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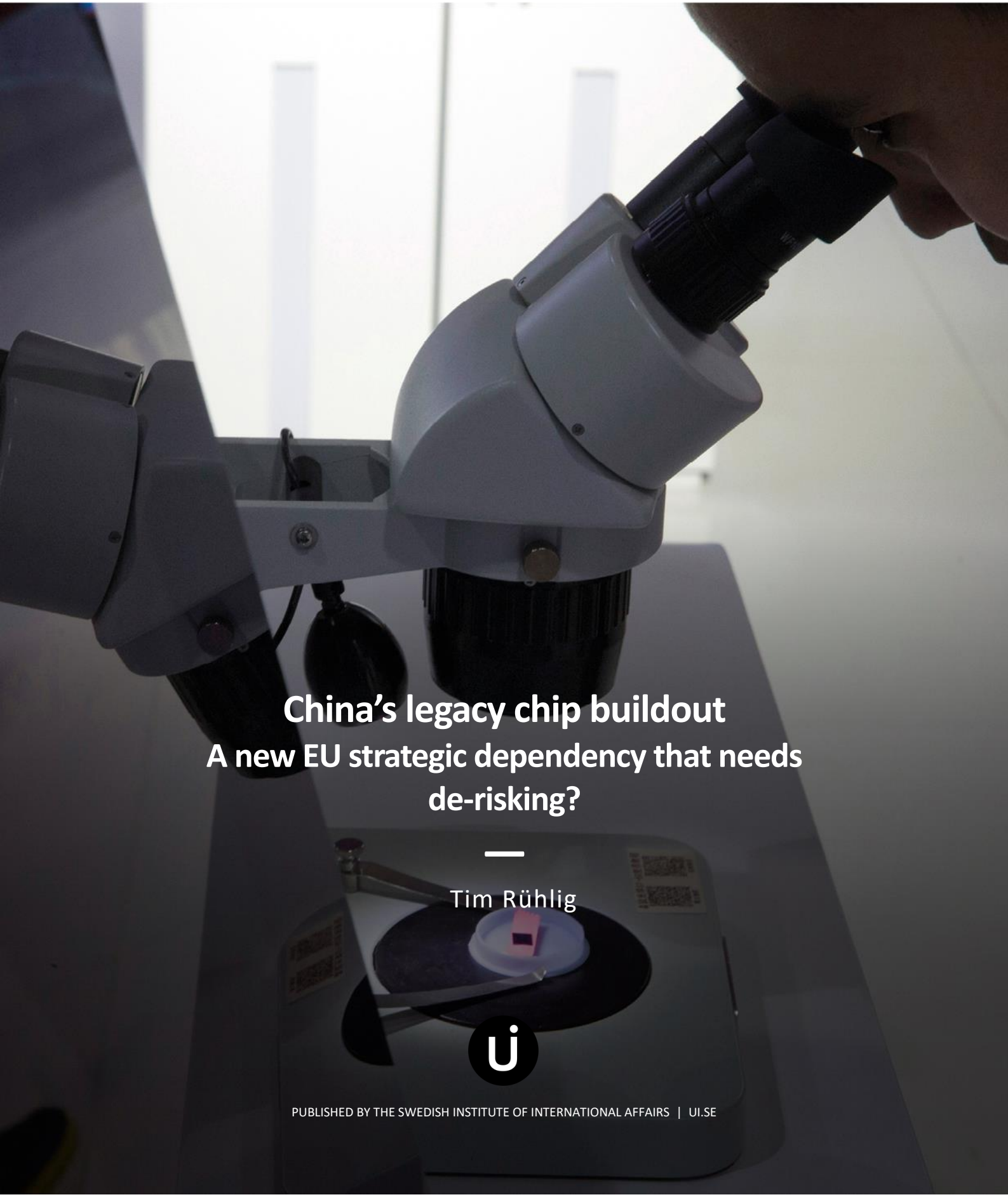

China's legacy chip buildout

A new EU strategic dependency that needs de-risking?

