrial electronics, computer hardware, electronic components, and light-emitting diode (LED) products. However, all of these industries rely heavily on semiconductors, transistors, microchips, diodes, and so on. The recent shortage in the semiconductor market will definitely pull down electronic manufacturing in India.



Source: Secondary data-NSSO **Figure- 1**

India is the second-largest producer of mobile phones in the world (Mani, 2019). The above data also shows that out of total electronic production from 2013–2021, mobile phone production alone stands at 33 percent, which shows the dominance of mobile phone production in India. India is expected to have a trillion-dollar digital economy by the year 2025 (Grace Chung, 2021), and the National Policy on Electronics (NPE) 2019 had a goal of attaining a turnover of $400 billion by 2025. These expectations and targets will only be attained if India succeeds in the production of semiconductors and related products.

Reasons for shortage and threat in semiconductor production:

- Huge Investment
- Monopoly Power
- Taiwan's Dominance
- Lack of knowledge
- Time
- Covid-19 Pandemic

Huge Investment:

It requires 15 to 20 billion dollars to build one semiconductor factory, and that will be obsolete within 5 years because those factories must be operated 24/7 around the clock to be competitive. (Ian King et al, 2021,). Hence, it is very difficult to build a semiconductor fab or foundry in a developing or underdeveloped country. As a result, most countries rely heavily on Taiwan and China. China has invested 1.4 trillion dollars in semiconductors (KEVIN XU, 2020, The Wire China) after the issue with Taiwan Semiconductor Manufacturing Company Ltd. (TSMC) and America. India also invested 76,000 crores for domestic semiconductor production (Government of India, 2021). This kind of huge investment suggests that the chip war has begun. Globally, if countries have to line up behind which sphere of production they see fit, most likely they will go for cost. And if China or India can manage to make sophisticated chips faster and cheaper, most of the countries will line up behind them.

Monopoly Power:

Advanced Semiconductor Materials Lithography (ASML), a Dutch company, is the only firm in the world capable of making the highly complex extreme ultraviolet (EUV) lithography or photolithography machines (Sam Shed, 2021) that

are needed to manufacture the most advanced chips at high volume and yield. But these machines cost approximately 140 million dollars (Sam Shed, 2021). Because of this monopoly power, many countries and companies depend only on ASML for their semiconductor plants. These machines are sold to giant semiconductor producers, including TSMC, Samsung, and Intel.

Taiwan's Dominance:

Taiwan is the dominant player in the chip-making industry; nearly ninety percent of the most advanced chips are made in Taiwan (Julian E. Barnes, 2022). Considering its geopolitical fragility in East Asia, clearly the world has a huge problem here since it is definitely too reliant on Taiwan (Ian King, 2021). If China overruns Taiwan, then the US will come into play, which will create chaos and a global shortage in semiconductor production.

Lack of knowledge:

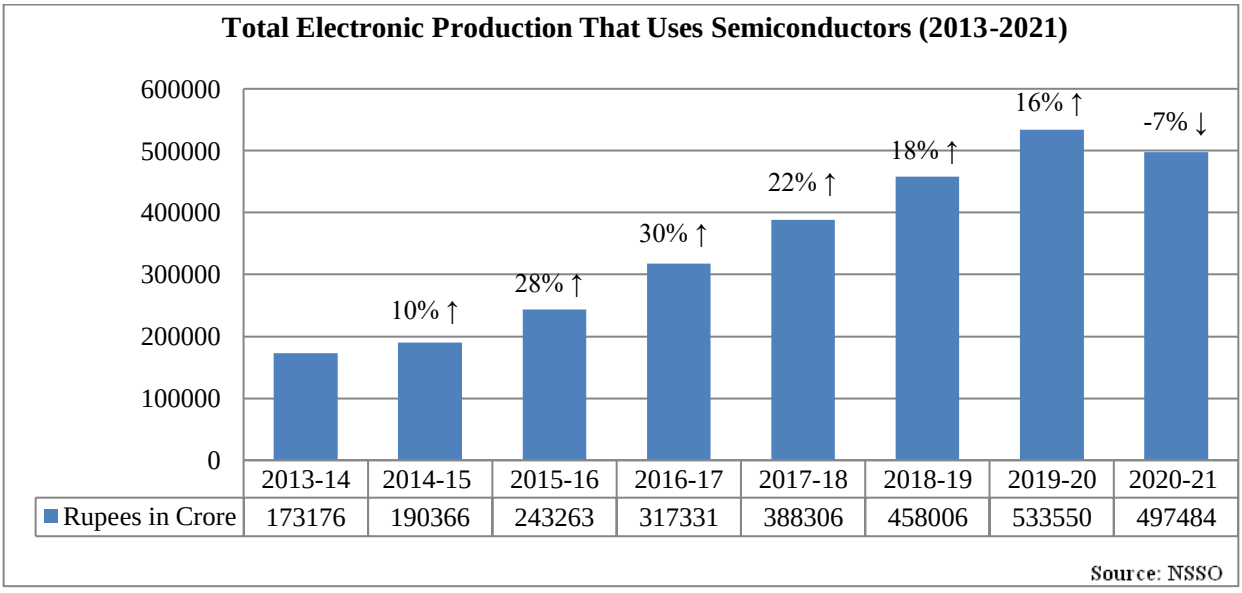
To produce the desired range of chips, semiconductors and related products require highly specialised inputs, designs, and equipment. There are more than 1,000 processes (source: Semiconductor Industry Association, SIA) involved in the overall manufacturing of semiconductors, and each process typically requires a variety of highly sophisticated tools and machines. Handling these kinds of equipment and designing a microchip requires vast knowledge and experience, which many countries lack. In short, making semiconductors is exceedingly hard.

