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The (global) supply chain of Chips, Chips in the European supply chain

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Abstract

Electronic circuitry has always be considered strategic. 40 years ago it was the dominant position of Japan that seemed to represent a threat to vital national security interests of the US. But, despite its perceived strategic importance, the global semiconductor market is rather small, only about 0.5% of world GDP – and is not a growth industry as this percentage has not increased over the last 20 years.

There are many different types of chips that fulfill very different functions (memory, logic and discrete). It is the most advanced logic chips with the smallest nodes that have captured the attention of policy makers. However, this type is little needed in Europe. The security of supply argument for subsidizing fabs to produce these chips is thus weak.

This contribution first analyses the key factors driving changes in the supply chain for chips over the last decades, which were mainly the migration of fabs to capital abundant countries in Asia and the increasing importance of software and design, that now account for over one half of the value of a finished chip. The global division of labor that has emerged is that the software comes from the US, the fabs are in Asia and Europe has a strong position in the machines to produce the most advanced (logic) chips. Semiconductors is one of the few industries in which China plays only a secondary role.

Strengthening the EU presence in the chip ‘ecosystem’ requires addressing the fundamental weakness in support for software development and R&D. Support for the precision manufacturing needed for the advanced chip manufacturing machines would also be useful but would require an order of magnitude less than the tenths of billions of euro for fabs foreseen in the Chips Act.

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1 Introduction

The strategic role of electronic circuitry is hardly news. Already in the 1980s the US was fretting about a major competitor threating vital national security interests by outcompeting the national semiconductor industry (Japan). And 30 years earlier, in the mid-1950s, the US had already imposed limits on the imports of transistors (the predecessors of integrated circuits) from Japan.

Despite its perceived strategic importance, the global semiconductor market (comprising all stages of production) amounts only to about 0.5% of world GDP – and this percentage has not increased over the last 20 years. The data in Yeung et al. 2023 suggests that it might actually have slightly fallen compared to 2000.[1]

The overall economic importance of chips is thus often vastly over-stated. However, for individual countries, the chips industry can be key. Taiwan provides an extreme example as its exports of electronic circuits amounted to $180 billion in 2022, worth over 25 % of GDP. For most other countries, very few jobs depend on their production. However, chips are indispensable for many products and many jobs would be at risk when chips are no longer available. Attention to the chips sector is thus justified on different grounds than jobs in producing chips or inputs for chips.

The paper will address two specific issues:

1. How has the supply chain for producing chips evolved over the last decades?

2. What role(s) play chips in European supply chains?

[1] To be precise: Yeung et al. 2023 report global revenues of $220 billion in 2000, worth about 0.65 % of 2000 world GDP, and revenues of $466 billion in 2020, worth about 0.55 % of 2020 world GDP of 85 trillion USD. A more recent source (from the US Semiconductor Industry Association (citing McKinsey) has similar numbers, reporting an increase from 139 bn USD in 2001 up to 573 bn US in 2022. The latter would correspond again to about 0.55 % of global GDP of slightly more than 100 thousand billion USD in 2022.

2 The evolving global supply chain for chips and the emerging dominance of software/design

There exist many detailed descriptions of how chips are produced (Miller, 2022, Conway 2023). The focus is usually on the most advanced chips and the marvels of technology needed to produce them. This paper will leave the technological issues aside and concentrate on the economic value embodied in chips, taking a longer view emphasizing the differences between different types of chips.

Taking the longer-term view is important to inform policy because most investments in this sector have to be long-term. The longer-term view reveals the key broad patterns that have led to today's global distribution of the key elements of the supply chain and thus provides an indication where the future might lay.

Analysis of the supply chips chain usually concentrate on the different physical inputs necessary for the production of chips. But software and design of the circuitry on chip have become increasingly important, especially for the most advanced types of chips that are nearing some physical limits on miniaturization. The economic value added embedded in the final product is thus coming less and less from the production of chips than from their design (the success of Nvidia is only the most prominent example of this trend).

However, the focus on the most advanced types of chips might be misleading because different applications require different types of chips and thus different technologies that are at different stages of development where design and software play.

3 Chips in the European supply chain: What kind of chips are needed in Europe?

Different types of chips fulfill very different functions and are thus not really substitutes. As their name indicates, memory chips serve only to store information. Logic chips constitute the type of chip at the centre of attention as they perform billions of calculations needed in data processing, AI and consumer electronics. The chips in smartphones need extremely fine patterns, called nodes (5 nm now standard) that absorb as little current as possible. By contrast, a chip needed to regulate the power of an electrical motor must have relatively wide nodes to absorb a substantial current. Moreover, the software can be very simple.

In the logic of securing a source of domestic supply the key issue for European policy makers is to find out what kind of chips are needed in Europe. The general finding is that the usual focus on the most advanced types of (logic) chips is not warranted in the case of Europe because they are simply not used by European industry.

The automotive sector that dominates European chips demand has different requirements for chips than the consumer electronics industry (Lawrence and VerWey 2019). Consumer electronic chips are designed to work at room temperature, chips for cars must work between minus 25 and plus 120 degrees Celsius. Semiconductors for cars are expected to work for at least 15-20 years (against 5 years for consumer electronics) and the failure rate tolerance is one in a billion (but one in a million for consumer electronics).

4 The globalization of the supply chain: From integrated manufactures to fabless (with Fabs elsewhere)

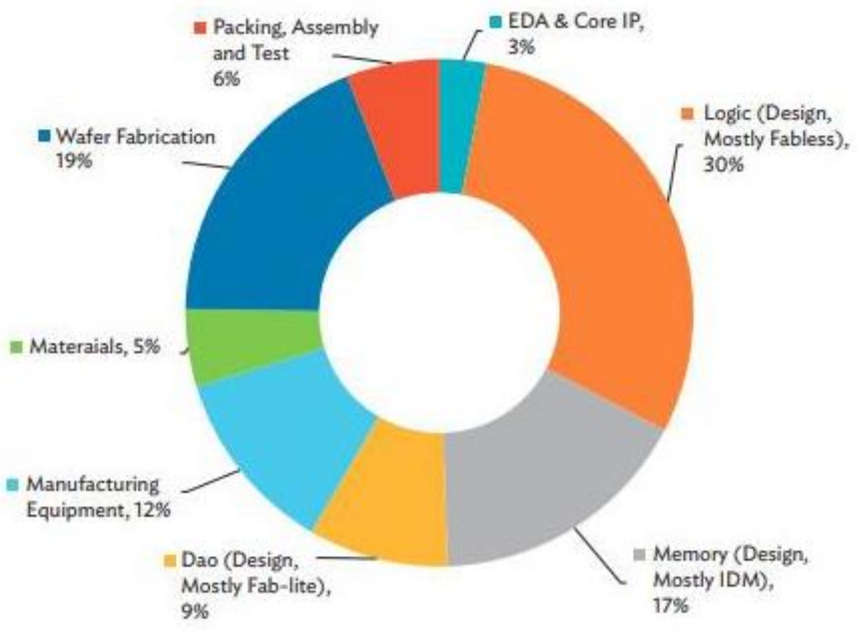
The supply chain of Chips has over time become global with a number of companies providing different inputs, thus creating potentially strategic choke points as well described in Miller 2022. Ciani and Nardo (2022) and Rosati et al. (2023) provide detailed analysis of the position of the EU in the chip supply chain.

