Special Report: The Global Semiconductor Industry During Turbulent Times

Clément Durif

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About the author:

Clément Durif holds a master’s degree in International Economic Policy from the School of International Affairs of Sciences Po Paris (PSIA). Specialized in Chinese and more generally Asian economic issues, he also studied one year at the University of Hong Kong (HKU) as part of an exchange programme. After various internship experiences in consulting and market analysis in the tech and innovation sector, Clément delved more into the macroeconomic field. He recently graduated from the Barcelona School of Economics (BSE) with a second master’s degree in Specialized Economic Analysis, more specifically in the International Trade, Finance and Development programme (ITFD). He is now working as a Junior Research Fellow at the Asia Centre.

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On September 30th 2022, for its second webinar of the academic year, Asia Centre had the pleasure to host Min Hua Chiang, research fellow and economist at the Heritage Foundation, to discuss both the development over the past decades and the current state of the global semiconductor industry. This special report aims at summarizing Min Hua's presentation as well as her main arguments made during the Q&A session. The webinar's recording is available at the following link (note that the Q&A part has been removed due to privacy requirements):

https://www.youtube.com/watch?v=J6CtnmFDRHg

Once again, Asia Centre is deeply grateful to Min Hua for coming to Paris to take part in this event.

A few words about Min Hua Chiang's background:
Min Hua is an International political economist specialized in East-Asian geopolitical and economic relations, with a particular emphasis on Taiwan. After graduating with a master's degree in International Business Economics from the Catholic University of Leuven, she obtained both a Masters in International Political Economy and a PhD in Economic Sciences at the University of Grenoble. She started to work as a Research Fellow in various research institutes in Taipei and then spent around ten years at the National University of Singapore in the East Asian Institute. It is during these years that she made the major part of her publications: peer-reviewed articles, book chapters and perhaps more importantly multiple single-authored books, notably on the Cross-Strait Relations between China and Taiwan or on the South Korean economy. She is now working in the Asian Studies Center at The Heritage Foundation which she was representing for this event.

I. Introduction: Turbulent times…

New export bans on advanced chips and manufacturing equipment to China were imposed by the US administration in early October 2022. Adding to an already long list of restrictions and against a backdrop of increasing geopolitical pressure surrounding Taiwan, this latest set of measures illustrates that the strategic battle over semiconductors is more than ever underway.

Semiconductors have indeed been at the core of recent international trade tensions and industrial rivalries because of their crucial role in the digitalization process of our societies. These materials, which possess special electrical properties (between conductor and insulator), are key for the manufacturing of microchips and integrated circuits (IC), and constitute the backbone of all ICT products and other edge-cutting technologies[1].

After decades of industrial development and investments in a globalizing world, the chipmaking supply chain is facing setbacks. In essence, the current ecosystem based on comparative advantages, which allocates chip design to the West and their production to Asia, is threatened by a combination of two entangled factors, namely self-reliance aspirations and a certain desire

[1] Artificial intelligence, automotive, medical equipment, 4G/5G, etc.

to contain China's ambitions. While the Trump administration launched hostilities on a bilateral basis against Chinese tech companies amidst the 2018 trade war, the pandemic crisis and subsequent supply chain disruption revealed at a more general level the extent of Western industrial vulnerabilities, and more specifically the need to reduce dependence on Asian production. China's pursuit of technological dominance and its growing assertiveness about a potential takeover of Taiwan, the world's center for high-end chip manufacturing, further reinforce the incentives to rethink the current model of production.

As a result, cost efficiency through global division of labor in the semiconductor industry seems to be more and more de-emphasized. Instead, concerns over national security and technological sovereignty tend to increasingly prevail and are likely to direct the global chip supply chain in the long-term.

How did this industry develop? How is the supply chain currently organized? What is the specific role of China? Why are geopolitical concerns over Taiwan so important? What are the main drivers of a potential decoupling?

This special report aims at discussing these questions from both the political economy and geopolitical perspectives. Section II will address the development of the semiconductor industry and its current value-added segmentation. Section III will tackle the causes and determinants of the ongoing supply chain rearrangement. Finally, Section IV will provide concluding remarks on future potential scenarios.