Time:

Production of finished chip products can take a minimum of 6 months (source: SIA). Producing a finished wafer and its fabrication process itself takes about 3 months, but for an advanced process, it may also take up to 5 months. After that, the semiconductors must go through another manufacturing process known as assembly, testing, and packaging (ATP) before they are finally ready for delivery to the end customer (Source: SIA). Assembly, testing, and packaging will take another 6 weeks to complete. Therefore, from raw material to the final product, it may take up to a total of 26 weeks (source: SIA).

Covid-19 Pandemic:

The COVID-19 pandemic has disrupted the production of semiconductors and fuelled the demand for electronic devices such as laptops, computers, 5G phones, gaming systems, and other IT equipment as the world turns into a virtual environment. The shortage of semiconductors due to the pandemic will make the countries think of hoarding their stock for future expected demand, and this action will affect those countries that only consume semiconductors.

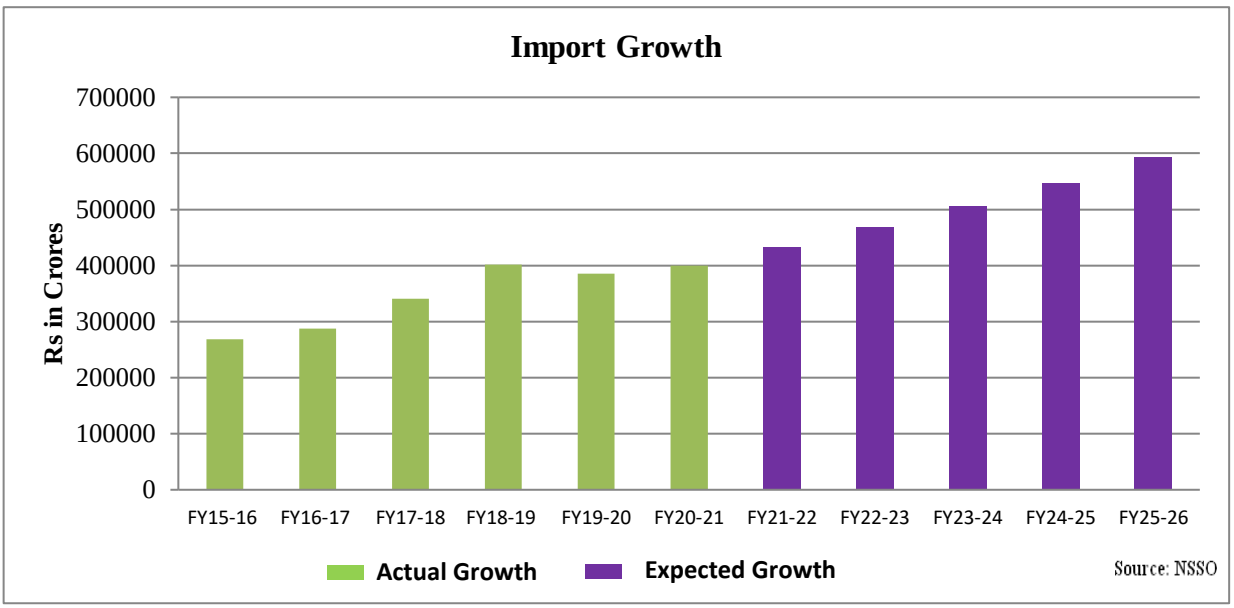


Source: Secondary data-NSSO **Figure- 2**

The above chart clearly shows that electronic production, which uses semiconductors, has decreased by 7% during the period 2020–2021 when compared to 2019–2020.