Tim Rühlig

PUBLISHED BY THE SWEDISH INSTITUTE OF INTERNATIONAL AFFAIRS | UI.SE

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Language review: Andrew Mash
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Introduction

Legacy chips have taken centre stage in the geopolitical rivalry between the United States and China. The European Union is concerned that it might soon be overly reliant on legacy chips from China. Legacy chips are of strategic importance as they are irreplaceable in a wide range of applications, from the automotive sector to medical appliances or the defence and aerospace sector. The challenge is real but, contrary to a popular belief, it does not stem from overcapacity. This has concrete policy consequences. Instead of "protect" measures, the EU should focus on "promote" and "partner" tools. The EU should strive to maintain a significant global market share for European chip makers by securing access to the domestic Chinese market. Furthermore, it should promote the diversification and expansion of the global supply of legacy chips, not least by expanding European investment in third countries. Finally, it should adopt strategies to maintain European technological strengths where they exist.

Background

The European Union (EU) has become increasingly concerned about strategic dependencies on Chinese technology. In a keynote address in March 2023, European Commission President Ursula von der Leyen emphasised the need to "de-risk" economic and trade relations with the People's Republic of China (PRC).[1] De-risking is now at the core of the EU's economic security. However, reducing strategic dependencies has become even more challenging. Long-term preferential treatment for domestic Chinese companies and an accelerating shortfall in domestic consumption have led to massive overcapacity in China. This overcapacity spills over into and distorts global markets. One category of strategic goods that is discussed in the context of both overcapacity and European de-risking is the older generations of chips, referred to as "mature node semiconductors" or "legacy chips".[2]

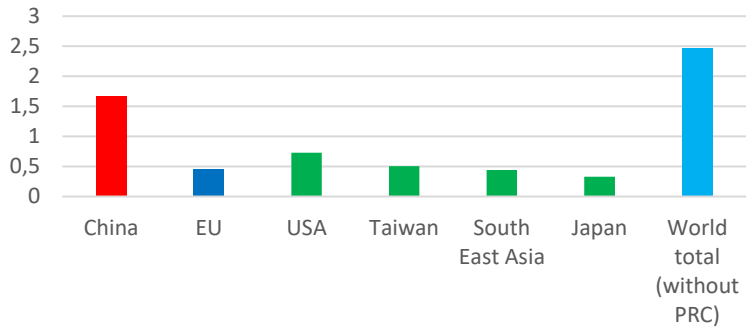
Concerns about overcapacity and economic security are interlinked but distinct. Chinese overcapacity is centred on market distortion linked to unfair competition. The concern is that European companies are being squeezed out of global markets as a result of the Chinese party-state's preferential treatment of Chinese companies. When Chinese firms cannot sell their highly subsidised chips on the weak domestic market, they export the resulting overcapacity, thereby eliminating competitive suppliers.

Economic security, by contrast, focuses on critical dependencies on Chinese supply and the risks of economic coercion or the erosion of supply chain resilience. At times, economic security also focuses on national security

[1] 'Speech by President von der Leyen on EU-China relations to the Mercator Institute for China Studies and the European Policy Centre', *European Commission*, 30 March 2023 (https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_23_2063).

[2] This paper adopts the definition of mature node semiconductors provided by the US Chips Act, accounting for everything as a legacy chip at 28 nm logic process node or higher as well as 128-layer NAND in memory.

Figure 1: Cummulated planned wafer capacity (excluding memory) at 20–45 and 50–180 nm as of March 2023, million wafer starts per month
Source: Rhodium Group



challenges. While overcapacity can result in critical dependencies, not all overcapacities pose economic security challenges. Conversely, not all economic security challenges are the result of Chinese overcapacity.