II. The global semiconductor ecosystem

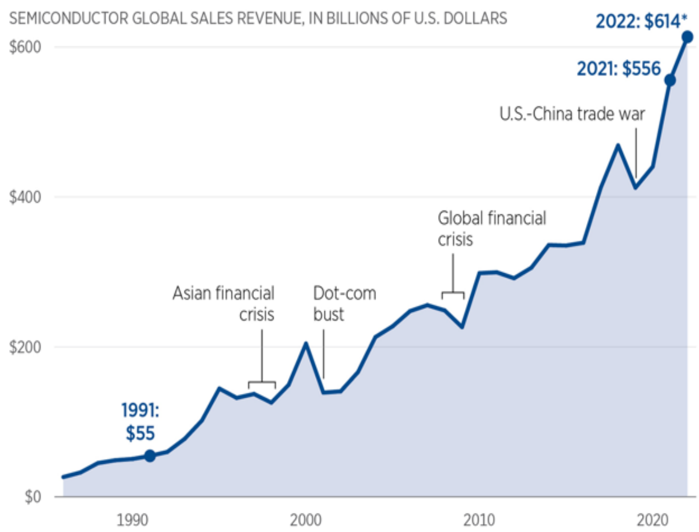
1. Birth and evolution of the semiconductor industry

With globalization and the emergence of the ICT market, the semiconductor industry grew at an extraordinary pace along the past decades. Global semiconductor sales revenue has increased more than tenfold in thirty years, starting from $55 billion in 1991 and reaching $614 billion in 2022 (see Figure 1). In terms of geographical distribution, Asia represents nowadays more than 60% of the sales, while North America and Europe account together for around 30%. This substantial growth and shift in production from the West to Asia was allowed by a favorable policy environment for both trade and investment.

In a general context of decreasing tariffs, the first version of the Information Technology Agreement (ITA) was signed in 1996 within the WTO framework. Initially including 29 countries, the ITA now covers 82 countries and 97% of the world trade in IT products. The signatory countries pledged to gradually eliminate all custom duties on listed products[2], although with different time schedules. After additional rounds of negotiations, the ITA expansion (ITA II) was approved in 2015 by 50 countries, including all the major players in the industry (US, Taiwan, South Korea, China, Japan, EU). They committed to further tariff cuts on a wider list of 201 covered ICT products, accounting for $1.3 trillion per year, which represent 90% of sectoral trade and 7% of total global trade.

On the financial side, while investment plans in the US and Europe targeting semiconductors have until recently mainly focused on high value-added products, global capital mobility liberalization and FDI promotion in East Asia during the 2000s triggered significant industrial relocations. Until the beginning of the 2010s, sales were still dominated by Japan and the US. The former, relying on earlier American technology transfers, was at the forefront of transistor production for consumer goods whereas the latter concentrated on more advanced market

[2] Semiconductor products, video cameras, headphones, pacemakers, etc.



* Estimated.
NOTE: A semiconductor is comprised of a discrete semiconductor, integrated circuits, sensors, actuators, and total application-specific integrated circuits.
SOURCE: CEIC Data, https://www.ceicdata.com/en (accessed August 1, 2022).

Figure 1

segments. Nowadays, even though the US is still present, all the major Japanese players have been outpaced by their Taiwanese and Korean counterparts. Building on initial foreign technological transfers[3] and continued innovation cycles, as well as lower labor cost but highly qualified human capital, the two Asian dragons succeeded in rapidly acquiring key positions in the market. To illustrate this shift, six Japanese companies were among the top ten semiconductor companies in the world in 1989. Thirty years later, none of them are in the ranking anymore. On the contrary, Taiwanese and South Korean companies enter the top ten alongside US players (see Table 1).

Top Ten Semiconductor Companies by Sales Revenue

	1989	1999	2009	2021
1	NEC (Japan)	Intel (U.S.)	Intel (U.S.)	Samsung (South Korea)
2	Toshiba (Japan)	NEC (Japan)	Samsung (South Korea)	Intel (U.S.)
3	Hitachi (Japan)	Toshiba (Japan)	Toshiba (Japan)	TSMC (Taiwan)
4	Motorola (U.S.)	TI (U.S.)	TI (U.S.)	SK Hynix (South Korea)
5	TI (U.S.)	STMicroelectronics (Switzerland)	STMicroelectronics (Switzerland)	Micron (U.S.)
6	Fujitsu (Japan)	Qualcomm (U.S.)	Qualcomm (U.S.)	Qualcomm (U.S.)
7	Mitsubishi (Japan)	SK Hynix (South Korea)	SK Hynix (South Korea)	Nvidia (U.S.)
8	Intel (U.S.)	AMD (U.S.)	AMD (U.S.)	Broadcom (U.S.)
9	Matsushita (Japan)	Renesas (Japan)	Renesas (Japan)	MediaTek (Taiwan)
10	Philip (The Netherlands)	Sony (Japan)	Sony (Japan)	TI (U.S.)