This paper concentrates only on the economics of two specific aspects, the differences across different types of chips and the bifurcation of production and design.

5 The increasing importance of design

The attention of policy makers is focused on the hardware, i.e. how and where chips are produced. This might be wrong. Recent data suggests that more than half of the total value added of the semiconductor industry now comes from software/design Palma et al 2022. Figure 1 shows also the differences across different types of chips (memory, logic DAO). See also Annex III for more detail. Wafer fabrication creates less than one fifth of the total value added. A generation ago, the largest firms integrated all steps from design to wafer fabrication. However, this changed over time as the capital outlays necessary for the most advanced node Fabs rose exponentially starting the early 1980s. Ibrahim et al. 2014 report that the cost of a standardized Fab rose 70-fold between 1980 and 2015. It has since risen even further with recent estimates reaching 20 bn USD for the construction of a single fab (for advanced logic ships, Tembey et al 2023). Start-ups with innovative ideas for chip design, that are key for logic chips, could not afford these costs and thus opted to have their ideas produced elsewhere.

Figure 1: Semiconductor Value Added by Activity, 2019 (in percent)



Source: SIA (2021)

This trend towards fabless firms represents a further step in the increasing specialization of the overall production process where the intangible element becomes ever more important. The design stage requires a different corporate culture than fabrication, which requires long term planning and capital expenditure discipline. The best illustration of the increasing importance of the design stage is Nvidia, whose stock market valuation has increased so much, which is a so-called fabless 'chip maker', meaning that it does not produce chips, it only designs the circuits and then has the chips produced by others, i.e. independent foundries, like TMSC.

The difference in the cost structures between integrated manufacturers and fabless can be illustrated by using Nvidia and Intel as the most prominent examples. Over the last three years, these two companies had similar revenues of around 60 bn USD for Intel (but declining) and 50 bn USD for Nvidia (but increasingly rapidly). For Nvidia material inputs were worth less around 12 % of revenues, against around 33 % for Intel. Operating expenses accounted for less than 20% of revenues in 2023, against 40 % of Intel.[2]

The difference in capital intensity is even larger between a fabless company like Nvidia and a (contract) manufacturer like TMSC (whose full name is Taiwan Semiconductor Manufacturing Company). The capital expenditure of TSMC is equivalent to almost 50 % of its revenues compared to only 8 % for NVIDIA.[3]

The movement towards 'Fabless' semiconductor companies started naturally in the US because that is where initially most of the integrated manufactures were. But the Fabs mostly arose in Asia. This is often ascribed to short term management incentives in the US. However, a more fundamental force was driving the movement of Fabs towards Asia: the availability of capital.

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[2] Source: Company accounts, https://s201.q4cdn.com/141608511/files/doc_financials/2024/ar/NVIDIA-2024-Annual-Report.pdf, https://www.intc.com/filings-reports/all-sec-filings/content/0000050863-24-000010/0000050863-24-000010.pdf.

[3] Source: European Commission, Industrial Scoreboard, Intel as an integrated manufacturer has capex worth over 35 % of revenues closer to TMSC than to NVIDIA.

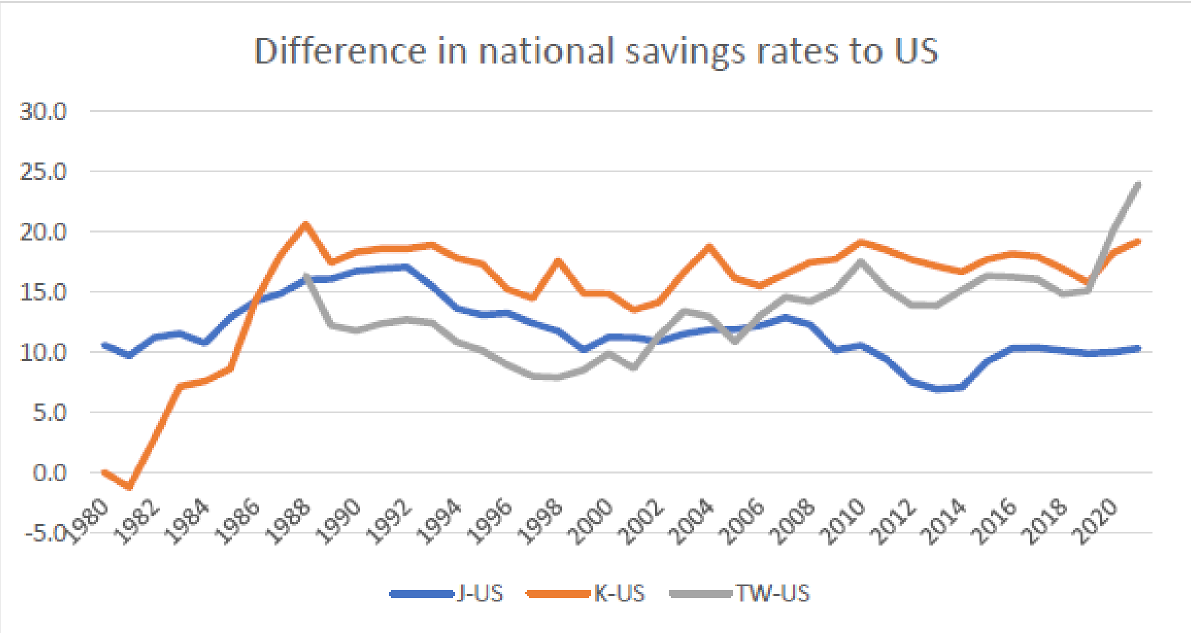
6 Capital abundance as the driver of Fab location

With the Fabs becoming ever more expensive it is natural that they should migrate to countries with abundant capital. Inn principle one could argue that with an integrated global capital market it should not matter for the location of capital-intensive projects where savings are generated. But a large literature on the FeldsteinHorioka puzzle has shown that as a matter of fact, countries with higher savings rates tend to have higher investment rates (Apergis and Tsoumas (2009).

Asian economies like Japan, Korea and Taiwan had then, and still have today, much higher savings and investment rates than the US. It was thus natural that the newest and most expensive Fabs should increasingly be constructed where capital was most abundant.

Figure 2 shows the difference between the national (not household) savings rate of three Asian countries and those of the US. For example, the value of close to 15 % in 1986 for Japan (and Korea) means that these two countries had savings rates that were 15 points of GDP higher than that of the US (Japan and Korea had then savings rates of around 35 % of GDP, compared to about 20 % of GDP for the US.

