

Semiconducteurs : prospects outside Asia

23/10/2023

Confidential

Summary

As a result of rising tensions between Washington and Beijing and fears of a Chinese military operation against Taiwan, the beating heart of the global semiconductor industry, the global giants in the sector are stepping up their plans to set up manufacturing facilities in the United States and Europe. But despite the major investment announcements, boosted by the billions of dollars in subsidies distributed by Washington and Brussels, this migration remains very embryonic when it comes to the final assembly stages that transform the silicon circuits etched by foundries such as Intel's or TSMC's, into finished products - processors, memories, 5G modems, etc.

These operations, known as assembly, packaging and testing (APT), can account for up to 30% of the cost of a smartphone processor. They are also concentrated in Asia, mainly in China and Taiwan. These two countries alone are home to more than half of the industrial sites specialising in APT. These activities are also labour-intensive and low-paying, making them difficult to relocate to developed economies - a reality that is, however, tending to change as a result of technological developments in the sector.

For a long time a blind spot in semiconductor sovereignty policies, these activities are now the subject of bilateral negotiations between Washington and several Latin American states (Mexico, Costa Rica, Panama), as part of a "friendshoring" approach, while some European Union countries, such as Poland, Portugal and Italy, are positioning themselves to host final assembly phases of chips manufactured in other member states. But these challengers are up against the efforts of the APT's historic bastions - China, Taiwan and Malaysia - to remain dominant, sometimes for geopolitical or security reasons, while Vietnam and other Asian countries are managing to move to the forefront.

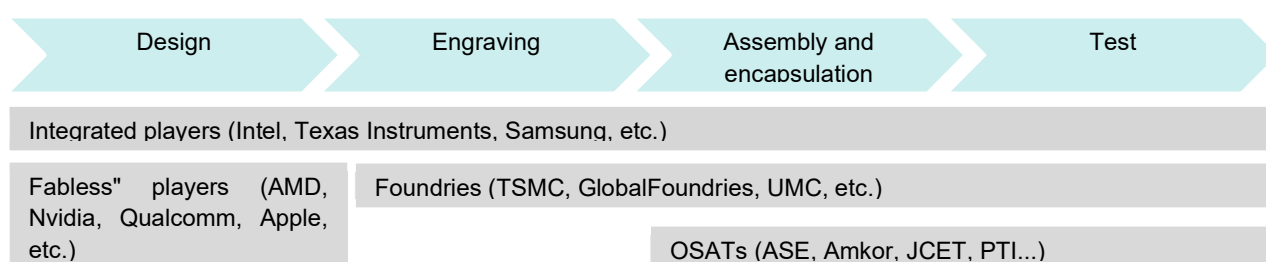
While the first wave of offshoring of APT activities in the 1960s and 1970s was largely explained by the abundance of low-cost labour in Asia, the parameters guiding investors' choices of location have changed dramatically. The skills of the workforce, the availability of guaranteed, low-cost electricity (preferably renewable) and water, and the logistical capacity of the host country have become the main investment criteria. Geographical proximity, long neglected, is once again being taken into account after the Covid-19 pandemic seriously disrupted global supply chains.

1. Assembly, a key stage dominated by Asia

1.1. An essential link in the semiconductor chain

The manufacture of an integrated circuit (processor, memory chip, 4G or WiFi *baseband*, etc.) is sequenced in a number of stages. Once the circuit has been designed, it is reproduced in miniature on an ultra-pure silicon substrate in a *fab*, or manufacturing unit. This stage, where the degree of precision required is measured in nanometres, involves various processes such as ultraviolet photolithography, etching, doping and the deposition of layers of insulating or conducting materials. The silicon "wafers" resulting from this process are then cut into silicon wafers a few millimetres square, which form the core of a chip. Next come the assembly, encapsulation and test (APT) stages: each wafer is mounted on a ceramic or plastic support and soldered to the connectors that will enable it to be integrated into the finished product (smartphone, PC, vehicle, etc.). Finally, each chip is tested and sorted according to its performance or quality characteristics ("chip binning").

Figure 1: specialisation of players at different stages of the value chain



Source: Global Sovereign Advisory

Some *integrated device manufacturers* (IDMs) such as Intel, Texas Instruments and Samsung are still capable of mastering this entire chain, but the industry has largely specialised into industrial stages. Design is carried out by specialists such as Qualcomm, AMD, NVidia and Apple, who design the circuits according to their needs or their customers' specifications. These "fabless" players - with no industrial capacity of their own - then entrust production to specialist foundries such as TSMC, UMC or GlobalFoundries, or to IDMs that have developed a foundry business (Samsung). The final stages - wafer cutting and APT - are increasingly the preserve of ultra-specialised subcontractors known as OSATs (Outsourced Semiconductor Assembly and Testing).

Assembly, a minority but growing part of the value chain

According to the US Semiconductor Industry Association (SIA), ATP stages - whether carried out in-house or by OSATs - will account for around 6% of the added value of the entire global semiconductor market in 2019. The global semiconductor market is growing steadily: from around USD 300 billion in 2013¹ to **USD 574 billion in 2022²**, despite the industry's historic disruption caused by the pandemic and global supply difficulties in 2021 and 2022. According to some estimates, it could reach USD 1,380 billion by 2029³. Depending on the source, the ATP subcontracting market now represents between USD 37 billion⁴ and USD 45.9 billion⁵ per year. Its share of the total semiconductor market could increase as increasingly sophisticated assembly processes play a greater role in overall chip performance (see chapter 1.3).

¹ *2022 Factbook, Semiconductor Industry Association (SIA), May 2022*

² *Global Semiconductor Sales Increase 3.3% in 2022 Despite Second-Half Slowdown, SIA, 3 Feb. 2023*

³ *Semiconductor market size, share and Covid-19 Impact Analysis, Fortune Business Insights, 2022*

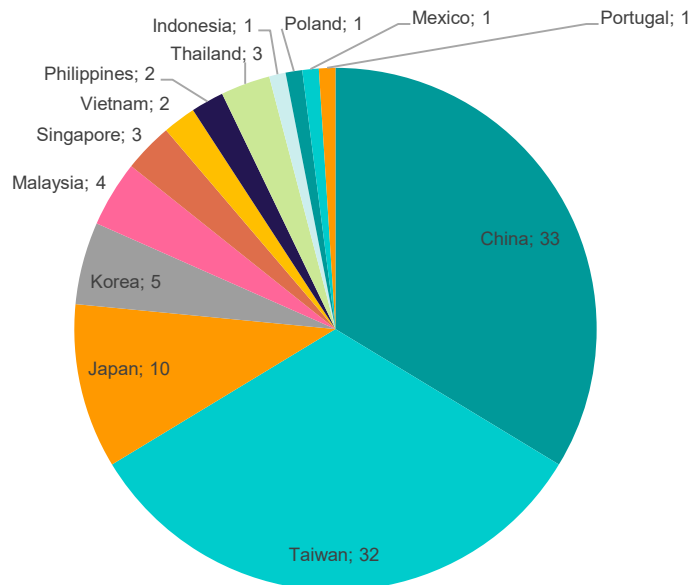
⁴ *OSAT Services Market Size, Share & Trends Analysis, Grand View Research, 2023*

⁵ *Fortune Business Insights, ibid.*

1.2. Asia predominant in assembly

Even more than foundries, **OSATs are highly concentrated in Asia**. Of the ten main players in this segment, who share more than 80% of the market, five are Taiwanese, three Chinese and one Singaporean. And number two, Amkor (14% of the market), although incorporated in the United States, has strong links with Taiwan, where it has most of its operations. The location of the production sites of these ten world leaders (ASE, Amkor, JCET, PTI, TFME, Huatian, Kyec, ChipMOS, Chipbond, and UTAC) illustrates the **absolute predominance of Asia in this activity** (Graph 2).