Total Number of Companies in Top Ten, by Country or Region

	1989	1999	2009	2021
Japan	6	4	3	0
U.S.	3	4	4	6
Europe	1	1	1	0
South Korea	0	1	2	2
Taiwan	0	0	0	2

SOURCES: Horng Show Koo, "Development and Tendency of Global Semiconductor-Related Industries," *Strait Business Monthly* (in Chinese), , and IC Insights, https://www.icinsights.com/ (accessed April 28, 2022).

Table 1

[3] For instance, RCA (US) for Taiwan or Motorola (US) for South Korea

2. The current division of labor along the supply chain

Trade and investment liberalization, as well as continually increasing demand for ICT products, created favorable conditions for the semiconductor industry to thrive. This globalization process also entailed a structuring of supply chain networks according to traditional comparative advantages, allocating high value-added (VA) segments of production to the West and lower segments to Asia.

In a nutshell, the current division of labor for the chip and IC industry is organized as follows: design, manufacturing and assembly (see Appendix 1). Chip design, usually referred to as the fabless part of the production process, is almost entirely located in the US and Europe. This part of the process, which consists in Electronic Design Automation (EDA) and logic formation, represents the major part of the total VA, with 33%, the US holding around 70% of it and Europe the rest (see Figure 2). Manufacturing (21% of VA) and wafer fabrication (19%), taking place in the so-called foundries, is concentrated in Asia. Although the US and Europe still have the major share of analog and discrete semiconductors' VA, with more than half of the total in this category, South Korea largely dominates in memory chips, (DRAM[4]) accounting for almost 60% of the segment's VA. In terms of wafer manufacturing, the VA is divided in shares of between 15 and 20% among four countries: South Korea, Taiwan, Japan and China. Finally, the testing, packaging and assembly part, which represents only 6% of the VA, is dominated by China and Taiwan. As for industrial capacities, the US, Japan and Europe provide all manufacturing equipment. Together, they account for more than 80% of the VA.

The semiconductor supply chain is therefore globally deeply fragmented and entails high levels of interdependence between countries. Even though large corporations such as the Korean *chaebol* Samsung or the American company Intel succeeded in integrating the entire production process, most of the stakeholders targeted the development of specific segments. To mention