Figure 2: Difference in national savings rates to US



Note: for the 1980s savings were calculated as investment plus the current account (both as % of GDP). Source: own calculations based on IMF data.

During most of the 1980s Japan had the highest gap in savings rates relative to the US, and its chips production grew rapidly to dominate the global market. By 1990 Korea has even higher savings rates than Japan and in the early 2000s Taiwan caught up. It is not a coincidence that this was also the period during which leadership in the production of chips shifted towards these two countries. All throughout these years US integrated manufactures lost interest in producing wafers, and these two Asian countries started large scale chip production. Figure 3 below shows how by 1990, 6 out of the top 10 global semiconductor companies were Japanese against only 3 from the US. By 2000 only 3 Japanese were left were left (with also 3 Europeans and 3 from the US). By 2020 7 of the top 10 are from the US, but most of them are fabless (with the notable exception of

Intel). This illustrated how the value added in chip making has increasing migrated towards the design stage.

Figure 3: Top 10 semiconductor companies by revenue

	1990	2000	2010	2020	2030
1	NEC	Intel	Intel	Intel	Leadership to be determined
2	Toshiba	Toshiba	Samsung	Samsung	
3	Hitachi	NEC	Toshiba	SK Hynix	
4	Intel	☆ Samsung	Texas Instruments	Micron	
5	Motorola	Texas Instruments	Renesas[1]	Qualcomm	
6	Fujitsu	Motorola	☆ SK Hynix	☆ Broadcom	
7	Mitsubishi	☆ STMicroelectronics	STMicroelectronics	☆ Nvidia	
8	Texas Instruments	Hitachi	☆ Micron	Texas Instruments	
9	Philips	☆ Infineon	☆ Qualcomm	☆ Apple	
10	Matsushita	Philips	Elpida[2]	Infineon	
Dropped out of top 10:		• Fujitsu • Mitsubishi • Matsushita	• Motorola • Hitachi • Infineon • Philips	• Renesas • STMicroelectronics • Elpida	

- US
- Japan
- Europe
- South Korea
- Taiwan
- ☆ = New entrant in top 10

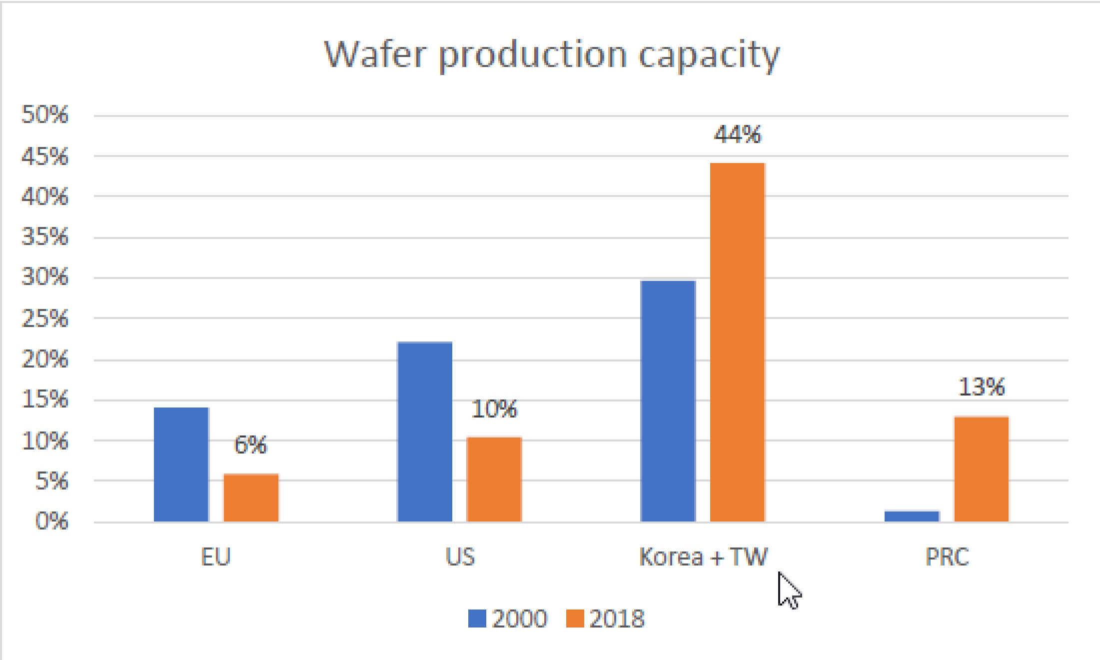
Source: Palma et al. 2022
The list excludes contract manufacturers.

By 2020 there was only one European company left among the top 10 semiconductor companies (against 3 in 2000). It is not clear whether Infineon would today still qualify among the top ten.

The number of foundries provides another metric. It has declined over the last decades in both the US and the EU by a similar percentage, around one third leading to a loss of about one third of their market share in the number of foundries for both.[4]

Since Fabs have tended to become bigger the decline of the market share of both the US and Europe has been even more pronounced in terms of Fab capacity. As can be seen in Figure 4, the share of Europe of global wafer production capacity halved, declining from close to 15 % to 6 %, whereas the shares of Korea and Taiwan have increased by almost 50%. These two countries accounted for 44 % of the global total. China was absent in 2000, but in 2018 it overtook the US.

Figure 4: Wafer production capacity



Capacity measured in thousands of 8-inch (200 mm) equivalent wafer starts per month.
Source: Yeung et al. 2.23, table 4.5.

Against this background, it is clear that, absent massive subsidies, the capital-intensive parts of the supply chain will not return to relatively low savings economies like the US or the EU.[5]

Another reason for fabs to migrate to Asia is that that is that this region dominates the production for the goods that incorporate many chips, smartphone and consumer electronics in general. By

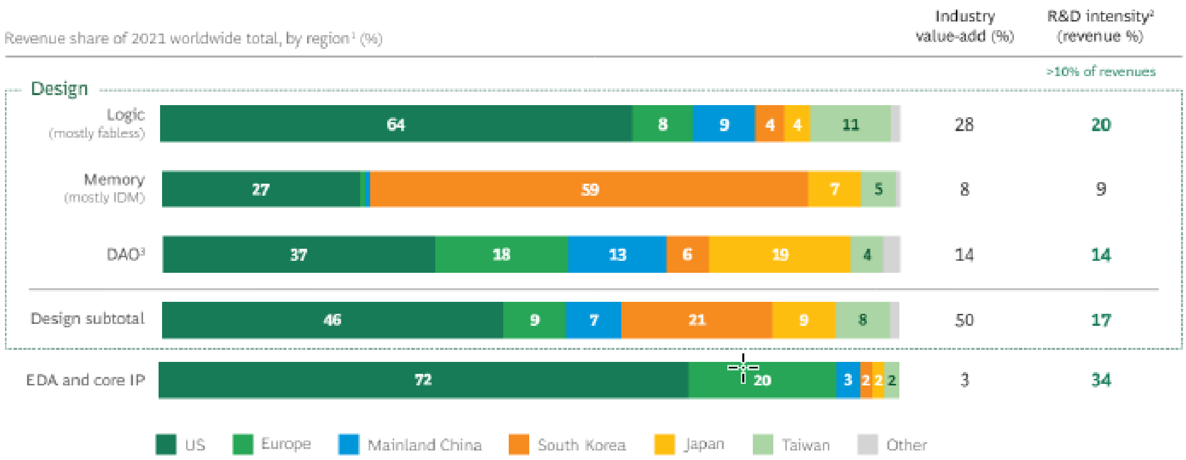
4 See Table 4.5 in Yeung et al. 2023.