Legacy chips are currently discussed in both contexts. The United States has expressed concern that China could flood global markets with mature node semiconductors. The US government deems such a development a risk to its economic and national security.[3] The Biden Administration allocated $10 billion from the US Chips and Science Act to support legacy chip manufacturing,[4] The US is currently considering further action to counter the growing role of Chinese mature node semiconductor production.[5] In previous years, the EU focused mainly on advanced semiconductors, which were at the heart of the European Chips Act.[6] The more recent shift in attention to legacy chips has led some observers to call for an update to the European chips policy.[7]

[3] 'Readout of Secretary Raimondo's convening on legacy semiconductors', *US Department of Commerce*, 6 August 2024 (https://www.commerce.gov/news/press-releases/2024/08/readout-secretary-raimondos-convening-legacy-semiconductors).

[4] 'Biden administration releases implementation strategy for $50 billion CHIPS for America program', *US Department of Commerce*, 6 September 2022 (https://www.commerce.gov/news/press-releases/2022/09/biden-administration-releases-implementation-strategy-50-billion-chips).

[5] 'Commerce Department announces industrial base survey of American semiconductor supply chain', *US Depart of Commerce*, 21 December 2023 (https://www.commerce.gov/news/press-releases/2023/12/commerce-department-announces-industrial-base-survey-american).

[6] 'European Chips Acts', *European Commission,* 21 September 2023 (*https*://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en)

[7] Tobi Sterling, 'EU Chips Act 2.0 should include legacy chips, says industry group chief', *Reuters,* 22 November 2024 (https://www.reuters.com/technology/eu-chips-act-20-should-include-legacy-chips-says-industry-group-chief-2024-11-22/)

It is hard to overstate the economic and technological relevance of mature node semiconductors, which is a broad category of chips that does not fall under US export controls. Many industries do not require the high-performance of cutting-edge chips. Most semiconductors in applications such as cars, medical devices, drones, robotics and aerospace are produced with mature nodes. Despite the name, legacy chips are not stale technology. The connotations of terms such as "mature" or "legacy" are misleading because these chips are constantly being refined for new requirements and applications.

Innovation is driving the development of mature node semiconductors, which means that legacy chips are and will remain relevant. They accounted for around 76% of global foundry production in 2024 and it is projected that they will still constitute 70% of global foundry production in 2027.[8] Foundry production refers to one of two business models for the manufacturing of legacy chips (see below). China is the world's largest producer of mature node semiconductors and accounts for 40% of global planned manufacturing expansion (see Figure 1).

Given the continuing relevance of legacy chips, should the European Union share the concerns of the United States? Do we face a situation of Chinese overcapacity? Are there critical dependencies on Chinese legacy chips that undermine European economic security? If so, how should the EU de-risk?

The EU has initiated a stocktaking exercise to understand the risks inherent in mature node semiconductor import dependencies on China.[9] This paper seeks to support the EU's efforts by making a nuanced argument. China's market share is already substantial and likely to expand, in part due to preferential treatment by the party-state. However, it is questionable whether this has resulted in a general overcapacity with regard to a broad range of mature node semiconductors. Global demand for legacy chips, not least in Europe and China, is and will remain high. In many mature node semiconductor categories, Chinese supply is meeting genuine demand and not distorting global markets or prices. Semiconductor markets tend to work very differently from others affected by Chinese overcapacity, such as solar panels or steel.

At the same time, however, China will be able to gain enough market share to create new critical dependencies that could undermine European economic security. The degree and pace of such dependencies are likely to differ enormously across different legacy chip types. This paper discusses how divergent market structures and the technological characteristics of different chip types result in different degrees of economic security risk for the EU. Market structure mainly relates to both supply- and demand-side

[8] Chung, E., '2022 a focus for 12-inch capacity expansion, 20% annual growth expected in mature process capacity, says TrendForce', *TrendForce*, 23 January 2022 (https://www.trendforce.com/presscenter/news/20220623-11274.html); Chaio, J. and Chung, E., 'China's share in mature process capacity predicted to hit 29% in 2023, climbing to 33% by 2027, says TrendForce', *TrendForce*, 18 October 2023 (https://www.trendforce.com/presscenter/news/20231018-11889.html).