Graph 2: Geographical distribution of industrial units of the ten main OSATs, 2023



Global Sovereign Advisory. Data: companies

According to a report published in 2021 by the US Semiconductor Industry Association (SIA) and The Boston Consulting Group (BCG), China accounted for 38% of APT activities worldwide in 2019, followed by Taiwan (27%) and South Korea (11%)⁶. This Asian leadership dates back to the birth of the semiconductor industry when, as early as 1963, the American company Fairchild Semiconductors decided to relocate the assembly stage of its integrated circuits to Hong Kong, and then to Penang in Malaysia, while Texas Instruments turned to Hong Kong and Singapore in the 1970s, and above all to Taiwan, under the impetus of Morris Chang, then its Director of Engineering, who founded TSMC in 1987⁷.

Initially, these American groups were looking for abundant, cheap labour: the transformation of silicon wafers into integrated circuits was largely manual, particularly the soldering of connectors. Then, the advent of Taiwanese (TSMC), South Korean (Samsung, SK Hynix) and Japanese (Renesas, Kyocera, Sony) processors and memory chip manufacturers encouraged the emergence of a local subcontracting network: the South Korean town of Hsinchu alone, where almost half the *fabs* of TSMC (the world's leading foundry) are located, is home to at least eight OSAT factories.

1.3. Ever more sophisticated assembly

From being a low value-added process requiring little know-how, APT has gradually become a highly technical stage. Moore's Law - which postulated in 1965 that the transistor density of a semiconductor would double

⁶ *Strengthening the Global Semiconductor Value Chain*, SIA, Boston Consulting Group, 2021

⁷ *Chip War - The Fight for the world's most critical technology*, Chris Miller, 2022

every two years, at a constant price - is increasingly coming up against the finesse of circuit engraving, a physical constraint that foundries, which already bear two-thirds of the industry's capital costs, will not be able to put off forever. To continue innovating, **manufacturers are therefore concentrating their R&D efforts on TPA processes**. 3D assembly and the use of *chipselets* (modular microchips), in particular, make it possible to combine the functionalities of several chips into a single one, while reducing energy consumption⁸. **The most advanced assembly plants increasingly resemble foundries' clean rooms, where a smaller but highly skilled workforce oversees highly automated processes using state-of-the-art machinery**. This development is driving foundries and IDMs to reinvest in assembly and encapsulation, at least for the most complex products. The most efficient OSATs are also adapting, by specialising in specific stages, and the most efficient could eventually be called upon to co-develop the chip with their customers⁹.

2. Fast-changing investment criteria

The evolution of the assembly business towards more technological and capital-intensive processes has **reshuffled the investment criteria for manufacturers** looking to relocate or outsource the final stages of assembly and testing. Whereas in the 1960s and 1970s Taiwan, Hong Kong and Malaysia capitalised mainly on their abundant low-cost labour to attract the first wave of relocations by American chip manufacturers, the situation is markedly different for the countries that are now seeking to attract this type of industry to their territory.

2.1. Skilled labour, the sinews of war

The presence of technical and professional human resources was already one of Intel's main investment criteria when, in the 1990s, it was looking for a site to set up a Pentium processor assembly unit, and its choice ultimately fell on Costa Rica¹⁰. This factor is even more important today, when the most advanced PTA plants no longer have much to envy, in terms of technical sophistication, to the clean rooms of foundries. The Asian champions are all working to strengthen their lead in this area, sometimes via ad-hoc institutions. As early as 1986, Malaysia developed tax incentives for companies to fund continuing education, as well as introducing specific modules in the public education curriculum¹¹. More recently, in 2021, the country set up a **national committee dedicated to** Technical Vocational Education and Training (TVET) for the **semi-conductor industry**, chaired by the Deputy Prime Minister. In the Philippines, it was initially the industry's trade association, SEIPI, which set up training programmes for engineers and technicians back in the 1980s¹², and which now works closely with the Technical Education and Skills Development Authority (TESDA)¹³. A late entrant in the semiconductor race, Vietnam has trained more than 5,500 technicians and engineers in just a few years¹⁴, but still faces a shortage: the Ministry of Planning and Investment therefore plans to train almost 10 times as many by 2030¹⁵.

The United States has also recognised that there is a shortage of talent in semiconductor production, assembly and testing. The CHIPS Act therefore contains training provisions, tasking the National Science and Technology Council (NSTC) with creating vocational training programmes dedicated to this ecosystem¹⁶. The NIST, for its part, is working to create a methodology for assessing labour shortages in this industry on an annual basis¹⁷.

⁸ *Advanced chip packaging: How manufacturers can play to win*, McKinsey, 24 May 2023

⁹ McKinsey, *Ibid.*

¹⁰ *Moving Up the Global Value Chain: The case of Intel Costa Rica*, ILO Americas Technical Reports, 2017

¹¹ *The Philippines in the Electronics & Electrical Global Value Chain*, S. Frederick, G. Gereffi, Duke University, 2016

¹² *Our History*, Semiconductor and Electronics Industries in the Philippines Foundation, Inc.

¹³ *TESDA partners with private sector to boost TVET*, Philippines Information Agency, August 2023

¹⁴ *Vietnam needs more engineers for its semiconductor industry*, HR Asia, Sept. 2023

¹⁵ *Fuelling Viet Nam's semiconductor growth through workforce and design innovation*, Viet Nam News, Oct. 2023

¹⁶ *Chips For America Outlines Vision For The National Semiconductor Technology Center*, American Institute in Taiwan, Apr. 2023

¹⁷ *R&D Workforce Working Group Update and Recommendations*, NIST, Feb. 2023

2.2. Considerable energy and water requirements

The global energy consumption of the semiconductor industry was estimated at more than 101 terawatt hours (TWh) in 2021 by Greenpeace¹⁸ - which estimates that this figure will reach 237 TWh in 2030 - and at 149 TWh, according to a Chinese university study of 27 major players in the industry¹⁹. These figures are equivalent to the annual electricity consumption of the Netherlands and Malaysia (114 TWh and 151 TWh in 2021, respectively).