Growth of Electronics Imports in India:

India's electronics imports are likely to grow at a compound annual growth rate of 8.3%. When compared to the financial year 2015–2016, India's imports are expected to rise up to 121% in the financial year 2025–2026. This indicates how much India is depending on other countries for its electronics demand.



Source: Secondary data-NSSO **Figure- 3**

Different Countries Percentage share in India's Imports of Diodes, transistors, and similar semiconductor devices etc.

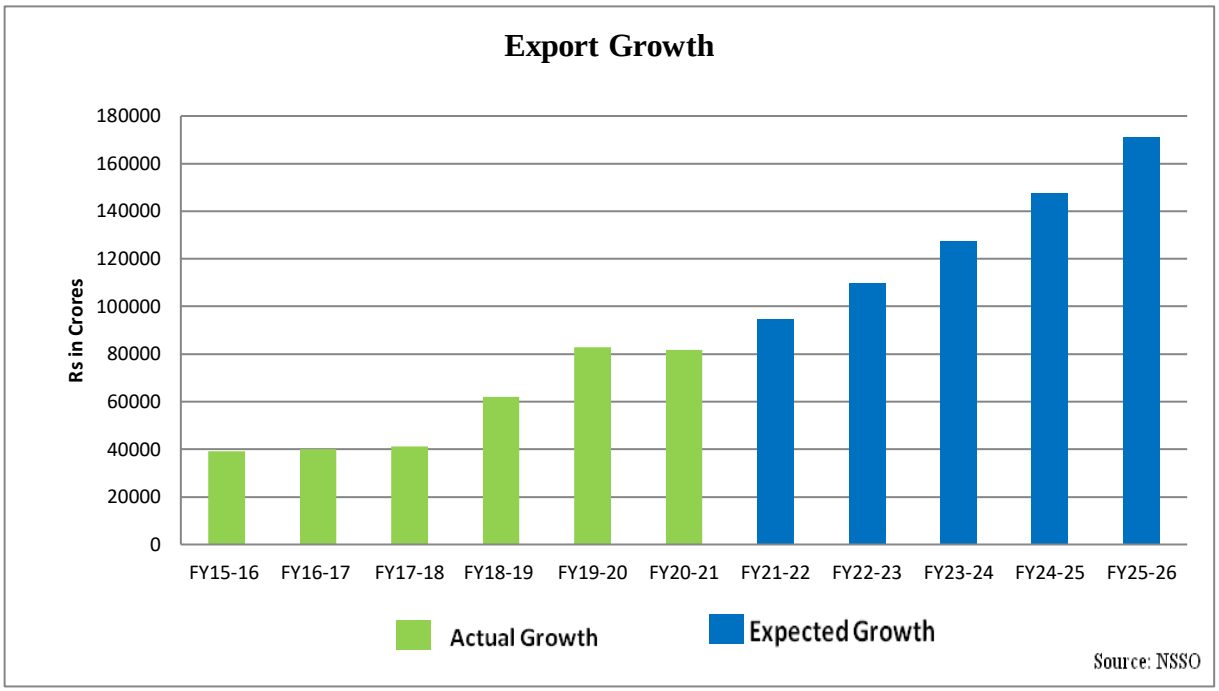
Partner Country	2015	2016	2017	2018	2019
China	71.00	78.62	81.92	70.02	62.45
Singapore	2.78	2.47	1.76	7.56	8.07
Malaysia	9.30	7.28	5.89	1.90	0.82
Japan	4.47	3.79	2.22	2.66	3.56
HongKongSAR	0.92	1.10	0.89	4.22	6.92
OtherAsia,nes	2.71	1.95	2.25	3.61	1.23
VietNam	0.05	0.07	0.70	1.59	5.36
Others	8.77	4.72	4.37	8.47	11.59
Total	**100**	**100**	**100**	**100**	**100**

Source: Secondary data - UN Comtrade database **Table: 2**

The above table shows that India is importing more than 70% of diodes, transistors, and similar semiconductor devices from China. It is high time that India should look for an alternative. When relying on others is not an option, India should use its technological superiority to try to do it itself.