[9] Sterling, T. and Carey, N., 'Europe seeks industry views on China's older chips', *Reuters*, 5 July 2024 (https://www.reuters.com/technology/europe-seeks-industry-views-chinas-older-generation-chips-2024-07-05/).

characteristics, as well as the risk of supply shortages. Technological characteristics refer to substitutability and product lifecycles.

In a nutshell, concerns about strategic dependency on Power metal-oxide-semiconductor field-effect transistors (Power MOSFET) chips are justified. Power MOSFETs are semiconductors that handle high power voltages at high switching speeds. They have a wide range of applications, such as in consumer electronics, radio-frequency applications, transport technology and the automotive sector. China could also gain substantial market share of NAND flash memory. NAND are long-term memory chips that are indispensable in any device that runs software. However, Europe might be less affected by market dominance, which would probably only be temporary due to US export controls. Strategic dependencies on Chinese-made general-purpose microcontrollers are unlikely. These are tiny computers on a single chip that have a broad range of applications, such as measuring, sensing and controlling in consumer electronics, cars, energy grids and hospitals, among other sectors.

In sum, economic security concerns are justified but not to the same degree across all legacy chip types. Such challenges are unlikely to be primarily the result of overcapacity.

Whether risks stem from overcapacity or are related purely to economic security is not an academic question. It has concrete practical implications. Policies to tackle overcapacity are mostly protective – even if the aim is to reduce market share not only of the Single Market but also globally. Economic security concerns, by contrast, aim for diversification to reduce dependencies and their coercive potential. In this context, the European Economic Security Strategy has usefully identified three interrelated types of policy measure that it structures in a triangle of "promote", "protect" and "partner".[10] Promote refers to policy measures that provide a conducive environment for, or direct incentives to build, critical industrial capacity in Europe. Instruments that hinder market access to the European Single Market for certain technologies or components fall under the protect pillar of the strategy. Partner measures involve the EU closely coordinating with international partners or investing in third countries to increase its own resilience.

Where economic security risks are not the result of overcapacity, a diverse expansion of supply requires a focus on promote and partner tools rather than protective measures. To mitigate the emerging risks, the EU should pursue three policy objectives, each of which require two policy actions.

1. The EU should seek to maintain a significant global market share for European companies. This will require access to the domestic Chinese market, which constitutes around 35% of global industrial manufacturing. Two types of policies could help to secure such market access.
    - Argue against local content requirements and other localisation practices in

[10] 'An EU approach to enhance economic security', *European Commission,* 20 June 2023 (https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3358)

interactions with China and – as a last resort – threaten to introduce local content requirements for the sale of strategic end-products in the EU's Single Market.
- Use very narrow, targeted tariffs only where there are market distortions and alternative supply is available.

2. The EU should promote diversification and expansion of the supply of global legacy chips. Two policy initiatives would help.
    - Set up a funding instrument similar to the US International Technology Security and Innovation (ITSI) Fund and make it a central feature of intensified EU chip diplomacy.
    - Intensify efforts to explain geopolitical risks, such as military conflict in the South China Sea or a blockade of Taiwan, and work closely with industry on stress testing exercises to raise awareness that a hard landing in a situation of escalating crisis would be more costly than gradual investment in resilience.

3. The EU should strive to maintain its technological strengths – even if only in niches – to ensure that it is not only European firms that depend on Chinese legacy chips, but that Chinese companies also need European technology. This would avoid one-sided dependencies on China.[11] The EU can promote such reverse dependencies through two types of policy.
    - Invest in European R&D strengths and promote innovative business models to maintain a European stronghold.
    - Intensify collaboration with European industry to better understand intellectual property (IP) theft and support company efforts to protect their IP.

This paper explains why existing risks do not primarily stem from overcapacity and differ according to legacy chip type. The conclusion summarises the policy recommendations. Four annexes provide further data and material to substantiate the arguments in the paper.