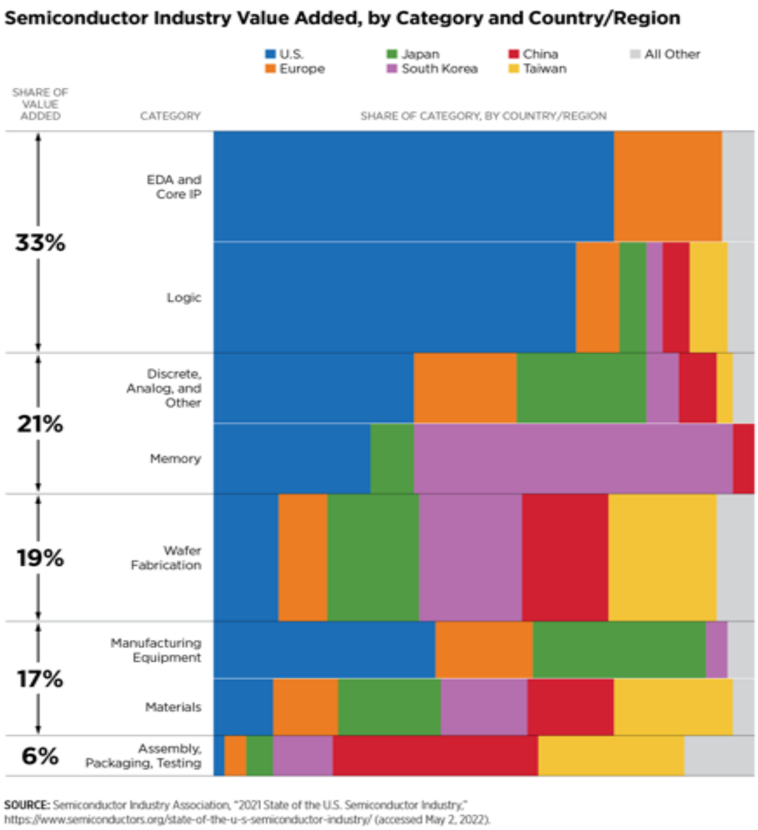


Figure 2

[4] Dynamic Random Access Memory

a few examples, the US based companies Qualcomm and Broadcom are specialized in EDA softwares and services for wireless communication. The Korean SK Hynix is the leader in DRAM and flash memory chips. Taiwan Semiconductor Manufacturing Company (TSMC), pioneer in the pure-player foundry business, acquired a dominant position in the advanced chip production.

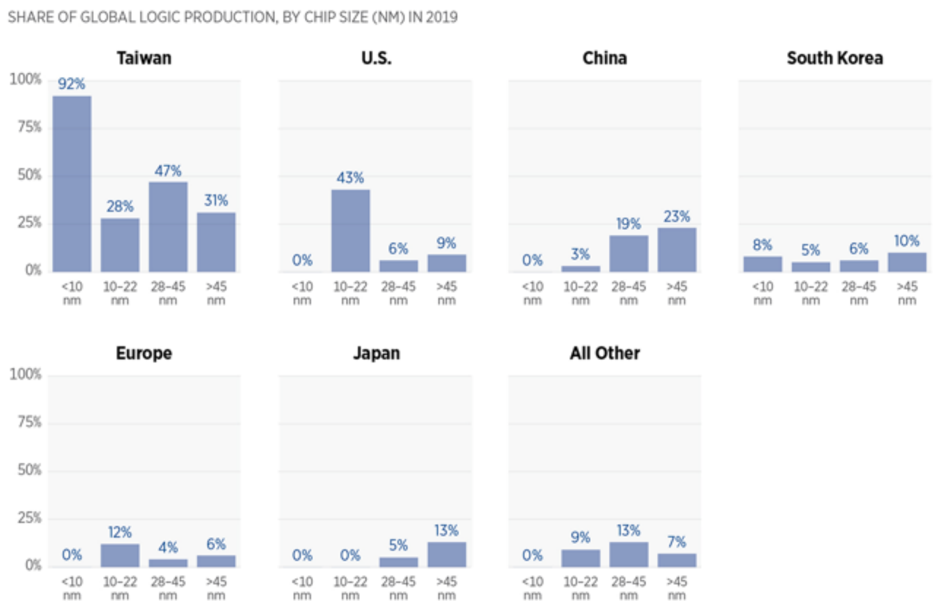
As a matter of fact, Taiwanese foundries have become crucial for the global ecosystem. Beyond its cheaper labor force, the island developed a particularly performant industry through a "chip making only" business model, strong state support, and special relations with US companies. It thus became the leader in high-end chip manufacturing. When looking at logic production by chip sizes, Taiwan is at the forefront of below 10 nm semiconductors, the most complex to fabricate, with 92% of the market (see Figure 3). In the more general foundry market, Taiwan represents 59% of the total revenue (with TSMC holding on its own 56%). Samsung possesses the second largest, but with only 16%. In even more details, TSMC is by far the main supplier of semiconductors for smartphones with a share of 70% (Samsung having the 30% left). The fact that the Taiwanese companies apply a no competition policy regarding their customers further reinforces their unique independence and key position in the supply chain.

III. A strategic reorganization of the supply chain?

1. China's technological ambitions

With its unprecedented economic rise, sustaining double digit GDP growth rates during almost three decades, China became the second world power and is nowadays holding a central place in global supply networks. While the Chinese model relied for a long time on low value-added manufactured goods exports, it is now evolving rapidly towards medium to high end production. Especially since the appointment of Xi Jinping as head of the Party (CCP), China has become more assertive about its ambitions to move up the value chain, placing a particular emphasis on the digital sector.

The ICT market in China has been growing considerably since the early 2000s. Benefiting from the opening up policies, the electronics and telecommunication equipment sectors attracted massive FDI inflows. From 2000 to 2019, between $6 and $8 billion of foreign capital were



SOURCE: Semiconductor Industry Association, "2021 State of the U.S. Semiconductor Industry," https://www.semiconductors.org/state-of-the-u-s-semiconductor-industry/ (accessed May 2, 2022).