5 The one exception to the qualification of 'low savings' economy might be Germany, whose national savings rate is now at close to 28 % of GDP close to that of Japan. But the national savings rate of Germany should matter less than the saving rate of the EU as a whole, given that European capital markets are much more integrated than global ones, at least within the euro area.

contrast, Europe has a strong automotive industry. It is thus natural that the few European fabs mainly produce chips for that industry.

The design phase has seen another concentration, namely in the US, which dominates this sector. Here again one finds considerable differences across different types of chips as documented in Palma et al 2022. US firms account for almost two-thirds of the global total in the market for the design of Logic ships, which are the ones at the center of attention of policy makers. In memory chips Korea dominates. European firms account in all areas for than 10 % of the market, except for the small DAO (Discrete, Analog and Opto) segment mostly used by the automotive industry and the even smaller EDA segment.

Figure 5: Semiconductor design revenues by country, as percent of global total



Source: Palma et al. 2022

The dominance of the US in the design phase seems natural in the light of the fact that US companies dominate investment in research and development in software industries as documented by Fuest et al. (2024).

The industry-wide evidence regarding the growing importance of the design stage should be buttressed by a more detailed analysis of the value added incorporated in different types of chips. A priori one would expect that the design stage is much less important for memory than for logic chips.

7 Chips manufacturing equipment

Part of the increasing cost of fabs is due to the escalation of the cost of the ever more sophisticated machinery needed to produce the most advanced chips with ever smaller nodes (another important part is the need for every cleaner 'clean rooms' to protect the wafers from impurities). This machinery constitutes another important part of the supply chain, so critical that the US administration has pressured the leading EU producer of these machines, ASML, to stop providing its most advanced models to China.

The economic importance of this sector is difficult to estimate since fabs not only necessitate these sophisticated machines to etch ever smaller circuits on the wafers, but also a number of other inputs, including advanced filters, ultra-pure chemicals, etc.). Industry sources report a global market of around 100 billion USD (2023), that is expected to grow at 8 % per year. The industry leader, ASML, would alone have a market share of about 20 % given its global sales of over 20 billion euro in 2022 (Rosati et al. (2023) estimate an overall share of the EU in chips manufacturing equipment of 20 %). The vast majority of the sales of ASML are in Asia, with almost nothing in Europe.

In this sector the EU has a strong revealed comparative advantage, with exports at close to 28 billion USD, and imports of around 8 billion USD. The EU surplus on chip making machinery is larger than the deficit on chips. Moreover, exports of this type of machinery have increased steadily over the last decade while imports have remained steady. It is somewhat surprising that support for the prominent European position in this type of machinery barely figures in policy discussions.

8 Chips in the European Supply Chain

Chips are used in many different products. Smartphones constitute a ubiquitous example, but the trend towards the 'Internet of Things' more and more basic consumer goods also incorporate chips. As mentioned above, the chips required for the IoT usually have only rudimentary functionality and thus do not need to be based on the smallest nodes, as is the case for smartphones. The chips required for the massive data centres are again different as they have to be programmed for specific tasks.

9 Chips Shortage

The chips shortage of 2021/2 is often used to show the key role of chips in the supply chain (see Rosati et al (2023) for a survey). It is thus useful to briefly summarize its genesis. Its origins stem from the decision of European automobile producers to cut their orders for chips when the Covid crisis hit in early 2020. The chips producers then sold the production no longer under long-term orders from the automotive industry to the electronic consumer goods industry, which apparently required similar types of chips. With the surge in consumption there were then too few chips available, and the automotive industry no longer had a priority claim on them.

This episode is supposed to show the key importance of Chips in the European supply chain. The Association of European Automotive Producers (ACEA) called for more EU-made Semiconductors. An ECB study shows that the dip in automotive production during the chips shortage period was specific to Europe. Production of cars actually increased in other major markets.

From an economic perspective the concept of a 'shortage' would mean that prices should increase when production is disrupted. But the claim that there was a physical 'shortage' of chips in Europe causing a fall in automobile production (and other goods) is difficult to square with the fact that imports of chips increased (in value) throughout 2021 and 2022 (from 32 in 2020 to 54 billion USD in 2022). The evidence of a shortage in the sense of a fall in supply is thus weak although an increase in chips prices might of course have over-compensated for a fall in the quantity of imports. The US BLS publishes a semiconductor price index that shows a dip in early 2020 followed by an increase in 2021/2. But the increase in the US import price index from the trough in 2020 is only about 10 % and thus not indicative of squeeze on global supplies and certainly not sufficient to explain the increase in the value of imports of chips of over 66 % during this period. Another element that is not compatible with a shortage is that extra-EU exports of chips also increased by 40 % during this period.

The increase in exports was possible also because, major European chip manufacturers increased production and the US Semiconductor Industry Association reports an increase in global capacity utilization rates over this period. All in all, there is thus limited evidence that Covid related supply disruptions lead to a global chip shortage, and it is very difficult to accept the claim that a chips shortage had a large negative impact on the automotive sector in general. The problems in Europe might have been caused by a simple miscalculation of the European car producers that are used to having monopsony power over their suppliers and discovered only too late that this was not the case for chips.

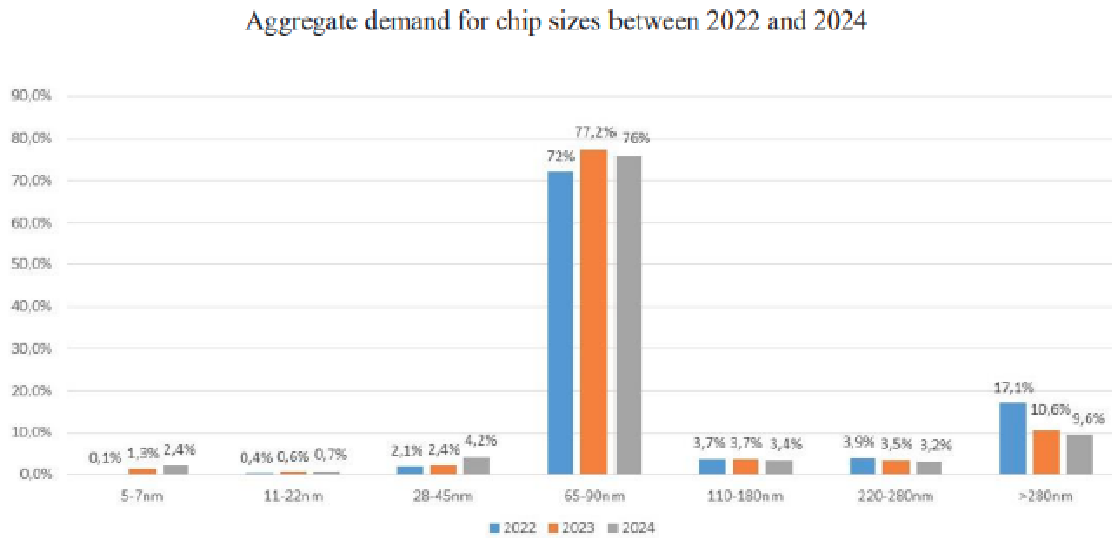
10 What type of chips are needed in Europe?