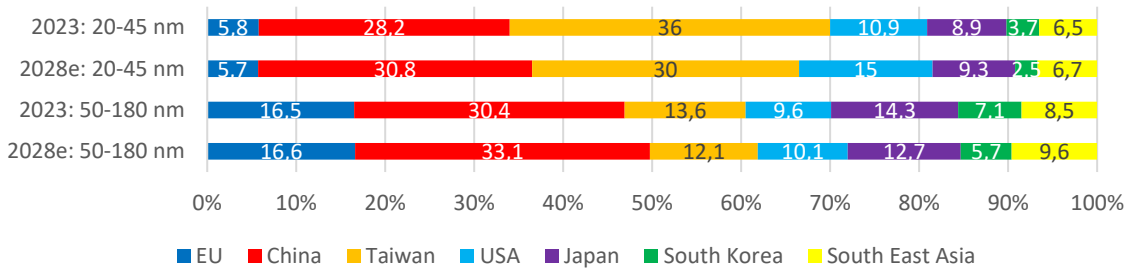
China's growing legacy chip production: not a case of overcapacity

Around 30% of global mature node semiconductor front-end manufacturing capacity at both the 20–45 nm and 50–180 nm process node is geographically located in China. China is not currently dominant but, given the amount of announced new manufacturing capacity, its global market share is likely to increase (see Figure 2).[12]

[11] Rühlig, T., 'Reverse Dependency: Making - Europe's Digital Technological Strengths - Indispensable to China', *Digital Power China,* 6 May 2024 (https://dgap.org/en/research/publications/reverse-dependency-making-europes-digital-technological-strengths).

[12] Kleinhans, J.-P. et al, 'Running on ice. China's chipmakers in a post-October 7 world', *Rhodium Group*, 4 April 2023 (https://rhg.com/research/running-on-ice/).

Figure 2: Current and planned wafer capacity (excluding memory) at 20–45nm and 50–180 nm, % of wafer starts per month
Source: Rhodium Group



China is also the second largest exporter of semiconductors (see Figure 3). This affects Europe as, if Hong Kong and Singapore are excluded as destinations that mostly re-export Chinese manufactured semiconductors, the EU is the third largest export destination for Chinese legacy chips, (Figure 4).

This reflects the strong demand from European industries for mature node semiconductors. Local semiconductor manufacturing in Europe will not meet the demand from EU industry for the foreseeable future.

Figure 3: Semiconductor exports by country, 2022, excluding re-exports where possible
Source: Silverado

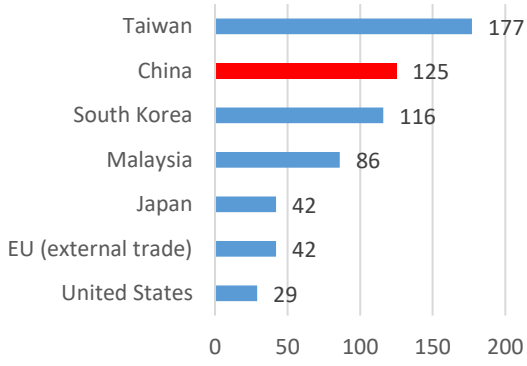
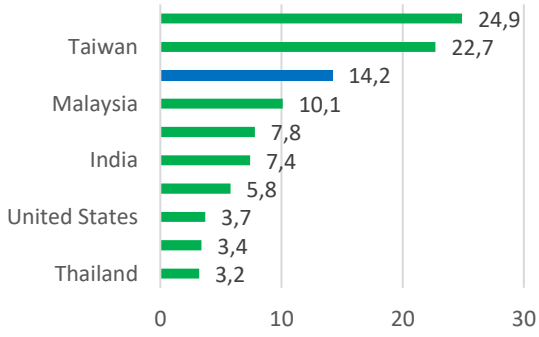


Figure 4: Top ten importers of semiconductors from China, excluding Hong Kong and Singapore, 2022, billion $
Source: Silverado



It is estimated that the total European supply gap will grow to 12.7 million wafers per year by 2030. The announced fabrication plant ("fab") build-up in the EU is only 4.5 million wafers[13] per year. Hence, EU companies will need to import at least 8.2 million wafers per year by 2030.