Consumption in the assembly segment is not known. However, the figures published by the three main OSATs provide a rough estimate. In 2022, Taiwan's ASE, America's Amkor and China's JCET consumed, respectively, 4.34 TWh, 2.03 TWh and 1.79 TWh (almost all electricity), figures that correlate almost perfectly with their respective market shares. With these three players together accounting for just over half of the global OSAT market, **it can be estimated that the industry consumed 14.7 TWh worldwide last year, or 10-15% of the semiconductor industry total.** This figure does not, however, include ATP activities carried out internally by chip manufacturers or foundries.

In any case, electricity requirements account for a very significant proportion of the operating costs of ATP players, prompting manufacturers to make the cost of electricity a major criterion in their choice of location. This may explain, in part, the strong appeal of Vietnam or Malaysia, which have competitive tariffs - compared with China in particular²⁰ - or, on the *other hand*, the slower growth of the Philippines²¹.

Under pressure from their own customers to improve their environmental credentials, manufacturers are also increasingly showing their willingness to source **all their electricity from renewable sources**. Most have committed to achieving carbon neutrality by 2050, and Samsung, TSMC, Intel, SK Hynix and others have joined the RE100 initiative, which aims to use 100% renewable energy. **Manufacturers are now explicitly citing access to "clean" electricity as a key investment criterion**, especially as these energy sources can help them hedge against fluctuations in energy prices. The director of Infineon in Kulim, Malaysia, recently called on the country to increase the availability of renewable electricity, or risk discouraging investors²². Other players have invested in self-generation: Amkor has installed solar panels in its factories in Porto, China and South Korea, representing a capacity of 8.3 GWh per year - less than 0.5% of its total requirements.

What is true for electricity is also true for water. Assembly plants consume large quantities of water (including in ultrapure form), the quality and flow of which must be guaranteed all year round. In 2022, OSAT Amkor alone will have withdrawn 15.8 million m³ worldwide, of which 3.8 million m³ will be permanently consumed. Countries with abundant freshwater reserves will therefore have a clear advantage in attracting semiconductor manufacturers, while others will have to invest in strengthening their water supplies.

2.3. Logistics and proximity: an increasingly decisive factor

Geographical location has long been a secondary criterion when semiconductor manufacturers choose a site or subcontractor. In the preliminary study carried out prior to the drafting of the European CHIPS Act, and published in July 2022, **the manufacturers questioned ranked geographical proximity in very last place when choosing a manufacturing or subcontracting site**²³. In fact, the reduced volume and weight of integrated circuits means that a large part of the supply chain can be handled by air freight. Silicon wafers etched in the United States or Europe can thus reach the production lines of an East Asian OSAT in just a few hours, before being reshipped by the same route to the end customer on another continent. **On the other hand, the capacity of the host country in terms of logistics, customs clearance and administrative**

¹⁸ *Semiconductor industry electricity consumption to more than double by 2030*, Greenpeace, Apr. 2023

¹⁹ *Environmental data and facts in the semiconductor manufacturing industry: An unexpected high water and energy consumption situation*, Qi Wang, Nan Huang, Zhuo Chen, Xiaowen Chen, Hanying Cai, Yunpeng Wu, Water Cycle, 2023

²⁰ *Electricity prices comparison of Vietnam to the world and current electricity prices management mechanism*, Vietnam Electricity, 2022

²¹ *Competitive Indonesian Electricity Rates in the ASEAN Region*, Digital Energy Asia, 2018

²² *Malaysia aims for chip comeback as Intel, Infineon and more pile in*, Nikkei, Sept. 2023

²³ *European Chips Survey Report*, European Commission, 2022

formalities, as well as transport infrastructure, plays a key role, as manufacturing chains cannot tolerate the slightest delay in supply.

However, the Covid-19 pandemic, which caused the worst semiconductor shortage in history, has led many players to take a closer look at the geographical criterion. Traumatized by the closure of their production lines as a result of this disruption to their supply chains, **European carmakers officially called in 2021, via their trade union ACEA, for semiconductor production to be relocated within the EU²⁴ , a stance which probably weighed heavily in the drafting of the European CHIPS Act.** More recently, **GM signed an agreement with GlobalFoundries to produce chips for its assembly lines in New York State²⁵** . The same is true of consumer electronics, where in May 2023 Apple signed an agreement with Broadcom to produce 5G *basebands* in the United States²⁶ , after having lobbied for the establishment of a TSMC *fab* in Arizona.

3. United States: the CHIPS Act does little for assembly

Adopted by the Biden administration in August 2022, the **CHIPS Act (Creating Helpful Incentives to Produce Semiconductors for America)** is the cornerstone of the US strategy to rebuild domestic semiconductor manufacturing capacity. It aims to "de-risk" the domestic industry's supply chain against a backdrop of heightened tensions with China and the risk of military conflict in Taiwan. The legislation provides for the allocation of USD 280 billion in funding to develop semiconductor research and production in the US over the period 2022-2026, including **USD 39 billion in subsidies dedicated to manufacturing²⁷** .

3.1. Incomplete consideration of assembly

The steps taken by APT have been taken into account by the legislature. Under the National Advanced Packaging Manufacturing Program (NAPMP), the CHIPS Act authorises **USD 2.5 billion in funding for the development of advanced encapsulation technologies.** The stated objective²⁸ is to ignore traditional APT methods, which are impossible to relocate to the United States profitably, and to concentrate on advanced assembly and encapsulation methods, which are virtually non-existent in the United States. More than a year after the CHIPS Act was passed, the NAPMP programme remains largely in its infancy: the National Institutes of Standards and Technology (NIST), which is responsible for its implementation, has for the time being devoted it solely to funding a network of research laboratories, shared between manufacturers. And it was not until September 2023 that Subramanian S. Iyer, a former IBM engineer, was appointed as the first director of the NAPMP²⁹ .

3.2. No rush from manufacturers

CHIPS Act subsidies for industrial projects have so far not benefited assembly, packaging or test projects. While gigantic foundry projects are multiplying - \$40 billion for TSMC's plant in Phoenix (Arizona) alone, and an equivalent sum for the two planned by Intel in Arizona and Ohio, not to mention the more modest projects by Rogue Valley Microdevices or Skywater Technology³⁰ - **all these players are planning to ship their silicon wafers abroad for final assembly: to Taiwan for TSMC³¹ , and to Asia for Intel³² . Only one assembly specialist is planning to build an industrial unit in the United States under the CHIPS Act:**

²⁴ *Chip shortage: auto industry calls for more EU-made semiconductors*, European Automobile Manufacturers Association, 2021

²⁵ *GM inks deal with GlobalFoundries to secure U.S.-made chips*, Reuters, Feb. 2023

²⁶ *Apple Strikes Multibillion-Dollar Deal to Use U.S.-Made Chips*, Time, May 2023

²⁷ *CHIPS Act of 2022 Provisions and Implementation*, Congressional Research Service, April 2023

²⁸ *Speech to the American Association for the Advancement of Science (AAAS)*, 4 March 2023

AAAS Business Meeting: When the Government Makes Big Bets on Science and Technology: The CHIPS Act

²⁹ *Subramanian Iyer Joins the CHIPS for America Research and Development Office, NIST*, 26 September 2023

³⁰ <https://www.semiconductors.org/u-s-semiconductor-ecosystem-map/>

³¹ *The Flaw in Apple's Plan to Make Chips in Arizona*; *The Information*, 11 September 2023

³² *Intel Reveals Plans for Massive New Ohio Factory, Fighting the Chip Shortage Stateside*; *Time*, 20 January 2022

Integra Technologies is planning to invest \$1.8 billion in a factory in Kansas³³ . But this site should only assemble a small proportion of the silicon wafers etched in the United States. Integra Technologies works mainly for defence and aerospace companies and US government agencies, which are required to do all their manufacturing in the USA.