Here again one has to distinguish between different types of chips. Since there is no smartphone production in Europe, there is little demand for the advanced logic chips they incorporate.

A good source for the type of chips demanded by EU industry is the survey of the industry, undertaken by the Commission in preparation of the Chips Act, in which most respondents came from a small number of large incumbent enterprises.

Figure 6 below shows that three-fourths of the demand for chips anticipated by EU producers for the next years is in the 65-90 nm nodes.[6] (Compared to the 5nm of advanced Asian producers). The types of chips demand by EU industry are thus about 3-4 generations behind the technology frontier (in miniaturization).

Figure 6: Demand for chip sizes between 2022 and 2024 (43 respondents)



Source: European Commission 2022, European Chips Survey,
https://digital-strategy.ec.europa.eu/en/library/european-chips-survey

More detailed evidence would be needed to obtain a clearer understanding of what types of chips enter the European value chain and what proportion is provided by domestic EU production. Rosati et al. (2023) report that "All production, including Chips and Printed Circuit Board (PCB) manufacturing, is concentrated in technologies above 28 nm."

The automotive industry will be one key driver of chip demand. A McKinsey study, Burkacky et al. 2022, predicts that automotive demand will outstrip other sectors, increasing from 8 % to about 15 % of the global chips market. A key driver behind this growth will the switch to electrical (or hybrid

[6] See figure 6. Curiously, the Commission comments this finding with the remark that there is 'clear growth for smaller technology nodes (categories: 5-7nm, 11-22nm, and 28-45nm). The growth rates of these smaller categories are indeed higher, but they remain marginal in the European market. Rosati et al. (2023) also report survey evidence.

ones) vehicles that require more DAO chips to control electrical motors.[7] Lawrence and VerWey (2019) come to a similar conclusion. These trends are consistent with the results of the Survey presented above. Both sources report that a car with an internal combustion engine and without autonomous driving features embodies about 300-500 USD worth of chips. By contrast, an electric vehicle with autonomous driving technology needs chips worth up to 4 000 USD. European demand should also increase strongly given the strong automotive industry in Europe, and existing European chips producers are well positioned to compete for the (mature) chips needed for the electric power train, but experience suggests that the more sophisticated (logic) chips needed for the software managing autonomous driving are likely to come from Asia.

[7] (So-called infotainment will also increase in importance, but this will require the same chips as those used in consumer electronics in general.)

11 From Fab to chips supply chain?

An interesting, related issue is whether the massive state aid allocated by Germany for large fabs in Eastern Germany will create a European supply chain of intermediate products[8]. Most of the inputs needed to construct and run a fab are traded globally because they require in turn highly specialized manufacturing processes. The value per unit of these specialized inputs is so high that transport costs become secondary. For example, only one third of the suppliers of even an EU based producer like Infineon are located in the EU. It is thus highly unlikely that the mere presence of a giant Fab in an industrially weak region would lead to the emergence of a local industry capable of producing ultra-pure chemicals or other inputs. The single fab in Germany will anyway constitute only a small part of the global market for these products, providing little incentive to locate nearby for the most technologically advanced items.

[8] See Soete and Stierna (2023) on place-based innovation and industrial policies. The software is anyway concentrated in the US and independent of the location of chips producers or their customers.

12 Security considerations. A Chips war?

A chips war has already started between the US and China as the US administration is increasing its efforts to deny Chinese industry access to advanced chips and the technologies deemed critical to produce such chips. The explicit geopolitical aim is to enhance US national security[9] by ensuring that China does not have access to this critical technology. This represents an important shift since in the past the US had been content to maintain an advance of one or two generations of technology.

The EU does not have a 'number one' position to defend and thus has no explicit policy of denying China advanced technologies, also in part because European Firms do not possess much critical technologies. The Dutch firm ASML, the leader in the machines used to etch ultra-fine patterns on wafers, mentioned above constitutes the one big exception.

The 'national' security concerns of the EU are more linked to the economy, namely to derisk European industry. The Chips Shortage of 2021/2 is often taken as an example of the cost of a potential supply disruption for chips. The facts reported above suggest that this episode was due more to an increase and shift in chips demand, rather than a physical shortage. However, a physical shortage could arise in future. Of particular concern is the position of Taiwan as the main source for the most advanced chips.

For example, the massive subsidies for 'first-of-a-kind' fabs (under the cover the Chips Act) have been justified by the argument that domestic production of advanced chips provides protection against a potential supply disruption from Taiwan. But this argument needs to be nuanced. EU fabs will at any rate have only a small market share (20 % is the official aim of the EU Chips Act) meaning that the vast majority of EU needs must be covered by imports (of which very little from China). The real question is how much would be gained from having at least part of European chips consumption produced in Europe. A concrete example can illustrate the limited gain from domestic production.

The German government is providing grants of 10 billion to support a new fab of Intel that will produce advanced node chips (reportedly the first fab in Europe using the most advanced machinery from ASML). This fab would provide a European source for advanced chips should supplies from Taiwan be interrupted. In this worst-case scenario, the price for chips will sharply increase globally. Intel will then have a strong incentive to sell its output to the highest bidder, which will not be necessarily European. The Commission could then issue 'priority-rated orders' under the Chips Act to force Intel to prioritize some EU customers. It is not clear which sectors the Commission could and would choose to favor (including the quantity and the price to be paid), but this scenario seems to constitute a concrete example of how domestic production subsidized under the Chips Act would increase European security of supply.

However, issuing any priority-rated orders to the detriment of third country customers would lead to reactions from the EU's partners that might stop the supply of critical inputs. The US in particular could intervene in the ability of Intel to continue production as US technology will certainly be used

[9] Neither the US, nor the EU mention chips for weapons in their motivation for support to the chips industry. Military applications require in most cases not the most advanced nodes, but very robust chips, often produced in very limited numbers by special foundries.

in its German fab. It is thus doubtful that the advantages from some EU production of advanced chips would be very large.