Figure 3

directed each year to these industries, accounting for the major share of FDIs falling in the manufacturing category. As a result, China is nowadays and by far the largest exporter in ICT products, encompassing telecommunication equipment, office devices and electronic data processing, with more than $500 billion worth of exports in 2020. More recently, the *Made in China 2025* (MIC25) plan, announced in 2015 by Premier Li Keqiang, set the medium term domestic industrial goals for China. This policy is aiming at developing further high value-added strategic sectors such as the above-mentioned ICTs, but also robotics, medicine, green energy or aerospatial by 2025.

China obviously identified semiconductors as vital to achieve these objectives as they are the base material for the targeted industries. Along with MIC25, the government set self-reliance goals in chip and IC manufacturing. Massive efforts and investments have therefore been mobilized in terms of R&D, acquisition of foreign technologies, and in training and hiring of relevant talents. Nevertheless, China is still heavily dependent on imports. Knowing that it is the world's biggest consumer of semiconductors, only 6% of the domestic chip sales and 7% of the global sales in 2020 were manufactured within the country. In the same year, the Chinese trade balance in IC and electronic components reached -$215 billion, whereas the US was at -$3.9 billion (see Figure 4). There are still no Chinese players among the top ten semiconductor companies worldwide (see Table 1), nor among the top ten investors in R&D (see Table 2), and they are not yet able to produce chips smaller than 22 nm. These elements show evidence that China remains for the moment a trade platform and a final assembly location for semiconductors.

Although this self-reliance strategy is currently facing structural difficulties, it is still a top priority for the country to move away from the "world's factory" for low-tech goods' model. In this regard, the increasing geopolitical tensions between China and Taiwan has drawn much attention. Against a background of intensifying military incursions and exercises in the Taiwan Strait, going hand in hand with CCP officials being more vocal about the reintegration of the island to the mainland territory, some observers argue that the Taiwanese "silicon shield"[5] could break. China's views on TSMC and other Taiwanese firms' leading-edge technology would constitute a strong incentive for an invasion if it fails at developing a performant domestic semiconductor industry within the years to come. While this outcome is unlikely in the short-term, the risk is taken seriously. Mark Liu himself, chairman of TSMC, has recently referred to

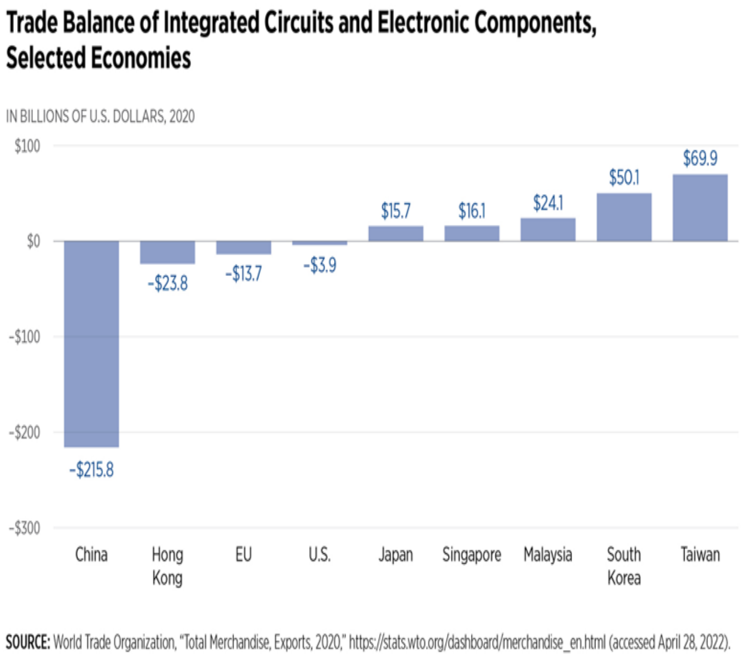


Figure 4

[5] Refers to China's high dependence on Taiwanese semiconductors preventing it from aggression

Top Ten Spenders on Research and Development in 2020

Rank	Company	Headquarters
1	Intel	U.S.
2	Samsung	South Korea
3	Broadcom	U.S.
4	Qualcomm	U.S.
5	Nividia	U.S.
6	TSMC	Taiwan
7	Media Tek	Taiwan
8	Micro	U.S.
9	SK Hynix	South Korea
10	AMD	U.S.