4. Towards a Latin American subcontracting pool?

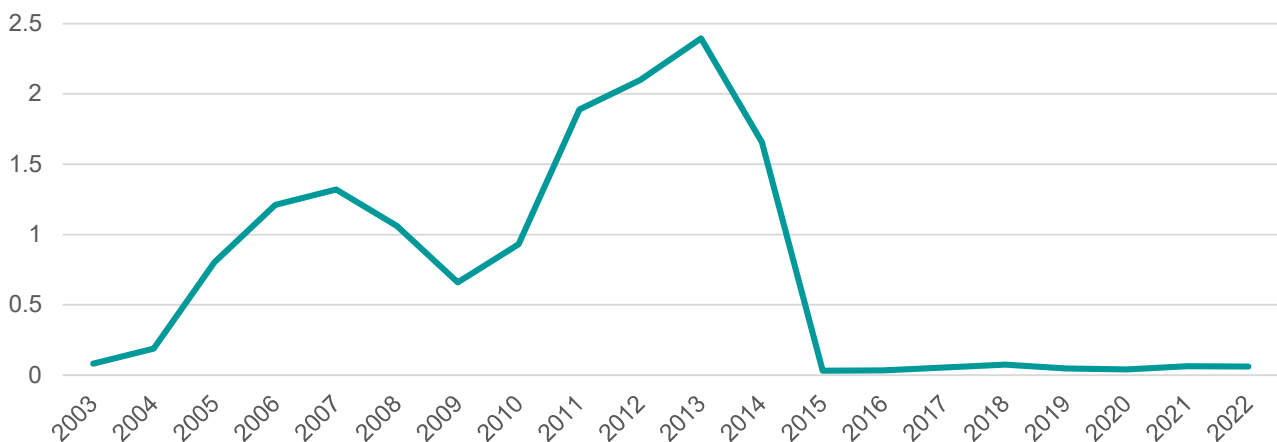
Although Latin America was home to chip assembly plants in the 1960s and 1970s, notably in El Salvador and Mexico³⁴ , these activities did not survive the massive relocation to Asia. But the United States' determination to limit the exposure of its *supply chain* to a crisis in Asia is opening up new prospects for Latin and Central America. The region is well positioned to benefit from the **International Technology Security and Innovation Fund (ITSI)**, created under the CHIPS Act, which allocates US\$500 million (US\$100 million per year starting in fiscal year 2023) to the State Department to support the diversification of the semiconductor supply chain³⁵ , including the offshoring of ATP activities.

4.1. As a major technology partner, Costa Rica is banking on the CHIPS Act

4.1.1 An American ally with the advantage of Intel's historic presence

In July 2023, the US State Department announced its intention to **partner with Costa Rica through the ITSI Fund** to explore **opportunities for developing a semiconductor supply chain³⁶** . Meeting at the White House at the end of August 2023, US President Joe Biden and his Costa Rican counterpart Rodrigo Chaves Robles reiterated their commitment to building a sustainable semiconductor industry in Central America³⁷ . **The US authorities regard Costa Rica as a leading partner in this field.**

Figure 3: Costa Rica's semiconductor exports, 2003-2022 (USD billion)



Source: TradeMap. (Code HS 8542)

Geographically close to the United States, its biggest trading partner, **Costa Rica already has a semiconductor industry and expertise** - a significant advantage in Washington's eyes. The US microprocessor giant **Intel** (which accounts for around 12% of the global semiconductor market³⁸) **has been based here for 25 years**, and **the country is home to the only major semiconductor assembly plant in**

³³ *Integra Tech selects Kansas for Largest OSAT Semiconductor Project*, Integra Technologies press release, Feb. 2, 2023

³⁴ IRLE, *Offshoring in the Semiconductor Industry: Historical Perspectives*, May 2005

³⁵ US Department of State, *The U.S. Department of State International Technology Security and Innovation Fund*

³⁶ US Embassy in Costa Rica, *Partnership with Costa Rica to Explore Semiconductor Supply Chain Opportunities*, July 2023

³⁷ The White House, *Readout of President Joe Biden's Meeting with President Rodrigo Chaves Robles of Costa Rica*, August 2023

³⁸ El Pais, *Costa Rica emerges as the winner in 'chip war' between US and China*, October 2022

the region. At the end of the 1990s, Costa Rica, which wanted to move from an assembly industry to a high value-added industry, introduced a number of incentives to encourage technology companies to set up in the country. **As early as 1997, Intel relocated some of its microprocessor assembly and testing activities to Costa Rica**, with a **definite economic impact on the country**: with over USD 1.7 billion in investment³⁹, almost 2,700 employees and 11% of total FDI between 2000 and 2012⁴⁰, Intel's activities accounted for a significant proportion of Costa Rica's total exports: 21% in 2013.

Against a backdrop of corporate restructuring, **Intel announced in April 2014 that it was relocating its assembly and test operations to Asia**, a move that had caused Costa Rica's semiconductor exports to almost collapse (chart 3). By consolidating its operations in its factories in China, Malaysia and Vietnam, the company intended to cut costs and move closer to its main markets. **Intel did, however, continue its R&D activities in Costa Rica**, whose economy has suffered as a result of the technology giant's withdrawal.

4.1.2 Intel's big comeback

In 2020, five years after its departure, **Intel announced the resumption of its PTA operations in Costa Rica**. Rising global demand and the company's desire to balance the weight of its operations, which were overly concentrated in Asia, led it to reopen the doors of its plant in the province of Heredia, with an initial investment of USD 350 million, increased to USD 1 billion⁴¹. Intel is thinking big: the company, which has new expansion plans, announced at the end of August 2023 that it would be **investing a further USD 1.2 billion in its Costa Rican operations over the next two years**⁴².

The investment by Intel, which **now employs almost 4,000 people in Costa Rica**, could set off a chain reaction, encouraging other companies to set up shop. San José already has legislation favourable to FDI, and is committed to strengthening the country's capacity in terms of infrastructure and skilled labour. Over and above the direct effects on the country's economy, **the transformation of its Costa Rican ally into a regional semiconductor production hub would benefit a Biden administration keen to control this industry**.