- If the EU aimed to close 80% of this local supply gap and source the rest from Japan, the US and the rest of

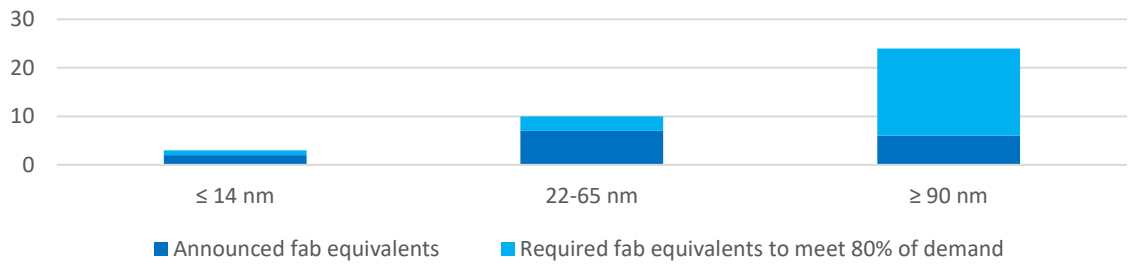
[13] A wafer is a thin slice of semiconductor material (usually silicon) that serves as the basis for the production of integrated circuits (ICs).

the world, it would need to build enormous additional capacity, accounting for 10.1 million wafers per year. Strikingly, the widest supply gap exists for mature node semiconductor production.

- If calculated in fab equivalents, two new fabs for 14 nm or smaller process nodes have been announced in Europe, but three such fab equivalents would be needed. The numerical supply gap is one fab equivalent.
- Seven announced fab equivalents for 22–65 nm process nodes do not match the demand for 10 fab equivalents. Hence, the numerical supply gap for 22–65 nm process node chips is three fab equivalents.
- It is in the above 90 nm process nodes that the gap is the largest. Europe has announced six fab equivalents but would need 24 fab equivalents to meet projected demand. Hence, the gap for above 90nm process nodes is 18 fab equivalents (see Figure 5).[14]
- This local supply gap will result in the need for imports. Since no other country is building nearly as much legacy chip manufacturing capacity as China, it is only logical that China-based fabs will meet most of the demand. This phenomenon is clearly not one of overcapacity; the demand is real. However, it is likely to result in yet another strategic dependency undermining European economic security.

The fact that there is this level of demand for legacy chips raises the question why European companies do not build up more mature node semiconductor manufacturing capacity. Conventional wisdom has it that profit margins for legacy chips are too narrow to be attractive to European companies.[15]

Figure 5: Gap between announced front-end capacity (without memory) and projected demand in Europe (in fab equivalents)
Source: VDA.



[14] 'Semiconductor crisis. Requirements for future relevance, competence and resilience for Europe', *VDA*, 22 May 2023 (https://www.vda.de/en/news/publications/publication/semiconductor-crisis).

[15] Ebrahimi, A., 'China's mature node overcapacity: unfounded fears', *institut français des relations internationals*, 8 October 2024 (https://www.ifri.org/en/memos/chinas-mature-node-overcapacity-unfounded-fears).

Chinese firms, by contrast, profit from lower labour costs and preferential access to capital in a sector that is highly capital intensive.

The conventional wisdom has some merit. Prices for commoditised chips, such as off-the-shelf power semiconductors, can be as low as a few cents. For example, studies show that Chinese NAND memory chip manufacturers have offered prices that are 20–30% below those of non-Chinese competitors in recent years.[16] China's party-state has also provided a wide range of direct and indirect subsidies to the country's semiconductor industry that have helped to raise the necessary capital for fabrication capacity buildout (see Annex 1).