Growth of Electronics Exports in India:

India's electronics exports are likely to grow at a compound annual growth rate of 15.9%. When compared to the financial year 2015–2016, India's exports are expected to rise by 339 percent in the financial year 2025–2026. But this rise in exports doesn't indicate that India is way ahead in domestic electronic production.



Source: Secondary data-NSSO **Figure- 4**

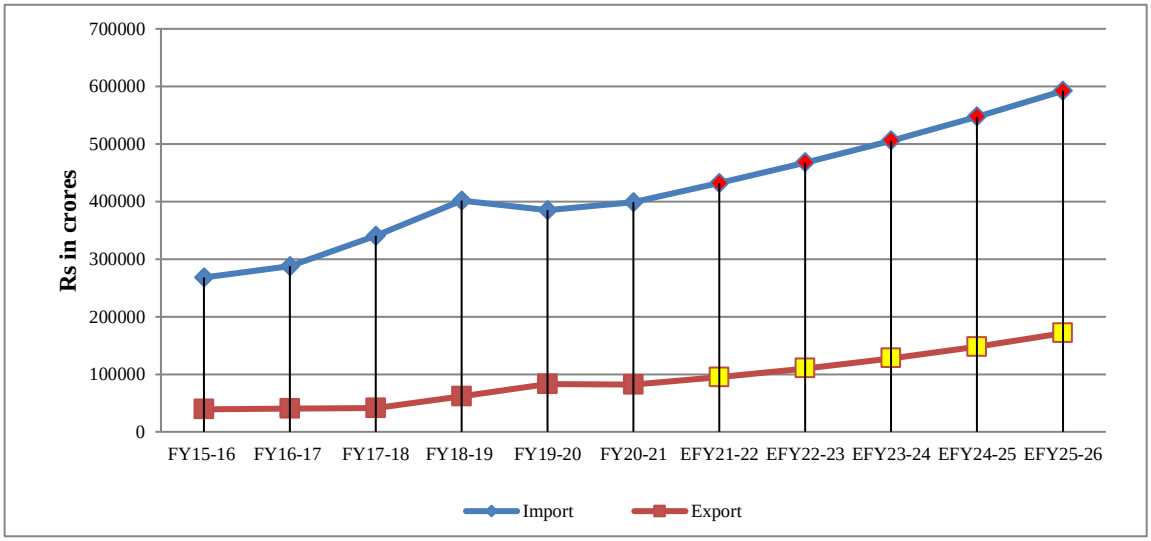
Different Countries Percentage share in India's exports of Diodes, transistors, and similar semiconductor devices etc.

Partner Country	2015	2016	2017	2018	2019
USA	7.70	5.62	24.00	34.98	55.66
United Kingdom	40.32	34.45	0.98	1.27	0.35
China, Hong Kong SAR	8.58	9.18	9.28	10.05	4.79
United Arab Emirates	2.20	1.22	0.82	2.55	14.52
Turkey	0.02	0.03	16.76	0.24	1.77
Belgium	4.08	5.26	5.46	2.71	1.97
China	5.00	4.94	2.04	2.74	1.68
Others	32.1	39.3	40.67	45.47	19.25
Total	**100**	**100**	**100**	**100**	100

Source: Secondary data - UN Comtrade database **Table: 3**

When compared to the rest of the world, India exports the majority of its diodes, transistors, and similar semiconductor devices to the United States. In order to raise exports, India should increase its production of electronic components. This can only be achieved when the government invests more in research and development.

