Reserve Bank of India Occasional Papers
Vol. 44, No. 1: 2023

Chip War: The Fight for the World's Most Critical Technology by Chris Miller, 464 pp, Simon & Schuster Ltd (2022), $20

On March 10, 2023, India signed a Memorandum of Understanding (MoU) with the US to establish partnership focused on semiconductor innovations in view of the growing semiconductor supply chain disruptions. Given the critical role played by semiconductors in the electronic industry, and thereby having far-reaching implications for consumer goods, computing, communications, healthcare, defence and renewable energy systems, the nation enjoying supremacy in semiconductor technology can become a global superpower in today's world. In this context, the book titled "Chip War: The Fight for the World's Most Critical Technology" provides a comprehensive assessment of the semiconductor industry and its impact on global politics. The book is divided into eight sections spanning eight decades. It begins with the origin of the concept of semiconductors as propagated by noted theoretical physicist William Shockley in 1945 and extends right up to the contemporary tensions between China and the US over supremacy in semiconductor chip production.

Shockley's theory, as outlined in Part one of the book, relates to materials that exhibit limited electrical conductivity but can become conductive when subjected to specific materials and an electric field. Walter Brattain and John Bradeen, two experimental physicists, who were inspired by this theory, invented the first semiconductor using germanium in 1947. This led to Shockley's frustration and the subsequent creation by him of his own transistor. However, poor management under Shockley's leadership led eight engineers to leave and establish their own semiconductor firm namely, Fairchild which is largely credited for the establishment of Silicon Valley. During this period, Jack Kilby at Texas Instruments (TI) developed integrated circuits. Fairchild too introduced a similar concept but without freestanding wires. Fairchild's initial success came from an order from the National Aeronautics and Space Administration (NASA) leading to transistor-based computers. With the increase in demand over time, Fairchild managed to reduce prices exploiting the economies of scale.

Fairchild pursued customers in the private sector. In comparison, TI focused on selling chips to military establishments, which required mass production and consequently, smaller transistors. In 1958, a TI engineer Jay Lathrop invented photolithography to create smaller transistors. Interestingly, Fairchild adopted this technology quite quickly. Occasionally, Fairchild also sold products below manufacturing costs to stimulate demand, and thus, combined innovative pricing with technological advancements. In sum, Part one of the book provides an interesting account of the evolution of the semiconductor industry in the US, and the practices adopted by the key players in this industry.

Part two delves into the developments relating to the semiconductor industry outside the US, following the foundation laid by Fairchild and TI in the 1960s. With the desire to catch up in semiconductor manufacturing, the Soviet Union created Zelenograd, a semiconductor city. In Japan, Akio Morita founded Sony with the support of US chipmakers. Japan excelled in manufacturing efficiency and cost-effectiveness penetrating new markets with tailored products. Meanwhile, to reduce labour costs, US chip firms began hiring women for assembly and explored offshore options like Mexico, Hong Kong, Singapore, Taiwan, and Malaysia. Simultaneously, the US-Vietnam War served as a testing ground for guided missiles where TI's technological innovations combined semiconductors and explosives, transforming warfare. In 1968, Intel was founded by two of the founding engineers of Fairchild, namely Bob Noyce and Gordon Moore, who laid down the famous Moore's law predicting the future growth of transistors on microchips[1]. Two years later, Intel introduced its first product: Dynamic Random Access Memory (DRAM). DRAMs facilitated the production of chips with consistent designs for various devices, leading to economies of scale through mass production.

Part three of the book examines the decline of the US as a global leader in semiconductor manufacturing during the 1980s. In fact, the US supported Japan's post-war transition into a leading transistor manufacturer, resulting in Japanese DRAM firms outperforming American counterparts in the later

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[1] Moore's Law observed that the number of transistors on computer chips doubled approximately every two years.

decades. The competition in a way, however, turned unfair given Japan's import quotas on US chips, substantial government subsidies for Japanese chipmakers, and Japan's lower borrowing costs. The struggle extended to suppliers with Japan's Nikon surpassing GCA corporation of the US in the lithography business. After the American chip industry's downfall during the 1980s, Jerry Sanders, Bob Noyce and others formed the Semiconductor Industry Association, lobbying with the US government to address Japanese subsidies as a national security concern, which resulted in reduced capital taxes and tightened semiconductor intellectual property rights in the US. A deal between Washington and Tokyo resulted in quotas on Japanese DRAM chip exports to the US. Meanwhile, the US Department of Defense also created a consortium called Sematech which focused on revitalising the lithography industry. The GCA corporation thrived under these initiatives until it succumbed to relentless Japanese competition in 1993.