However, these factors alone do not explain China's enormous development. China is not the only country with low labour costs; nor are profit margins as low as for non-commoditised legacy chips. Historical data demonstrates that the production of legacy chips can be a lucrative business.[17] The margins, capital expenditure, depreciation and overall financial performance levels of leading Chinese chip manufacturers compare well with global industry averages. Hence, it is questionable whether Chinese firms are cutting prices because of government subsidies.

Instead of price advantages, Chinese firms largely profit from a localisation trend coupled with a specific business model for the production of legacy chips. Both factors deserve further exploration.

- *Localisation*: A significant proportion of the end-user industries for legacy chips are based in China. Around 35% of global industrial manufacturing capacity is located there. Many chip suppliers produce for Chinese

[16] Chan, R., 'Chinese memory module firms offering low prices to compete for market share', *DigiTimes*, 15 September 2023 (https://www.digitimes.com/news/a20230914PD212/china-memory-chips.html?mod=3&q=semiconductor+price); Cheng, T-F. et al., 'Apple freezes plan to use China's YMTC chips amid political pressure', *NikkeiAsia*, 17 October 2022 (https://asia.nikkei.com/Business/Tech/Semiconductors/Apple-freezes-plan-to-use-China-s-YMTC-chips-amid-political-pressure#:~:text=Apple%20freezes%20plan%20to%20use%20China%27s%20YMTC%20chips%20amid%20political%20pressure,-Company%20previously%20planned&text=TAIPEI%2FPALO%20ALTO%2C%20U.S.%20%2D%2D,multiple%20sources%20told%20Nikkei%20Asia); Huang, A. and Shen, J., 'Taiwan MCU suppliers brace for price war triggered by Chinese peers', *DigiTimes*, 17 May 2023 (https://www.digitimes.com/news/a20230516PD217/32-bit-mcu-china-holtek-semiconductor-nuvoton-sonix-technology.html);'周期的深度思考. 半导体季度策略报告2022Q4 [Deep reflections on (industrial) cycles: Semiconductor quarterly strategy report 2022 Q4]', *Minsheng Securities*, 17 December 2022 (https://pdf.dfcfw.com/pdf/H3_AP202212191581193169_1.pdf); Huang, A. and Strom, E., 'China MCU industry may face major reshuffle', *DigiTimes*, 27 April 2023 (https://www.digitimes.com/news/a20230426PD218/china-mcu-microcontroller-unit-reshuffle.html); Ho, J. and Chan, R., 'Diodes says no plan to join PMIC price war in China', *DigiTimes*, 14 July 2023 (https://www.digitimes.com/news/a20230713PD212/china-diodes-pmic.html).

[17] According to industry insiders, historically, IDMs such as Texas Instruments or NXP had profit margins as high as 45-60%. The Taiwanese foundry United Microelectronics Cooperation (聯華電子, UMC) has margins of around 30%.

market players, which increasingly tend to source from local suppliers. This can be the result of formal local content requirements. In some cases, however, the situation is more complicated. Insiders in several industries report informal party-state guidance on localisation. In addition, Chinese industries are showing a growing awareness of geopolitical risks, which could result in decoupled supply chains. Hence, localisation is the result of a combination of formal and informal political signalling, as well as attempts by Chinese industry to increase its geopolitical resilience.

The enormous size of the Chinese market makes this trend forceful. While Chinese chip manufacturers increase their fabrication capacity in China, foreign-owned fabrication plants are also growing steadily there. Around 13% of additional fabrication capacity in China planned for 2030 is likely to be foreign owned. Like Chinese companies, foreign legacy chip manufacturers do not want to miss out on opportunities in the Chinese market.