13 Conclusions

The key trend over the last decades has been the rising importance of design and software as producers have packed ever more elements on a single chip. European firms are present in the physical aspects of the global supply chain, mostly through the near monopoly position of the Dutch producer of advanced lithographic machines, essential for the most advanced chips. But most production takes place in Asia while the design and software come from the US. European Fabs produce mostly mature node chips needed in manufacturing, mainly the automotive sector. This constellation confirms the more general finding of Europe being stuck in a 'middle tech' trap (Fuest et al 2024).

Strengthening the EU presence in the chip 'ecosystem' requires addressing this fundamental weakness with support for software development and R&D in the critical elements of the supply chain. Even these modest steps would require additional resources. Little will be gained by just shifting funding from other areas.

Concentrating funding on the end of the supply chain (i.e. fabs) in the hope that the other elements will then follow is unlikely to work for the reasons outlined above.

For the 'national' security of the EU China is not the key problem in the chips sector. The dominance of Taiwan in advanced chips is a global issue, but which affects the EU relatively than others. Moreover, the increasing importance of software gives the US an additional lever to constrain EU exports towards China. Strengthening the EU's position in the supply chain, both in the physical and the software part seems more promising than subsidizing a small number of fabs.

As an aside one should note that European (and in general Western) subsidies for advanced chip production will benefit mainly China, which is by far the biggest net importer of chips (Gros 2024).

References

Apergis, N. and Tsoumas, C., 2009. A survey of the Feldstein–Horioka puzzle: What has been done and where we stand. *Research in Economics*, *63*(2), pp.64-76. https://www.sciencedirect.com/science/article/pii/S1090944309000155

Burkacky, Ondrej with Julia Dragon, and Nikolaus Lehmann, 2022, *The semiconductor decade: A trilliondollar industry* Mckinsey, The semiconductor decade: A trillion-dollar industry | McKinsey.

Business Saxony 2023, 10,000 Million Euros: Semiconductor Manufacturer TSMC Invests in Dresden, August, 2023, https://business-saxony.com/en/10000-million-euros-semiconductor-manufacturer-tsmcinvests-in-dresden

Ciani, A., & Nardo, M. (2022). The position of the EU in the semiconductor value chain: evidence on trade, foreign acquisitions, and ownership (No. 2022/3). JRC Working Papers in Economics and Finance.

European Commission, 2022 "European Chips Survey", https://digitalstrategy.ec.europa.eu/en/library/european-chips-survey

Conway, E. (2023). *Material World: A Substantial Story of Our Past and Future*. Random House.

European Commission, 2013, 'Comparison of European and non-European regional clusters in KETs. The case of semiconductors' (Final Report: A study prepared for the European Commission DG Communications Networks, Content & Technology, Brussels: European Union). https://www.ipcei-me.eu/wpcontent/uploads/2020/11/ComparisonofEuropeanandnon-EuropeanregionalclustersinKETsthecaseofsemiconductors_2013.pdf

Flamm, K. and Reiss, P.C., 1993. Semiconductor dependency and strategic trade policy. *Brookings Papers on Economic Activity. Microeconomics*, *1993*(1), pp.249-333.

Fuest, Clemens, Daniel Gros, Philipp-Leo Mengel, Giorgio Presidente and Jean Tirole (2024a) Reforming innovation policy to help the EU escape the middle-technology trap, Voxeu.org, 19 Apr 2024, https://cepr.org/voxeu/columns/reforming-innovation-policy-help-eu-escape-middle-technology-trap

Fuest, Clemens, Daniel Gros, Philipp-Leo Mengel, Giorgio Presidente and Jean Tirole (2024b) EU Innovation Policy - How to Escape the Middle Technology Trap, Institute for European Policymaking at Bocconi University, https://iep.unibocconi.eu/publications/eu-innovation-policy-how-escape-middletechnology-trap

Gros, Daniel, 2022, "The European Chips initiative - Industrial policy at its absolute worst", CEPS, https://www.ceps.eu/the-european-chips-initiative-industrial-policy-at-its-absolute-worst/

Gros, Daniel 2024 Western Chip Subsidies Will Benefit China, Project Syndicate, January, https://www.project-syndicate.org/commentary/us-eu-chip-subsidies-will-benefit-china-by-lowering-costsby-daniel-gros-2024-01

Huggins, R., Johnston, A., Munday, M. and Xu, C., 2023. Competition, open innovation, and growth challenges in the semiconductor industry: the case of Europe's clusters. *Science and Public Policy*, *50*(3), pp.531-547. https://academic.oup.com/spp/article/50/3/531/7072258

Ibrahim, K., Chik, M.A. and Hashim, U., 2014, August. Horrendous capacity cost of semiconductor wafer manufacturing. In *2014 IEEE International Conference on Semiconductor Electronics (ICSE2014)* (pp. 329331). IEEE.

Irwin, D.A., 1996. Trade policies and the semiconductor industry. In *The political economy of American trade policy* (pp. 11-72). University of Chicago Press.

Ji, Kan, Lize Nauta, James Powell 2023 Mapping Global Supply Chains – The Case of Semiconductors, Rabobank, https://www.rabobank.com/knowledge/d011371771-mapping-global-supply-chains-the-case-ofsemiconductors

Lawrence, Amanda and, John VerWey, 2019, U.S. *The Automotive Semiconductor Market – Key Determinants of U.S. Firm Competitiveness*, International Trade Commission (USITC) Executive Briefings on Trade, May 2019.

Miller, C. (2022). Chip war: The fight for the world's most critical technology. Simon and Schuster.

Palma, Ramiro, Raj Varadarajan, Jimmy Goodrich, Thomas Lopez, and Aniket Pati 2022, "The Growing Challenge of Semiconductor Design Leadership", November 2022 https://web-assets.bcg.com/3f/b4/fd384ccd46dc8a381bd61a648105/bcg-the-growing-challenge-ofsemiconductor-design-leadership-nov-2022-r.pdf

Rosati, N., Bonnet, P., Ciani, A., Duch Brown, N., Miguez, S., Zaurino, E. (2023) "The EC consultation on the semiconductors' value chain" JRC Technical Report,

SIA (2021), 2020 State of the U.S. Semiconductor Industry, Semiconductor Industry Association, https://www.semiconductors.org/wp-content/uploads/2020/07/2020-SIA-State-of-theIndustry-Report-FINAL-1.pdf

Consulting Group and SIA (Semiconductor Industry Association). https://www.semiconductors.org/wpcontent/uploads/2024/05/Report_Emerging-Resilience-in-the-Semiconductor-Supply-Chain.pdf

Soete, L., & Stierna, J. (2023). Revisiting Schumpeter in Europe: Place-based innovation and transformative industrial policy. https://cris.maastrichtuniversity.nl/en/publications/revisiting-schumpeter-in-europe-placebased-innovation-and-transf

Tembey, Gaurav, Adriana Dahik, Christopher Richard, and Vaishali Rastogi "Navigating the Costly Economics of Chip Making", Bostong Consulting Group, September 28, 2023, https://www.bcg.com/publications/2023/navigating-the-semiconductor-manufacturing-costs

R A J V A R A D A R A J A N / I A C O B K O C H - W E S E R / C H R I S R I C H A R D / J O S E P H F I T Z G E R A L D / JASKARAN SINGH / MARY THORNTON / ROBERT CASANOVA / DAVID ISAACS (2024) EMERGING RESILIENCE IN THE SEMICONDUCTOR SUPPLY CHAIN MAY, Boston

Yeung, H.W.C., Huang, S. and Xing, Y., 2023. From fabless to fabs everywhere? Semiconductor global value chains in transition WTO reports https://www.wto.org/english/res_e/booksp_e/07_gvc23_ch4_dev_report_e.pdf.

