GEOECONOMICS AND INDO-PACIFIC ENTERPRISE INITIATIVE

# The Challenge to Cultivate Global Semiconductor Talent

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As the main component in all modern electronics, semiconductors are critical to the global economy. Countries around the world serve as key nodes in a dispersed network of suppliers for the core building blocks of the technology that modern society has come to rely upon. Over the past three decades, the chip industry has been a driving force for global growth as well. The semiconductor market worldwide grew at a 7.5 percent compound annual growth rate from 1990 to 2020, outpacing the 5 percent growth of global GDP during that time.

The risks for disruption in the semiconductor supply chain are therefore significant, and G7 leaders have clearly recognized the need to address supply chain resiliency challenges. There are no shortage of risks, from disruptions due to a natural disaster such as an earthquake or typhoon, global shocks to the trading system like the COVID-19 pandemic, or upheaval caused by political considerations such as an armed conflict. Clearly, all these risks can cause significant disruptions in the semiconductor supply chain. But the world's wealthiest nations must also recognize the urgent need to invest in the infrastructure of a technology-focused workforce. After all, a shortage of talent to design the next generation of computer is becoming acute at even as innovation remains key for competitiveness.

Semiconductor devices are highly complex products to design and manufacture. In 2021,the Semiconductor Industry Association (SIA) reported that that the semiconductor supply chain "consists of four broad steps, supported by a specialized ecosystem of materials, equipment and software design tools and core IP suppliers."[1] The four broad steps are: 1) Pre-competitive research; 2) Design; 3) Frontend manufacturing (wafer fabrication); and 4) Backend manufacturing (assembly, packaging, and testing). All of these require a sophisticated workforce, but the specific needs are different .[2]

**Pre-competitive research** focuses on identifying fundamental materials and chemical processes and to make innovations in design architectures

1 Varas, Antonio, Varadarajan, Raj, Goodrich, Jimmy, and Falan Yinug, "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," Semiconductor Industry Association, April, 2021, https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era/

2 "United States, Taiwan, and Semiconductors: A Critical Supply Chain Partnership", *Project 2049 and US-Taiwan Business Council*, June 8, 2022. https://www.us-taiwan.org/events/report-release-event-initial-report-us-taiwan-and-semiconductors-a-critical-supply-chain-partnership/.

that will enable the next commercial leaps in computing power and efficiency. Much of this basic research is done at universities, and is supported by government funding. Pre-competitive research is then followed by industrial research, which helps translate the new innovative ideas into practice — although direct benefits are often not realized for over a decade. This step requires a mix of highly educated scientists and engineers.

**Design** involves developing the architecture for integrated circuits. While computer chips were originally designed manually, that is not possible for the complex chips produced today. Instead, current chip design work relies on sophisticated Electronic Design Automation (EDA) software and reusable architectural building blocks. Even with these tools, developing leading-edge chips can take several years and requires the work of hundreds of highly specialized design engineers. U.S. IDMs and fabless companies are still the leaders in chip design, with 10 of the top 20 semiconductor design companies, including both fabless and IDMs, headquartered in the United States.

**Frontend manufacturing** starts with a wafer made of raw silicon or other semiconductor material. The electronic circuitry is fabricated onto the wafer layer by layer in a wafer fabrication facility (wafer fab). Frontend processing is very capital-intensive, comprising approximately 64 percent of industry-wide capital expenditures. These plants also require a wide variety of top notch engineering support including chemical, electrical, and industrial/manufacturing engineers. Wafer fabs are therefore usually built where there is a strong supply of engineering talent at the BS, MS, and PhD levels. When it comes to wafer fabrication, four regions in Asia make up the bulk of the manufacturing capacity. The United States is down to a 12 percent share, while Taiwan is at 20 percent, South Korea at 19 percent, Japan at 17 percent, China at 16 percent, Europe at 9 percent, and the rest of the world with 6 percent.[3] The growth of wafer fabrication capabilities in East Asia was primarily due to decades-long government investment strategies and incentives.

3 “World Fab Forecast (WFF),” op.cit.