4.2. Panama on a charm offensive

Like its Costa Rican neighbour, Panama is also attracting the attention of the United States. Also as part of the ITSI Fund, in July 2023 the State Department launched discussions on the **development of the APT sector**⁴³. While this follows on from the CHIPS Act, the US announcement also comes after **intense lobbying by the Panamanian authorities to turn the country into a semiconductor assembly site**. Panama's trade minister, Federico Boyd, had already discussed the matter with his American counterpart⁴⁴, while the ambassador in Washington has been giving numerous speeches highlighting the country's opportunities⁴⁵. As part of this partnership, Panama is proposing to **finalise on its soil the assembly of semiconductors manufactured in the United States**⁴⁶. Panama has already signed a memorandum of understanding with **Arizona State University**, a renowned player in the semiconductor industry, to set up a **cooperation platform in the field of advanced technologies**; this collaboration will be aimed in particular at training a Panamanian workforce qualified for this industry⁴⁷. Panama is also in **talks with Samsung to draw up a training plan for the national workforce**⁴⁸.

³⁹ ILO, ILO Americas Technical Reports 2017/8, *Moving Up the Global Value Chain: The case of Intel Costa Rica*, 2017

⁴⁰ The Economist, *Intel outside*, April 2014

⁴¹ El País, *Costa Rica emerges as the winner in 'chip war' between US and China*, October 2022

⁴² Intel, *Intel reafirma su compromiso con Costa Rica como un actor clave en la creciente demanda global de semiconductores*, août 2023

⁴³ US Embassy in Panama, *New Partnership with Panama to explore semiconductor supply-chain opportunities*, July 2023

⁴⁴ Panamanian Ministry of Trade and Industry, *Ministro Federico Alfaro Boyd realiza conversatorio con la Secretaria de Comercio de EE.UU. Gina Raimondo, para promover Panamá*, juillet 2023

⁴⁵ RealClearPolicy, *Panama: An Opportunity for the Semiconductor Industry*, May 2023

⁴⁶ Bloomberg, *Panama Says It Can Cut Risks to US Semiconductor Supply Chain*, July 2023

⁴⁷ Panamanian Ministry of Foreign Affairs, *Panamá y Arizona State University firman acuerdo histórico para fortalecer cooperación científica y educativa en tecnologías avanzadas*, October 2023

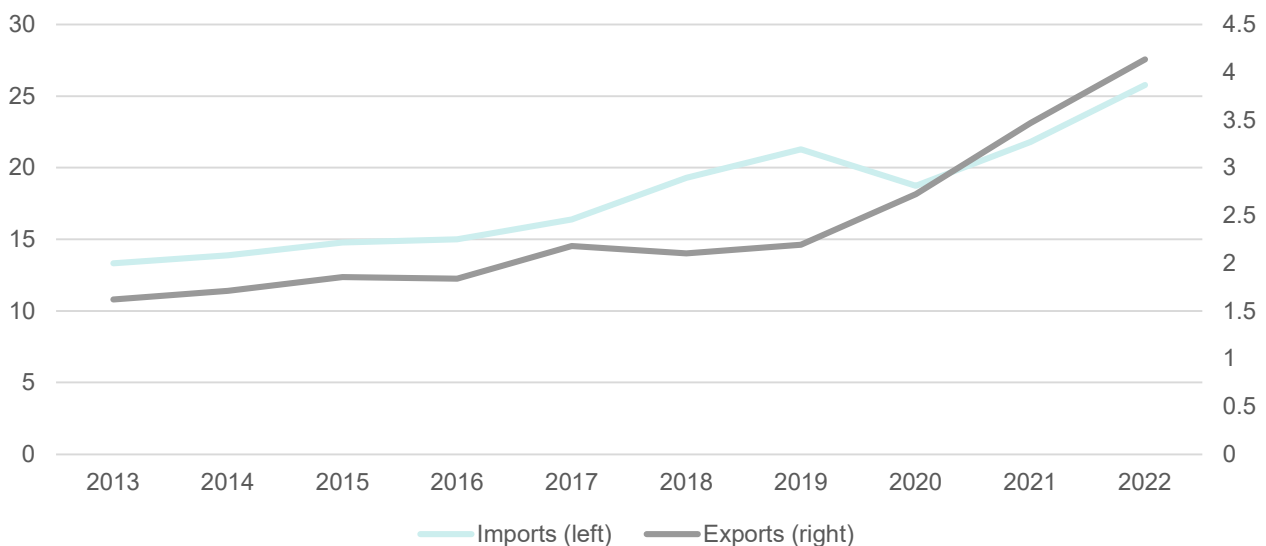
⁴⁸ Revista Martes Financiero Panamá, *¿Cuánto costará instalar una planta para ensamblar semiconductores en Panamá?*, August 2023

Panama already has a regulatory framework that encourages relocation. In addition to the SEM legislation⁴⁹ of 2007, which encourages multinationals to set up their regional headquarters in Panama, the EMMA law⁵⁰ adopted in 2020 encourages manufacturing companies to locate their production plants here. The Panamanian authorities have announced their intention to study **new tax incentives to attract semiconductor companies**⁵¹. The country has other advantages: a strategic trading position, a dollar-based economy, economic stability, the presence of free trade zones, and so on.

4.3. Mexico capitalises on its proximity and the automotive industry

As the United States' main trading partner, **Mexico could take advantage of its close proximity to the United States and its considerable expertise in the manufacturing sector (particularly automotive) to play a growing role in semiconductor production**. With a skilled, low-cost workforce, Mexico shares a large border and an extensive free trade agreement with the United States. Already home to several semiconductor assembly and packaging plants⁵², Mexico exported more than USD 4.1 billion worth of semiconductors in 2022, compared with USD 1.6 billion in 2013⁵³. However, Mexico remains a net importer, with imports of more than USD 25 billion in 2022, mainly due to its role in automotive assembly.

Figure 4: Semiconductor imports and exports, Mexico, 2013-2022 (USD billion)



Source: TradeMap. (Aggregation of HS codes 854231, 854232, 854233, and 854239)

All these factors could make Mexico a priority destination for US investment and ATP facilities; **already highly integrated in the automotive manufacturing sector, the two neighbours could easily promote the integration of a semiconductor supply chain**. The mutual interest of the two partners is growing: in January 2023, alongside their Canadian neighbour, **Mexico City and Washington pledged to cooperate in this area**⁵⁴. Meeting in May 2023, the three countries also issued a joint statement announcing the launch of the **North American Semiconductor Conference**, reflecting their commitment to strengthening the resilience of the North American supply chain⁵⁵.