ZVEI (Zentralverband der Elektro- and Digitalindustrie), 2024 PWC Study on the economic and social effects of microelectronics funding, forthcoming.

List of figures

Annexes

Annex 1. Excerpts from: Regulation strengthening Europe's semiconductor ecosystem and amending the EU's Chips Act https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1781

The following provisions constitute the core of legal provisions regulating how the EU could react to a crisis. The legal text does not provide clarity on a number of points:

When can the Commission intervene? This requires a crisis defined in art. 23, which in turn seems to require two conditions, 'serious disruptions in the semiconductor supply chain' (a concept not clearly defined) and that this affects critical sectors. The list of 13 critical sectors in the Annex contains mostly industries that have little need for new chips to maintain their current operations. The exception would by transport if one interprets the production of cars as part of the transport sector. Similarly, a large need for new chips could be construed if energy comprises the installation of new renewable plants. But the number of chips needed in this sector is rather low and maintaining the current operation of the electricity grid does not require continuously new chips. But these aspects are not clarified in the legal text. It is thus not clear whether a lack of chips for the automotive sector (and maybe renewables) would qualify as a crisis.

Article 27 provides for common purchases. This instrument was very useful during the Covid emergency. But the markets of vaccines and chips are completely different. The billions of vaccine doses need to stop the spread of Covid were identical products. By contrast, the needs for chips of hospitals or the public administration concern small lots of very different chips, rendering common purchases impractical.

Article 23

Activation of the crisis stage

1. A semiconductor crisis shall be considered to occur where:

   (a) there are serious disruptions in the semiconductor supply chain or serious obstacles to trade in semiconductors within the Union causing significant shortages of semiconductors, intermediate products or raw or processed materials; and

   (b) such significant shortages prevent the supply, repair or maintenance of essential products used by critical sectors to the extent that it would have serious detrimental effect on the functioning of the critical sectors due to their impact on society, economy and security of the Union.

3. The Council, acting by qualified majority, may activate the crisis stage by means of a Council implementing act. The duration of the crisis stage shall be specified in the implementing act and it shall not exceed 12 months.

Article 26

Priority-rated orders

1. Where the crisis stage is activated pursuant to Article 23, the Commission may require integrated production facilities and open EU foundries to accept and prioritise an order of crisis-relevant products (priority-rated order). Such an obligation shall take precedence over any performance obligation under private or public law.

2. Where applicable, the obligation under paragraph 1 can be imposed to other semiconductor undertakings which have accepted such possibility in the context of receiving public support.
3. When a semiconductor undertaking established in the Union is subject to a third-country priority-rated order measure, it shall inform the Commission. If that obligation has a significant impact on the operation of certain critical sectors, the Commission may require that undertaking, where necessary and proportionate, to accept and prioritise orders of crisis relevant products in accordance with paragraphs 5, 6 and 7.
4. Priority-rated orders shall be restricted to beneficiaries who are users of semiconductors from critical sectors or undertakings supplying critical sectors whose activities are disrupted or at risk of disruption and who, having implemented appropriate risk mitigation measures, were unable to avoid and to mitigate the impact of the shortage. The Commission may request a beneficiary to submit appropriate evidence thereof.
5. The obligations under paragraphs 1, 2 and 3 of this Article shall be enacted as a last resort measure by the Commission via decision. The Commission shall take that decision after consulting the European Semiconductor Board and in accordance with all applicable Union legal obligations, having regard to the circumstances of the case, including the principles of necessity and proportionality. The decision shall, in particular, have regard for the legitimate aims of the undertaking concerned and the cost, effort and technical adjustments required for any change in production sequence. In its decision, the Commission shall state the legal basis of the priority-rated order, fix the time-limit within which the order is to be performed, and, where applicable, specify the product and quantity, and, where applicable, state the penalties provided for in Article 33 for non-compliance with such an obligation. The priority-rated order shall be placed at fair and reasonable price.
7. Where an undertaking is required to accept and prioritise a priority-rated order, it shall not be liable for any breach of contractual obligations that is required to comply with the priority-rated orders. The liability shall be excluded only to the extent the violation of contractual obligations was necessary for compliance with the mandated prioritisation.

Article 27

Common purchasing

1. Where the crisis stage is activated pursuant to Article 23, the Commission may, upon the request of two or more Member States, act as a central purchasing body on behalf of all Member States willing to participate (participating Member State) for their public procurement of crisis-relevant products for <u>critical sectors</u> (common purchasing). Participation in the common purchasing shall be without prejudice to other procurement procedures. The request for common purchasing shall set out reasons on which it is based and shall be used exclusively to address supply-chain disruptions of semiconductors leading to the crisis.

Annex 2. Critical sectors

1. Energy 2. Transport 3. Banking 4. Financial market infrastructure 5. Health 6. Drinking water 7. Waste water 8. Digital infrastructure 9. Public administration 10. Space 11. Production, processing and distribution of food 12. Defence 13. Security