**Backend manufacturing** begins by slicing the wafers produced in the frontend processes into individual chips and then assembled and packaged into protective plastic or ceramic frames and encased in a resin shell to become usable in electronic devices. Finally, the chips are thoroughly tested to determine their operating characteristics, such as the speed for a microprocessor. While backend processing requires sophisticated equipment, it is not as capital-intensive as the frontend. Backend processing does not require the same level of highly trained engineering support as the frontend, but is more labor intensive. Therefore these facilities have traditionally been in countries with relatively inexpensive labor. Currently, only about 2 percent of backend operations are done in the United States, and China and Taiwan account for more than 60 percent of the world's assembly, packaging, and test capacity.

The six regions mentioned above have strengths in different parts of the semiconductor supply chain. While the United States was once the leader in all aspects of the industry, that has evolved over time. Today, the United States is still the leader in intensive R&D activities, but the bulk of manufacturing is now conducted in East Asia.[4]

## Talent shortages will hurt innovation

The largest risk on the design side of the global semiconductor industry is access to highly skilled talent. Talent shortages may not pose an immediate threat of large-scale disruption for the industry, but it could significantly reduce the industry's long-term ability to maintain its rapid pace of innovation. The industry workforce is aging, with a significant number of current employees in technical positions likely to retire over the next ten to 15 years, Furthermore, the industry needs to attract talent with different skill sets, particularly in software development and artificial intelligence.

In the near term, talent has also become a major concern for the industry. In a 2021 survey of semiconductor industry leaders by KPMG, 30 percent named talent as one of the top 3 risks threatening their ability to grow over the next three years.[5] This was the third-highest risk factor behind territori-

4 See Exhibit 14 in "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era" report, op.cit., for a detailed breakdown.

5 "Global Semiconductor Industry Outlook," *KPMG*, February 2021, https://advisory.kpmg.us/content/dam/advisory/en/pdfs/2021/semiconductor-industry-outlook-2021.pdf

alism—including cross-border regulation, tariffs, new trade agreements, and national security policies- and supply chain disruptions. In the 2020 version of this survey, talent was tied for the number one risk. The report went on to speculate that the decrease in the 2021 ranking was likely due to the new work-from-anywhere paradigm.

Most of the needed new talent for the semiconductor industry will come from university undergraduate and graduate programs. More sophisticated roles will likely be filled by graduate students, who are conducting research with funding grants from the government, research consortia, and directly from industry. While U.S.-based academic institutions have traditionally provided much of the talent for industry, this is changing. First, many of the Chinese students now choose to go back to China upon graduation. Second, academic institutions in Taiwan, China, Korea, Japan, and Europe now have strong graduate programs that help support the industry.

## The U.S. talent dilemma

Even before COVID and the announcement of new fabs being built in the US by Intel, Micron, Samsung, and TSMC there were thousands of semiconductor jobs were going unfilled.[6] The new fabs are expected to create at least 70,000 new semiconductor manufacturing jobs.[7] This does not include the additional jobs that are needed in the chip design arena.

The U.S. semiconductor talent shortage is being addressed by both the government and the semiconductor industry with the government helping more on the mid-term and long-term problem, while the companies are more focused on the short-term problem. In the recently enacted CHIPS and Science Act, $13.2 billion is allocated for R&D and workforce development.[8] R&D funding is important in addressing the talent shortage because many of the

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6 Silverberg, Elliot and Hughes, Eleanor, "Semiconductors: the skills shortage", *theinterpretor*, September 15, 2021, https://www.lowyinstitute.org/the-interpreter/semiconductors-skills-shortage.

7 VB Staff, "Report: Critical talent shortage for over 70,000 semiconductor manufacturing jobs", *VentureBeat*, December 9, 2021, https://venturebeat.com/social/report-critical-talent-shortage-for-over-70000-semiconductor-manufacturing-jobs/.