⁴⁹ *Sedes de Empresas Multinacionales Law, 2007*

⁵⁰ *Especial de Empresas Multinacionales para la Prestación de Servicios Relacionados con la Manufactura, 2020*

⁵¹ Bloomberg, *Panama Says It Can Cut Risks to US Semiconductor Supply Chain*, July 2023

⁵² Foreign Affairs, *Mexico's Microchip Advantage*, August 2023

⁵³ TradeMap data

⁵⁴ Les Echos, *Les États-Unis lancent une coopération sur les semi-conducteurs avec le Mexique et le Canada*, January 2023

⁵⁵ The White House, *Joint Statement on the Launch of the North American Semiconductor Conference and North American Ministerial Committee on Economic Competitiveness*, May 2023

Aware of the opportunities that this industry represents, Mexico is keen to make its development a priority. In 2022, the Mexican authorities stated that they wanted to introduce **incentives for companies looking to relocate their semiconductor production**⁵⁶. While the details of these initiatives remain vague, the AMLO government is hoping to attract companies to the state of Sonora, which borders the US state of Arizona (where TSMC is building its US *fab*) and which is the focus of a major development plan. The governor of Sonora, Alfonso Durazo, expressed his willingness to welcome investment from **Foxconn** and **TSMC** during a recent visit to Taiwan⁵⁷. The Mexican authorities are also stepping up the training of their workforce: in 2022, Arizona State University has committed to establishing a partnership with the Mexican government and a number of universities to train Mexican workers for the microelectronics industry. **The Mexican Ministry of the Economy and chip giant Intel also signed a memorandum of understanding in April 2022 to promote innovation and the training of Mexican talent**⁵⁸. The company, which already has an engineering centre in the state of Jalisco, recently announced a programme to train Mexican workers in the semiconductor industry⁵⁹.

While Mexico appears well placed to benefit from the CHIPS Act, **no concrete investment has yet been announced in the country**. Major challenges remain in terms of costs and training. **Despite growing interest, the United States has yet to launch a partnership with Mexico via the ITSI fund**.

5. A timid start to relocation in Europe

5.1. The European CHIPS Act leaves assembly out of the equation

Adopted on 13 September 2023, the "European regulation establishing a framework of measures to strengthen the European semiconductor ecosystem"⁶⁰, better known as the "European CHIPS Act", pursues more or less the same objectives as the American text. It aims to give the European Union the means to establish, at least partially, a strategic autonomy in semiconductors, to reach 20% of the market share by 2030, compared with 10% today, thanks to €43 billion of public and private investment, including €15 billion directly mobilised thanks to the legislative package.

Like its US counterpart, **the regulation clearly identifies ATP activities as crucial to achieving autonomy, and sets as one of its operational objectives the strengthening of European capabilities in "heterogeneous systems integration and advanced module assembly and packaging"**. However, the text makes no specific provision for strengthening this segment of the industry, apart from a call for the creation of "pilot lines" incorporating the "*latest research and innovation activities*". The European Commission also stresses the need to "*set up international semiconductor partnerships with like-minded countries*"⁶¹, **thus adopting a friendshoring approach**. The text itself, however, says nothing about this, merely calling for dialogue with strategic international partners to better secure the European supply chain.

5.2. Manufacturers focus on Poland and Portugal

Germany has been able to attract TSMC to Magdeburg and GlobalFoundries, Intel and Infineon to Dresden, where a major industrial cluster is emerging to supply the automotive industry. Intel has also modernised its Irish unit to produce its latest generations of processors, while GlobalFoundries has joined forces with STMicro to set up a unit in France. **The assembly activity, less favoured by this flow of investment, has not been totally forgotten**. Intel plans to finalise its *made-in-Ireland* chips in Poland, where the US *chipmaker* announced in June 2023 that it would invest **up to \$4.6 billion to build an assembly and testing plant near**

⁵⁶ Bloomberg Linea, *México analiza incentivos para atraer inversión a chips: Tatiana Clouthier*, August 2022

⁵⁷ Reuters, *Mexico eyes US energy exports from solar farm, chip supply chain role*, September 2023

⁵⁸ La Jordana, *México acelera el desarrollo de la industria de semiconductores*, May 2023

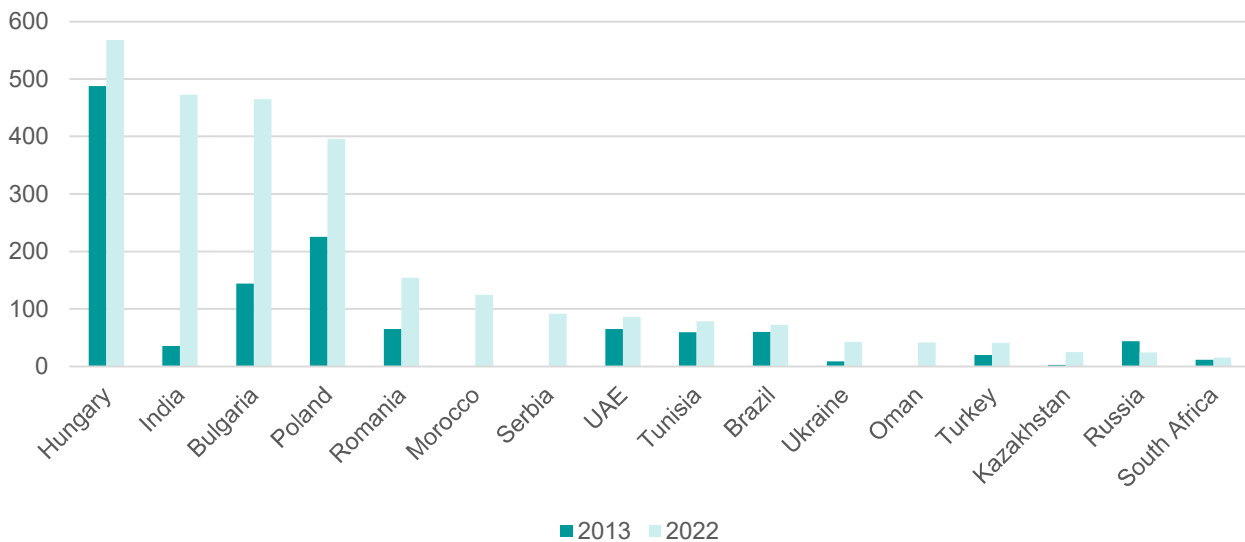
⁵⁹ Intel, *Intel y el Gobierno de Jalisco formarán a 100 jóvenes mexicanos en chips*, August 2023

⁶⁰ *Regulation establishing a framework of measures to strengthen the European semiconductor ecosystem*, Sept. 2023

⁶¹ *European Semiconductor Regulation*, European Commission presentation page, consulted in Oct. 2023

Wrocław⁶² . For its part, **GlobalFoundries will ship silicon wafers manufactured in Dresden to Amkor's advanced packaging unit in Portugal**. This plant has been a major contributor to the revival of Portuguese semiconductor exports since Amkor bought out its former owner Nanium in 2017. More broadly, European countries with skilled, relatively low-cost labour are well positioned to attract investment in semiconductor assembly and testing. Competition is fierce. While the Portuguese authorities are stepping up meetings with Korea's SK Hynix, **Italy, after failing to attract Intel to the Veneto region**⁶³ , **has not hesitated to abandon China's New Silk Roads initiative in the hope of attracting Taiwanese investment in this sector**⁶⁴ , without success to date.