Top Ten Companies by Country	
U.S.	6
Taiwan	2
South Korea	2

SOURCES: IC Insights, "Industry R&D Spending to Rise 4% after Hitting Record in 2020," January 19, 2021, https://www.icinsights.com/news/bulletins/Industry-RD-Spending-To-Rise-4-After-Hitting-Record-In-2020/ (accessed May 2, 2022).

Table 2

the possibility of a takeover, even though he stated that China would not have the ability to operate TSMC foundries because of their high level of sophistication.

2. Technological war and technological sovereignty

China's technological aspirations have prompted Western nations to adopt more aggressive stances. The trade war initiated by the US in 2018 was the first sign of a strategic shift to reduce reliance on Chinese production and specifically to target China's main weakness, namely its semiconductor supply. However, there is growing evidence that the battle for chip and IC dominance goes beyond the case of China. The Covid-19 pandemic revealed a general lack of industrial capacities in the West, which is consequently taking steps to reorganize the supply chain in order to be more self-sufficient.

The US-China trade war launched by President Trump quickly turned into a technological war, itself gradually focusing on semiconductors. Initially raising tariffs to boost its trade balance and denounce China's unfair competition[6], the US administration published for the first time in 2019 a blacklist of Chinese companies for which an export license was then required. In addition, it banned US tech companies from dealing with Chinese counterparts that could pose a threat to national security, for example through private data management. In the months that followed, Huawei and ZTE dropped their sales of telecom equipment, TikTok and WeChat were banned from the US. Since then, weaponization of technology through export controls, acquisitions blocking, and licensing requirements, has been increasingly used to cripple Chinese development in key technological sectors. The arrival of Joe Biden at the White House actually reinforced this trend by emphasizing restrictions on chips. The latest set of measures mentioned at the very beginning of this report prevent US companies and foreign subsidiaries based in the US from exporting advanced chips, as well as manufacturing equipment for below 14 nm technologies. By putting such barriers on Chinese semiconductor supply and potential production the US is clearly trying to push China towards a forced decoupling, or at least constraining it to remain at its current status.

Apart from the US-China tensions, the semiconductor supply chain disruption caused by the pandemic crisis acted more generally as a catalyst for advanced economies to reduce dependence on foreign capacities. The ongoing chip shortage in the car industry for instance, is

[6] Excessive subsidization, intellectual property infringement, industrial espionage and copying

a typical consequence of the pandemic and calls for more technological sovereignty in this particular sector. As a result, growing incentives for industrial reshoring have appeared and are now leading to a series of government policies related to the chip sector in the US, Europe, South Korea and other economic powers. The US Chips Act, EU Initiative on Processor and Semiconductor Technologies, EU Chips Act, South Korean K-Semiconductor Belt or even the Indian Semiconductor Mission are all examples of initiatives aiming at bolstering subsidies and investments in leading-edge chip design and manufacturing.

While most players in the semiconductor industry are currently seeking less reliance on foreign production, Taiwan is on the contrary trying to depend less on domestic capacities. The fact that the vast majority of Taiwanese foundries is located on the island puts its main economic driver at risk. A potential Chinese incursion could indeed result in a complete takeover of the industry, but more realistically, Taiwan could lose its competitive advantage, considering that all other stakeholders are putting efforts in the relocation of high-end chip fabrication. To mitigate this risk, TSMC has officially announced multi-billion investments in both Japan and the US, and is also in advanced talks with Germany to set up its first European factory. However, it is important to note that these plans represent only 10% of Taiwan's domestic capacity.

As a whole, it seems therefore clear that a reorganization of the global chip industry is happening. The traditional division of labor along the supply chain, which targets cost-efficiency, is no longer a priority. Technology is now linked to countries' security, prosperity, social stability and therefore calls for government intervention. The term "techno-nationalism" emerges when it comes to describing this phenomenon.

IV. Concluding Remarks

Both aspirations for technological sovereignty and growing antagonism towards China are pushing nations to take a step back from the globalized structure of the chip industry. The vital characteristic of semiconductors for the digitalization of societies is indeed generating fierce competition between the main players, who are all trying to gain the upper hand in advanced technologies.

Although the reorganization process of the supply chain will certainly take time, multiple hubs of production across the globe, namely in North America, Europe and Asia could develop, as opposed to the current cost-efficient division of labor. Nevertheless, it is unlikely that Asian countries will lose their manufacturing dominance, which stemmed from thirty years of industrial evolution. The simple reason for this is that labor costs in the West are still very high compared to Asia. Relocations in the US or Europe will hence focus on rebalancing high-end chips production but not lower segments of production.