8 "FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China", *The White House*, August 9, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/.

students working on R&D projects at universities ultimately go to work in the industry. The experience gained in working in the R&D environment makes the transition to industry easier than it is for students who don't have this experience. Without much governmental R&D funding for semiconductor manufacturing over the last two decades, a number of research labs at US universities were shut down. In looking even further into the future, the legislation authorizes new and expanded investments in STEM education and training from K-12 to community college, undergraduate and graduate education, particularly for marginalized, under-served, and under-resourced communities.

In the private sector, semiconductor firms are looking for ways to attract and retain the talent needed to run their business. An important aspect of this to increase diversity of the workforce. Many of the companies have goals and strategies regarding seeking out more women, unrepresented minorities, and veterans. There also significant efforts underway to reskill their workers to address changes in the nature of the work. Salaries in the industry have also been increasing in response to competition from other industries.

## Beefing up Europe's tech talent pool

Europe's microelectronics sector currently has 200,000 direct jobs (and 1,000,000 indirect) high-skilled jobs. As worldwide demand for chips continues to increase, the need for semiconductor workers in Europe will increase. Intel plans to invest up to €80 billion over the next decade to build up Europe's supply chain for semiconductor chips including every part of the chip supply chain with investments also going to France, Ireland, Italy, Poland and Spain.[9] Their initial investment of 33 billion euros will create about 5,500 jobs at the company, plus thousands more in construction and at suppliers and partners.

In 2019, SEMI and 19 partners from 14 European countries launched the METIS—Microelectronics Training, Industry and Skills—initiative to fill the skills gap and boost workforce diversity by strengthening collabora-

9 Cooban, Anna, "Intel will invest nearly $90 billion in Europe's chipmaking industry", *CNN Business*, March 15, 2022, https://www.cnn.com/2022/03/15/tech/intel-chips-europe/index.html.

tion between the microelectronics industry and education providers.[10] The four-year project focuses on the skills and related training needed to support emerging verticals such as artificial intelligence, autonomous driving and Industry 4.0 in Europe.

## Taiwan's China challenge in the chip space

The recently released Taiwan 104 Manpower Bank *2021 Taiwan Semiconductor Talent White Paper*, indicates that the second quarter average monthly talent gap in the semiconductor industry was almost 28,000 which was the highest total over the last 6-and-a-half-years[11]. The white paper also broke down the gap by discipline and indicated that 55 percent of the gap was for engineers, mostly for Frontend and Backend manufacturing. The average monthly salary of the industry is 52,288 yuan which ranked second to the computer and consumer electronics industry. The higher salaries are one of the main ways that Taiwanese firms are attempting to attract and retain top talent.

The Taiwanese government has done a couple of things to address the semiconductor gaps. First, the Taiwanese government devoted significant resources to establish "chip schools" within top universities on the island.[12] The leading chip companies are partnering with the government to establish these talent pipelines. According to the Taiwan Ministry of Education, four chip schools were established in 2021 and one additional school has been approved. Each school was given a quota of about 100 master's and PhD students. The schools will operate year round with no winter and summer breaks in order to produce graduates more quickly.

10 Pelé, Anne-Françoise, " Semiconductor Industry Needs to Close Talent Gap, *EE Times Europe*, July 8, 2021, https://www.eetimes.eu/semiconductor-industry-needs-to-close-talent-gap/.

11 iNews, "Taiwan's semiconductor talent gap hits a 6-and-a-half-year high, the most shortage of engineers", *iNews*, September 26, 2022, https://inf.news/en/taiwan/348b5ee33b530474fb4f8e95007457b4.html.

12 Wu, Sarah, "Taiwan invests in next generation of talent with slew of chip schools", Reuters, March 10, 2022, https://www.reuters.com/markets/funds/taiwan-invests-next-generation-talent-with-slew-chip-schools-2022-03-10/.

Part of the problem for Taiwan is the fact that the over 3,000 engineers and corporate leaders from Taiwan have accepted employment in China.[13] In response, the second thing that the Taiwanese government has done is to tell recruiting firms to remove listings for high-tech positions based in China.[14]

Those firms that violate this rule will be subject to fines and those fines will be greatest for those job openings in the semiconductor industry. It should be noted that this is also a signal to the US that Taiwan views China as a major threat.