Figure 5: Semiconductor exports by non-Asian emerging countries, USD million



Data: Trademap. Aggregation of HS codes 854231, 854232, 854233, and 854239. Mexico and Costa Rica excluded, see chapter 3

6. In Asia, a market in transition

Despite the efforts made by Latin American and European countries to position themselves as destinations for *friendshoring*, all the signs are that **Asia will remain the main source of subcontracting for the global semiconductor market**, and that the American and European CHIPS Acts could **accelerate the redistribution of these activities that is already underway, to the detriment of China and Taiwan** and to the benefit of new players such as Vietnam, the Philippines and India.

6.1. New subcontracting champions in South-East Asia

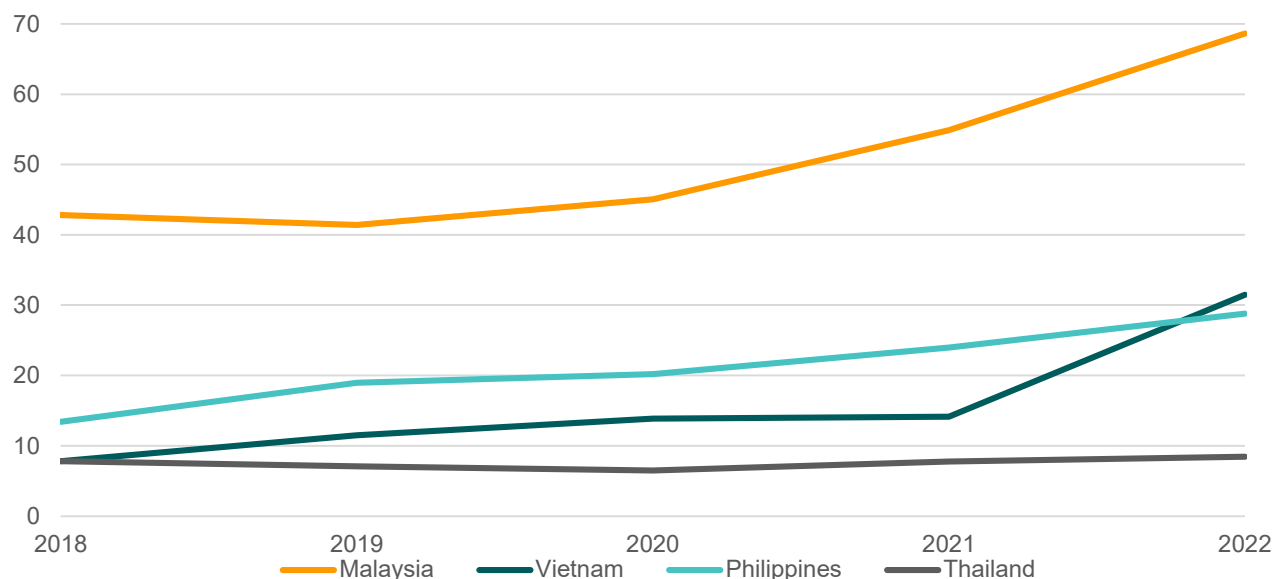
6.1.1 Vietnam, a new key player, seduces US manufacturers

Just over a decade after the opening of Intel's first assembly and test plant in 2010, **Vietnam is well on the way to establishing itself as one of Asia's semiconductor assembly champions**. Between 2018 and 2022, the country quadrupled its semiconductor exports to reach **USD 31.5 billion, still far behind Malaysia and Singapore, but ahead of Japan and the Philippines**.

⁶² *Intel plans Assembly and Test Facility in Poland*, Intel press release, June 2023

⁶³ *Italy and Intel choose Veneto as preferred region for new chip plant*, Zonebourse, Sept. 2022

⁶⁴ *Italy Eyes Taiwan Chip Deals Ahead of Decision on China Pact*, Bloomberg, April 2023

Figure 6: Semiconductor exports, USD billion

Source: TradeMap (Aggregation of HS codes 854231, 854232, 854233, and 854239)

This trend is set to accelerate, thanks in particular to the development of the APT segment. **The inauguration of the Amkor plant in October 2023 - which is expected to attract USD 1.6 billion in investment over time - was the culmination of a succession of major industrial announcements in this sector, from the extension of the Intel plant to the establishment of two plants by South Korea's Hana Micron in 2022 and 2023.** And the authorities are not giving up hope of convincing Samsung to invest more than US\$2 billion in its Thai Nguyen plant, which until now has been dedicated to assembling smartphones, in order to launch a chip assembly business there. This project, unveiled in 2022, has been put on hold due to Samsung's already significant investments in the country - more than USD 20 billion in just over a decade⁶⁵.

Vietnam appears to be **particularly well positioned to benefit directly from the impact of the US CHIPS Act, as demonstrated by President Joe Biden's visit to Hanoi in September 2023**, which attracted several senior executives from US semiconductor companies. During this visit, the two countries signed a **memorandum of cooperation on semiconductor supply chains**, workforce development and strengthening the industrial ecosystem⁶⁶. Similarly, **US Treasury Secretary Janet Yellen encouraged US investors interested in setting up in Vietnam to apply to the ITSI fund**⁶⁷.

6.1.2 After the Duterte era, are the Philippines back in the running?

Integrated into the global semiconductor value chain from the 1970s, thanks to the relocation of assembly activities by Texas Instruments, Fairchild and Intel in particular, the Philippines has managed to maintain this position, attracting other players such as the Americans Analog Devices and Onsemi, and assembly specialists Amkor and SFA Semicon. Several of these players have recently announced plans to expand their operations in the country, including Texas Instruments, with plans to expand its factories in Clark and Baguio (USD 1 billion), and Analog Devices (USD 200 million). **However, the pace of new investment has slowed, and growth in semiconductor exports, although dynamic (+114% between 2018 and 2022), is three times lower than in Vietnam.** In addition to certain structural factors, such as the **high cost of electricity**⁶⁸ and rapidly rising minimum wages, this relative lack of interest in the

⁶⁵ *Samsung smartphone slump casts shadow over Vietnam, Nikkei, Sept. 2023*

⁶⁶ *President Biden, General Secretary Nguyen Phu Trong Announce U.S.-Vietnam Comprehensive Strategic Partnership, White House press release, Sept. 2023*

⁶⁷ *Yellen urges Asia to tap CHIPS Act Funds for Semiconductors, Nikkei, Jul. 2023*

⁶⁸ *Cost structure of electricity in the Philippines and other Asian Countries, Ateneo de Manila University, Jan. 2023*

Philippines on the part of global semiconductor manufacturers should be seen in a broader context. **After increasing tenfold between 2010 and 2017, to reach just over USD 10 billion, foreign direct investment (FDI) into the archipelago has slowed sharply until 2021**⁶⁹. This period corresponds to the presidency of Rodrigo Duterte (2016-2022), whose unorthodox style of governance, coupled with plans to partially dismantle benefits granted to large companies⁷⁰, had worried many investors. Its rapprochement with China also provoked strong tensions with Washington, which may have slowed US investment. The election of President Ferdinand Marcos Jr in 2022 has cleared up these misunderstandings, and semiconductor manufacturers operating in the Philippines, represented by the trade organisation SEIPI (Semiconductor and Electronics Industries in the Philippines Foundation), hope to benefit from the CHIPS Act⁷¹. However, this prospect has not yet been raised directly by the two countries.