Comparison between Electronics Export and Import Growth



Source: Secondary data-NSSO **Figure- 5**

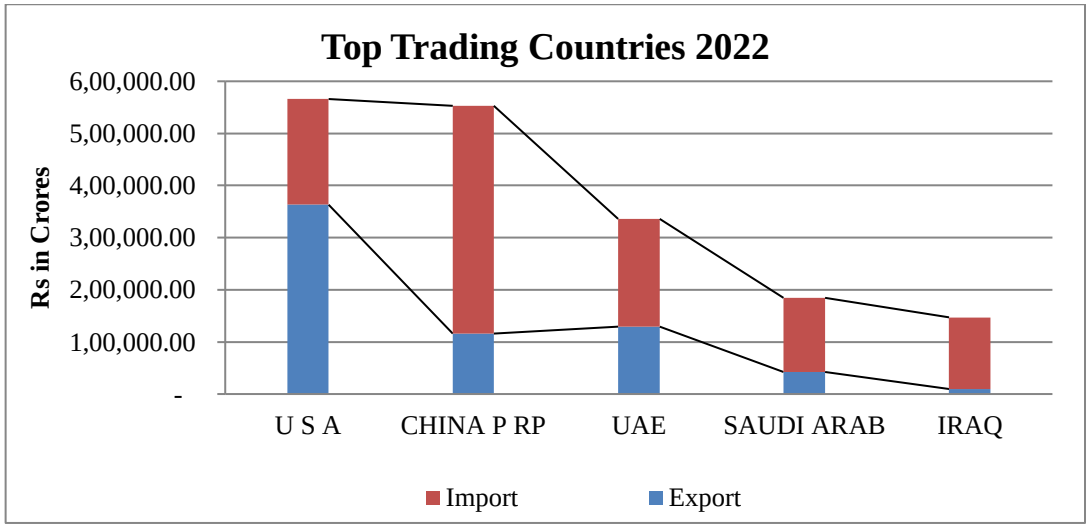
The above data clearly indicates that India is well short in indigenous production of electronics, which is why India's imports are higher than its exports. Most of the electronics production done here is by foreign companies through outsourcing, and India is just a mere consumer. India has only a few companies or not even a single company that produces devices such as digital cameras, Android TV, computer chips, computer hard discs, mobile phone chips, printers, projectors, electronic musical devices, CCTV cameras, and thousands of other electronic components needed for electronic production. If the rest of the world stops selling these devices or stops outsourcing their products, then the Indian economy will dig its own graveyard. A country of 1.3 billion people doesn't know how to produce basic devices. This is a sad reality.

India's Top Trading Countries in 2022:

Position	Trading Countries	Export	Import	Total	Balance of Trade
1	AMERICA	363,179.66	202,772.95	565,952.61	160,406.71
2	CHINA P RP	115,725.65	437,643.52	553,369.17	-321,917.88
3	U ARAB EMTS	129,455.85	206,617.15	336,073.00	-77,161.30
4	SAUDI ARAB	42,647.35	142,219.06	184,866.41	-99,571.71
5	IRAQ	9,661.63	137,481.02	147,142.65	-127,819.38

Source: Ministry of Commerce and Industry **Table: 4**

America tops the list of top trading countries with India, followed by China, the UAE, Saudi Arabia, and Iraq. India exports much more to America than it imports, which explains why the trade balance between the two countries is positive. But for the other countries, India's trade balance is negative due to excessive imports. This criteria is explained in the below bar diagram.



Source: Secondary data-Ministry of Commerce and Industry **Figure- 6**

The above diagram reveals how much India is dependent on China. That's why America's ban on semiconductor exports to China will surely backfire on India's electronic production.

How to overcome the shortage:

- India should increase the level of policy support to promote and increase electronic production.
- Drives such as "Make in India" and "Digital India" should be sprinkled at regular intervals.
- Skill development programmes should be rolled out all over India.
- Foreign direct investment (FDI) inflows and outflows should be increased.
- A powerful research and development ecosystem should be created.
- Semiconductor startups should be encouraged.
- Funding must be available to young inventors who have the capability to create new devices.
- Tax exemption should be given to those startups that concentrate on semiconductors.
- Decentralization of wafer and chip production should be made.
- More competition is required; competition is not a bad thing in economics. That's not the worst-case scenario. On the contrary, it's the best. The more competition, the better the product at a lower price.
- War hawks and ultranationalists in the United States and China feed off each other in a symbiotic relationship. The world needs strong organisation to increase cooperation and understanding between both countries, or else there is a chance of bipolarization in the world.

Conclusion:

As the world shifted to virtual mode using personal computers, laptops, and smart phones, semiconductor demand grew rapidly, but the road ahead may be different because disruptive technologies will emerge as a catalyst for another round of growth. Then people will demand a higher level of technology than today, which in turn creates more demand and a shortage for semiconductors. This kind of demonstration effect in the human mind has always created a hunger for better technology. Sometimes, the hunger to do better can be destructive. Why do we need smaller nanometer chips? Why can't we be satisfied with what we have? How important is it to have a smarter TV or a much better smart phone? The market's desire for technological luxuries endangers national independence and creates massive power concentration. Now if a handful of companies are not supplying enough chips, a country can go into recession, and people will end up jobless and homeless. That's a great insight considering the next cold war is going to be about technological advancements rather than political ideologies. It's fascinating to see how the world evolved from fighting for food and land to competing for technological supremacy. Ultimately, it is all for power.

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