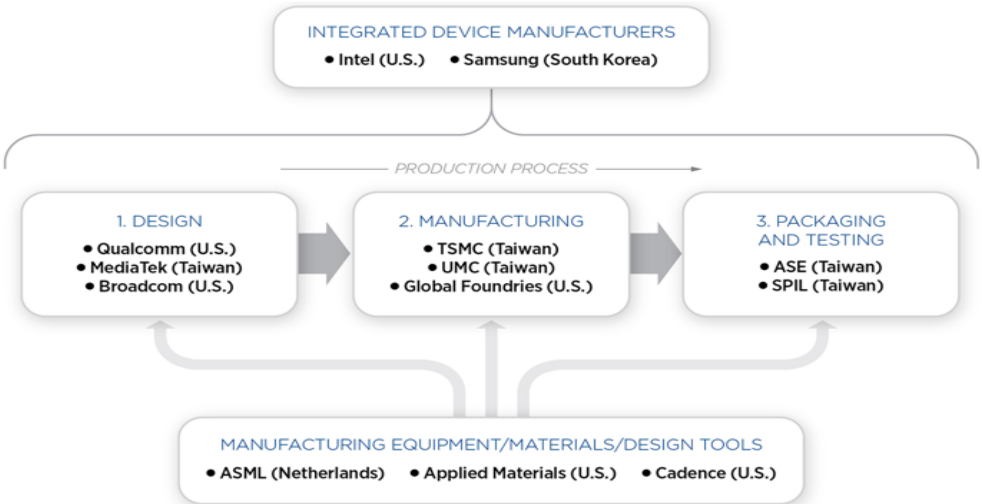
Several question marks remain. The most obvious one is whether China will be able to catch up in the semiconductors race. Still far from its self-sufficiency targets, and despite the open tech war waged by the US, the country is still putting massive efforts in the sector. Some elements could give hope to the CCP in reducing the gap with more advanced countries. For instance, open-source chip design could help in emancipating from protected Western knowledge. Moreover, Semiconductor Manufacturing International Corporation (SMIC) has announced during Summer 2022 that they were able to produce 7 nm chips. But while this represents a substantial breakthrough for the Chinese chip sector, TSMC was in the meantime announcing the launch of 3 nm semiconductor technologies manufacturing. China is therefore still lagging two or three generations behind the technologies of the main leaders in the sector. Especially with the significant trade barriers imposed by the US, it will be hard for a late comer such as

China to catch up. The country lacks experience in the sector and will not receive any technological transfer to enable more advanced production. Taiwan took decades to reach performant wafers' yield rates[7]. Currently, China's technologies are not mature enough to achieve regularity in this matter. Some also argue that the state-controlled nature of the Chinese economy is not suited for the development of a successful innovation environment and work culture. Semiconductors are and will remain in the short-term China's Achilles' heel.

Another question relates to the ability of Taiwan to keep its central position in advanced chip making. As discussed above, the geographical concentration of foundries on the island exposes Taiwanese companies to both a Chinese invasion and a catch up from other nations. As a result, a dilemma is emerging between diversification of production locations and supply advantage against China. On the one hand, the fact that Taiwan is trying to set up foundries in advanced markets could help them remain the main provider of leading-edge chips and IC. On the other hand, it is weakening the interdependence with China[8], which represents one of its most important lines of defense against a takeover. Even though Taiwanese technologies will stay fundamental in the short-term, a clear long-term and viable strategy still needs to be found.

Finally, the renewed trend in industrial policies for semiconductors, particularly in the West, poses the threat of creating overcapacities. With the different Chips Acts and programs across the globe, investment and subsidization competition could decorrelate production from demand. Even though this hypothesis is plausible, the global digital needs will remain strong in the years to come. The market will hence have space to adjust.

Appendix



SOURCES: George Calhoun, "Semiconductors: The Chips Act-Is It Really Necessary (Part 3)," *Forbes*, November 29, 2021, https://www.forbes.com/sites/georgecalhoun/2021/11/29/semiconductors-the-chips-act--is-it-really-necessary-part-3/ (accessed May 6, 2022), and other various media reports.

Appendix 1

[7] The yield rate is the number of operational chips on a wafer divided by the total number of potential chips
[8] Because exports to China from potential Western located subsidiaries would be more difficult