## Growing South Korea's tech talent

The South Korean semiconductor industry is faced with a significant talent shortage. In addition to the challenges faced by other countries in the industry, South Korea has long had an extremely low birth rate. Both the South Korean government and South Koreans companies have taken actions to reduce the current and future talent shortages in the semiconductor industry. The South Korean Ministry of Education recently set a goal of training 150,000 people with semiconductor expertise over the next ten years.[15] The plan includes the establishment of new departments of semiconductor studies at four advanced research institutions across the country. It also will raise current student quotas at universities in and around Seoul for departments with semiconductor-related and semiconductor-supporting programs. It plans to bolster academic-industrial cooperation programs in advanced degree programs to promote chip engineers and hope to expand exchange programs with overseas schools, institutes, and tech companies. [16] In a somewhat controversial move, the government also will redirect $2.8 billion from its childhood education budget to higher and lifelong education including educational

13 Ihara, Kensaku, "Taiwan loses 3,000 chip engineers to 'Made in China 2025'," *Nikkei Asia*, https://asia.nikkei.com/Business/China-tech/Taiwan-loses-3-000-chip-engineers-to-Made-in-China-2025

14 Mott, Nathaniel, "China's Efforts to Recruit Semiconductor Talent Hit by Taiwan Ban", *Tom's Hardware*, April 30, 2021, https://www.tomshardware.com/news/taiwanese-ban-hits-chinas-efforts-to-recruit-semiconductor-talent

15 Lem, Pola, "Korea's semiconductor talent boost 'too little, too late'", Time Higher Education, August 31, 2022, https://www.timeshighereducation.com/news/koreas-semiconductor-talent-boost-too-little-too-late.

16 "3,000 semiconductor professionals to be trained", *Korea Joong Ang Daily*, May 30, 2022, https://koreajoongangdaily.joins.com/2022/05/30/business/tech/Korea-semiconductor-talent/20220530183757599.html.

efforts to develop and grow semiconductor talent. [17]

South Korean semiconductor companies have also been making efforts to attract and retain semiconductor talent. The industry faces stiff competition for talent from gaming and internet companies as well as Chinese companies who are offering ever-increasing salaries. This has led Samsung and other semiconductor companies to offer significant bonuses to all employees and to increase entry level salaries.[18] In order to retain some of their top talent that is aging, several South Korean semiconductor companies are offering employees the chance to put off retirement past the standard retirement age of 60. Some of these companies are also moving some of their younger employees into "honored engineer" positions in order to retain their top performing younger employees.

## Japan's private and public investments to meet demand

The Japan Electronics and Information Technology Industries Association (JEITA) estimated that the eight large Japanese semiconductor companies will need to hire 35,000 engineers in the next 10 years to support expansion of the industry. [19] These companies are targeting local universities for entry-level talent and are expending large amounts of money in their recruitment efforts.

In response to the current and future talent challenges, the Japanese government is looking into establishing talent development programs that involve industry, academia, and government collaboration. The programs are based on a framework established in a joint chip-making venture By TSMC and Sony Group Corp. that involved Kyushu University and nine local governments.

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17 "South Korea will redirect 3.6 trillion won (US$2.8 billion/100.8 billion baht) from its budget for childhood education to higher and lifelong education, such as nurturing semiconductor talent, the government said on Thursday", *The Nation Thailand*, July 8, 2022, https://www.nationthailand.com/international/40017515.

18 "The semiconductor talent war heats up Samsung employees purse bulging", *RMC Team*, February 10, 2022, https://www.realmicentral.com/2022/02/10/the-semiconductor-talent-war-heats-up-samsung-employees-purse-bulging/

19 Valero, Beatriz, "Skills shortage threatens Japan's semiconductor industry", *Engineering and Technology*, June 28, 2022, https://eandt.theiet.org/content/articles/2022/06/skill-shortage-threatens-japans-semiconductor-industry/.