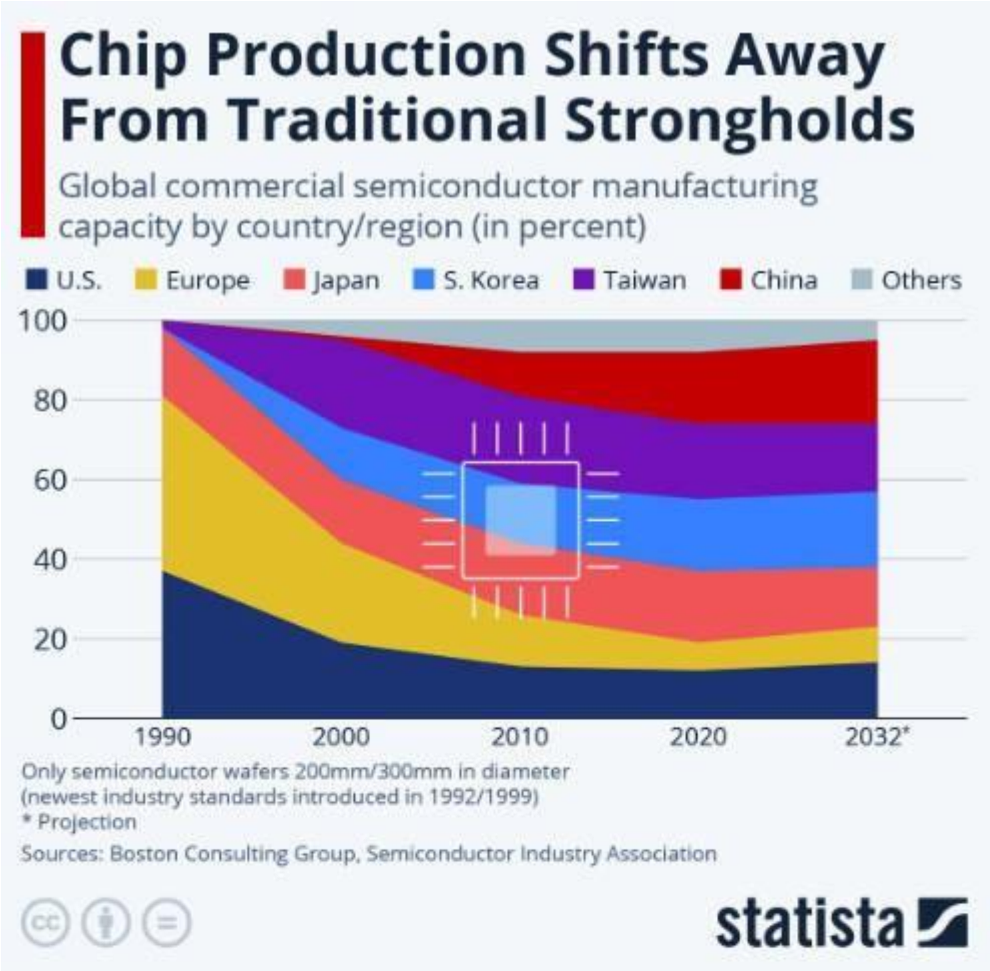
None of these sectors need a continuous supply of new chips for their regular operations that are running on an installed basis with little wear and tear on the chips themselves.

Annex 3. Chip Production Shifts Away From Traditional Strongholds

The figure 7 below has been the source claims that in the past Europe did have a strong positions in manufacturing semiconductors.

However, this has been disputed. See Jan-Peter Kleinhans (2021). Europe didn't Have 44% of Global Chip Production Capacity in the 90s. https://www.linkedin.com/pulse/europe-didnt-have-44-global-chipproduction-capacity-90s-kleinhans/.

Figure 7: Chip Production Shifts Away From Traditional Strongholds

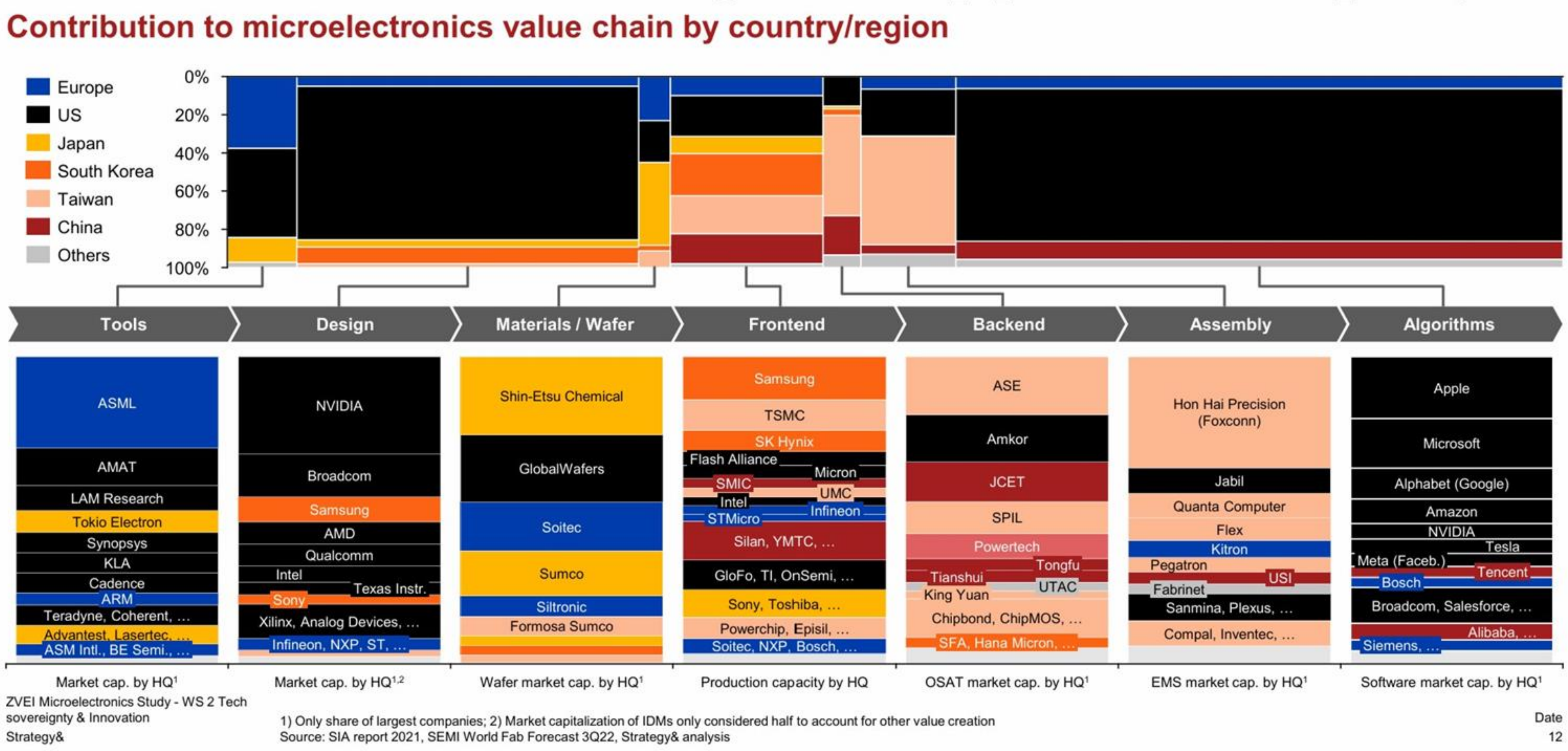


Source: Boston Consulting Group, Semiconductor Industry Association

Annex 4. Contribution to microelectronics value chain by country / region

The figure 8 below provides a rough illustration of the importance of different stages of the supply chain on the horizontal axis. Design is as large as all the physical aspects (tools, materials, frond and back-end operation, and assembly). European firms provide only an insignificant sliver within most segments, with the exception of material and tool

Figure 8: Contribution to microelectronics value chain by country / region



Source: ZVEI Microelectronics Study

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