6.1.3 Thailand finds its way

For several decades, Thailand has been home to certain back-end activities (assembly and testing) of manufacturers such as NXP Semiconductors⁷², the American Microchip Technology, the Japanese Toshiba⁷³, as well as factories of the Singaporean chip assembly specialist UTAC. **But the kingdom, which in 2018 was still on an equal footing with Vietnam and the Philippines in terms of exports, has since fallen completely behind** (Chart 6). A number of factors could explain this setback, including **relatively high electricity and labour costs and chronic political instability**. The adoption in 2021 of a package of tax incentives targeting semiconductor assembly activities in particular⁷⁴ has not really changed the situation. To breathe new life into this industry, **Bangkok is openly playing on the geopolitical context, arguing that it is "neutral" in the Sino-American confrontation in order to attract American, Japanese and South Korean investment**⁷⁵. In 2022, Sony invested USD 70 million in its Bangkok factory to produce optical sensors for autonomous vehicles, while Murata committed an equivalent amount to produce capacitors for Apple.

6.2. Manufacturers bet on India

Still a small player in the global semiconductor industry, India is also trying to attract the interest of manufacturers. In December 2021, the country approved a **USD 30 billion investment programme to position itself as a global hub for the manufacture of electronic products, with semiconductors as the cornerstone of this strategy**. One of the components of this programme, unveiled at the end of 2022⁷⁶, is aimed specifically at developing ATP activities and attracting the world's leading OSATs. This could prove a great success. In September, the American company Micron launched the construction of an assembly plant, due to come on stream in 2024⁷⁷. The American group will invest USD 825 million, out of a total of USD 2.75 billion, the rest being covered by government subsidies. Local companies such as Sahasra Semiconductor are also positioning themselves in the assembly market⁷⁸.

6.3. Taiwan, China and Malaysia defend their turf

Faced with this growing competition, the countries that have so far dominated the semiconductor assembly business are seeking to preserve their gains, and are stepping up plans for new ATP plants, focusing on the most advanced processes. **A month after inaugurating its fifth advanced assembly site in Taiwan, at Chunan, in June 2023**⁷⁹, TSMC has announced the construction of a sixth unit in the country, this time

⁶⁹ *Foreign Investment Database, World Bank*

⁷⁰ *Duterte spooks foreign investors with tax 'sword of Damocles', Nikkei, 2018*

⁷¹ *PHL electronics industry welcomes US Chips Act, BusinessMirror, 2022*

⁷² *NXP Worldwide Locations: Thailand*

⁷³ *Thailand as Toshiba's Strategic Manufacturing Hub of Discrete Semiconductors for the Digital Century, Toshiba, 2022*

⁷⁴ *Thailand's new semiconductor incentives timed to support rising E&E Investment, Bangkok Post, 2021*

⁷⁵ *India and Thailand jockey for spot on Asia's chipmaking map, Nikkei, August 2023*

⁷⁶ *Revised guidelines for setting up of fabs and OSAT facilities and India, Ministry of Electronics and Information Technology, June 2023*

⁷⁷ *Micron begins construction of \$2.75bn semiconductor packaging plant in Sanand, Moneycontrol, Sept. 2023*

⁷⁸ *Sahasra Semiconductor to start chip production from September 23, Indian Express, Sept. 2023*

⁷⁹ *TSMC Announces the Opening of Advanced Backend Fab 6, TSMC, August 2023*

at Miaoli, for USD 2.9 billion⁸⁰. And it is in Taiwan that TSMC plans to transform the silicon wafers etched in its *fab* currently under construction in Arizona into chips. The Taiwanese authorities are doing their utmost to keep not only the *fabs*, but also the most efficient assembly sites, on their territory. In addition to providing electricity, water and land at preferential rates, **next year the authorities will unveil a ten-year programme of support for the industry**. The calculation is not just economic: Taipei postulates that maintaining these activities, on which the world's major economies, starting with China, depend, will dissuade Beijing from launching a military offensive against the island⁸¹.

Malaysia also remains an attractive location for ATP activities. **Intel is planning to invest USD 7 billion** to set up its world's largest 3D assembly facility in Penang - due to come on stream in 2024 or 2025 - as well as another unit in Kulim⁸². At the end of 2022, the world's leading OSAT, ASE, launched work on two new factories in Penang⁸³.

But it is undoubtedly China that will be making the greatest effort to strengthen its ATP industry. US export restrictions on the most advanced classes of processors (particularly those designed for *machine learning* and artificial intelligence) are forcing Beijing to cultivate its own strategic autonomy. **Chinese manufacturers, such as SMIC, are betting heavily on advanced assembly and encapsulation to make up for their lag in the finesse of silicon wafer etching** (SMIC's most recent processor, used in the latest Huawei smartphone, uses 7nm etching, compared with 3nm for the TSMC chips used in Apple's iPhone 15). **SMIC, Huawei and Chinese OSATs such as JCET and Tongfu are therefore stepping up their research and patent applications in the field of 2.5D and 3D assembly**⁸⁴. **The challenges associated with advanced assembly are now at the heart of the Chinese authorities' strategy**⁸⁵, and APT's activities will be able to benefit from the **USD 143 billion incentive package dedicated to the development of the country's semiconductor industry**⁸⁶. As for the world's major chip manufacturers, they seem reluctant to abandon their Chinese industrial base, despite the geopolitical context. In June 2023, at the height of tensions between Beijing and Washington, Micron announced its intention to invest more than \$600 million to expand and modernise its assembly and test unit in China⁸⁷.

⁸⁰ [Intel to quadruple cutting-edge chip packaging capacity by 2025, Nikkei, August 2023](#)

⁸¹ [Taiwan will not surrender its semiconductor capacity, The Economist, Oct. 2023](#)

⁸² [Intel to quadruple cutting-edge chip packaging capacity by 2025, Nikkei, August 2023](#)

⁸³ [ASE breaks ground on new chip assembly and testing facility in Penang, ASE, 2022](#)

⁸⁴ [China Ramps Multi-Chiplet Efforts with Industry Heavyweights, Tom's Hardware, August 2023](#)

⁸⁵ [Chip wars: How 'chiplets' are emerging as a core part of China's tech strategy, Reuters, Jul. 2023](#)

⁸⁶ [Exclusive: China readying \\$143 billion package for its chip firms in face of U.S. curbs, Reuters, 2022](#)

⁸⁷ [Micron plans factory expansion in China, Mobile World, June 2023](#)