## China's goal for self-sufficiency

China has set a target of 2035 to be fully self-sufficient in tech by 2035[20] and some believe that they will lead the global semiconductor industry by 2030 due to its growing market size and domestic production capacity.[21] Even though China plans to invest about US$150 billion by 2030 to ramp up its semiconductor manufacturing capacity, the biggest obstacle to achieving self-sufficiency is not funding, but is a chronic shortage of talent.[22] China reportedly needs 400,000 more semiconductor employees to meet its goals. [23] China's biggest talent challenge is the need for chip manufacturing talent. Even though China has numerous excellent universities that turn out a significant number of graduates with advanced degrees in microelectronics and communications, they suffer the same issue faced by their competitors—many of the top graduates prefer to go to work for internet firms.[24] In addition, they need engineers with practical work and leadership experience as they try to close the gap on their competition.

China has reacted to the current and future talent shortage by doing what most of their competitors have done. They have established integrated circuit schools at two of the top Chinese universities: Tsinghua University and Peking University. These new schools will provide the students with classroom knowledge and hands-on experience. The Chinese government has given tax breaks, incentives, and subsidies to Chinese semiconductor companies to scale up production. Chinese companies have been increasing wages for their key semiconductor talent which has resulted in a somewhat larger number of Chinese students who studied abroad (mainly the US) returning to their

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20 Gaikwad, Sumeet, "Opportunities with China's semiconductor push", Asia Fund Managers, July 18, 2022, https://www.asiafundmanagers.com/us/opportunities-with-chinas-semiconductor-push/.

21 Williams, Lara, "China will lead the global semiconductor industry by 2030 due to its growing market size and domestic production capacity", Investment Monitor, July 25, 2022, https://www.investmentmonitor.ai/analysis/china-lead-global-semiconductor-growth-2030.

22 Qu, Tracy, "China's semiconductor talent shortage poses biggest obstacle to Beijing's chip self-sufficiency ambitions, SMIC founder says", *South China Morning Post*, November 18, 2021, https://www.scmp.com/tech/tech-war/article/3156576/chinas-semiconductor-talent-shortage-poses-biggest-obstacle-beijings.

23 Silverberg, Elliot and Hughes, Eleanor, "Semiconductors: the skills shortage", *theinterpretor*, September 15, 2021, https://www.lowyinstitute.org/the-interpreter/semiconductors-skills-shortage.

24 "China's semiconductor industry faces a growing talent shortage as Beijing aims for global dominance in chip manufacture", *Colombo Gazette*, October 26, 2021, https://colombogazette.com/2021/10/26/chinas-semiconductor-industry-faces-a-growing-talent-shortage-as-beijing-aims-for-global-dominance-in-chip-manufacture/#:~:text=China%20faces%20a%20chronic%20shortage%20of%20scientific%20and,a%20dearth%20of%20qualified%20senior%20professionals%2C%20they%20said.

homeland. Chinese companies also use promotions as a way to retain key personnel.[25] Finally, Chinese companies have actively been recruiting engineers and semiconductor leaders away from their Asian competition (particularly Taiwan) to join them.

## No silver bullet to cultivate much-needed tech talent

It is clear that the current and future semiconductor talent shortages are not restricted to a single country. While there are some differences in the problems faced by each country, all are challenged by the fact that many of the students that in the past would have gone into the semiconductor industry, now prefer to go to work for gaming and internet companies. Governments and consortia are investing in workforce development programs. In the United States and Europe, there are special efforts to get more participation from underrepresented groups. In Asia, there is considerable focus on creating new semiconductor degree programs and/or on allocating more MS and PhD slots in existing programs. Governments are also putting more funds into R&D at key universities. The R&D funds are allowing the universities to produce highly educated students with an increased understanding of the challenges faced by the industry. Semiconductor companies are offering higher salaries and promotions to recruit and retain the talent that they need.

25 Hsu, Edward, "Spotlight on pay and talent trends in Asia's lively Semiconductor industry", *WTW*, January 2022, https://www.wtwco.com/en-US/Insights/2022/01/spotlight-on-pay-and-talent-trends-in-asias-lively-semiconductor-industry.

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