Part four of the book explores the resurgence of the American semiconductor industry after its decline in the 1980s. A factor that helped the US to overtake Japan in DRAM production was the strategic outsourcing to Taiwan and South Korea in the 1990s, which resulted in cost advantages. Micron, a new American DRAM company could greatly reduce its costs and outperform its Japanese counterparts. Meanwhile, Intel's DRAM chip business model faced disruptions from the ongoing innovations in the US. In 1980, IBM's contract to make chips for personal computers (PCs) provided a ray of hope for Intel. Intel took a risk by exiting the DRAM space and focusing on microprocessors for PCs. In the 1980s, Samsung, a South Korean company, could undercut Japanese producers with support from Silicon Valley. The 1990s witnessed American leadership in crucial war technology; precision munition and enhanced surveillance, which was showcased during the Gulf War, represented the future of warfare. Japan, once a serious challenger, faced turmoil in the 1990s with a market crash. The Japanese companies had also not diversified into microprocessors. Consequently, by 1993, the US had regained its top spot in semiconductor shipments, with South Korea following suit.

In Part five, the author discusses the global integration of the chip industry's supply chains. In 1987, Morris Chang founded the Taiwan

Semiconductor Manufacturing Company (TSMC) with a strong support from the government. Taiwan excelled in semiconductor device assembly, but its real profits came from designing and manufacturing advanced chips. Not just with government support but also a strong connection with the Silicon Valley, TSMC came to dominate advanced chip production. In 2000, Richard Chang, a fab specialist at TI, established Semiconductor Manufacturing International Corporation (SMIC) and introduced chip production to China. SMIC prospered with government's support and numerous overseas chipmakers, marking China's arrival on the global semiconductor stage.

Part six of the book discusses the apprehensions around the "fabless" semiconductor revolution and the successful instances of offshoring innovation[2]. While some believed that separating fabrication from chip design would lead to inefficiencies, some of the US companies proved them wrong by offshoring fabrication to companies in Taiwan and South Korea. Eventually, many US companies separated chip fabrication from design. And the race for the best fabrication company took off. Currently, Apple's chips are being designed in California, assembled in China, and exclusively fabricated in Taiwan.

Part seven of the book deals with China's rise in the semiconductor industry. China recognised the critical role of semiconductors for its digital security, and in the 2000s and 2010s, allocated increased funds to semiconductor imports. Huawei, a Chinese company, which dominated the phone industry faced vulnerabilities due to its reliance on imported chips. Over time, the company began producing its own chips. Although Huawei has still not achieved self-sufficiency in chip production, but the recent trends suggest that by 2030, China could become a formidable competitor to Silicon Valley.

Part eight of the book addresses the issue of global supply chain disruptions caused during COVID-19. The chip shortage during COVID-19 was notable due to significant fluctuations in chip orders. For instance, demand for PC chips rose, while demand for automotive chips decreased. Moreover,

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2 Fabless semiconductor companies design and sell the semiconductor chips but outsource the fabrication of these chips to a manufacturing plant.

even as the situation began to normalise, chip supply could not keep pace with the increasing demand.

The book concludes by highlighting the role played by the semiconductor industry in geopolitics, particularly the recent US-China tensions. If China surpassed Taiwan in the semiconductor production, it could have significant effects on the global political and economic dynamics. On the whole, the book contains several technical details, presented in an extremely engaging and lucid manner. The book argues that given the globalisation of semiconductor production, countries with significant stakes in chip manufacturing will emerge as the new centres of power. It also emphasises on the role played by industrial policies of various countries in stepping up semiconductor and chip production. In light of the discussion in the book, the proactive measures by the Government of India, such as the "Programme for Development of Semiconductors and Display Manufacturing Ecosystem in India" are indeed timely. While Moore's Law has held true over a large part of the history of the semiconductor evolution, it remains to be seen if limits to this Law are reached owing constraints on innovations or the combative approach taken by the big chipmaking countries.

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