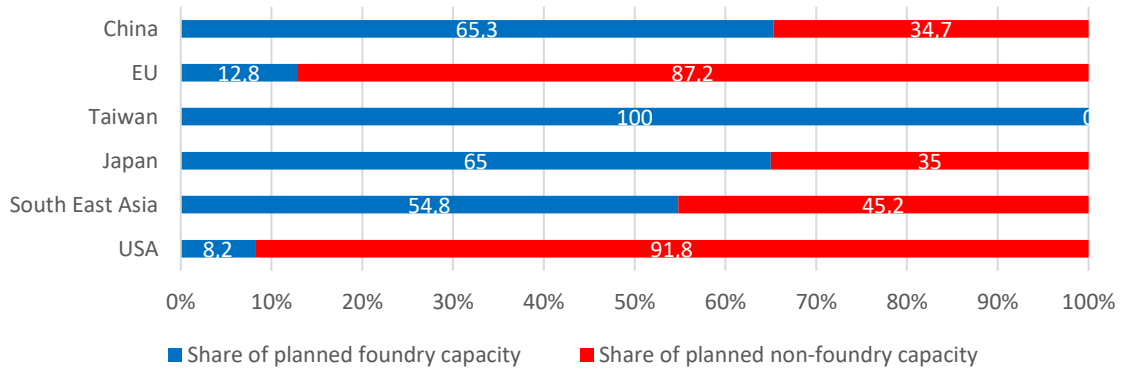
- *Business model*: China-based additional manufacturing capacity is mostly linked to foundries rather than Integrated Device Manufacturers (IDMs). A foundry is a front-end semiconductor fabrication plant that produces chips based on a design that is developed by a separate entity. This business model stands in contrast to IDMs, which design and produce semiconductors within the same company. Foundry capacity is of strategic importance because – in principle – it is more flexibly available to the market. Adapting foundry production to different customers is anything but simple (see below). However, foundries are more flexible than IDMs because they do not meet the demand "only" for in-house chip designs. Hence, foundries are better placed to meet demand for legacy chips from many different customers and industries.

Europe's legacy chip production capacity buildout is overwhelmingly linked to IDMs (87.2%), while China's is mostly based on foundries (65.3%) (Figure 6). As a result, Chinese legacy chip manufacturers can take advantage of a broader set of market opportunities from the diversified expansion of demand for mature node semiconductors. In contrast to European IDMs, they can theoretically pick up demand from a broader set of sectors.

Localisation trends and China's enormous market for industrial manufacturing, coupled with a business model focused on foundries, provide far more opportunities for China's legacy chip producers than for Europe's.

In sum, China's capacity buildout is probably not a result of general overcapacity and is not primarily the result of market-distorting practices. Instead, a combination of localisation requirements in the lead market for industrial manufacturing and a focus on foundry capacity is likely to result in growing dependencies that could pose economic security challenges for the EU. The beneficiaries of China's capacity buildout are

Figure 6: Share of foundry and non-foundry buildout of the planned mature node semiconductor buildout until 2030 (by country/region, in %)
Source: Rhodium Group.



primarily domestic end-user industries such as the automotive or telecommunications sectors. Even non-Chinese original equipment manufacturers (OEMs) with production facilities in China could increasingly source from Chinese chipmakers. This could provide an even wider gateway for Chinese legacy chips on to global markets. The resulting dependencies run counter to the EU's de-risking attempts, but they are not the result of overcapacity.

Exploring economic security risks across legacy chip types

Any increase in European import dependencies on Chinese legacy chips will create economic security risks. As outlined above, mature node semiconductors are of strategic importance, so growing import dependencies undermine the EU's supply chain resilience and increase the risk of economic coercion. However, legacy chips are a broad category of very different semiconductors. The following analysis demonstrates that both the degree of risk and the pace at which risk is likely to materialise for the EU differ significantly according to chip type.

Legacy chips fulfil very different functions across a broad range of products and sectors. Not all sales markets work equally. Nor do technical and product characteristics allow for Chinese domination in all sectors. Even chips produced at the same process node vary greatly in design and composition. For example, a 28 nm logic chip can be made up of different materials, be built on different machinery, be classified as a different chip type, ranging from microcontrollers to analog semiconductors, and perform different functions in a diverse set of industries and products with divergent demands. Hence, the technical characteristics of and the customers for legacy chips diverge, and adapting production to other types of mature node semiconductors is anything but simple. This means that Chinese firms do not have the same likelihood of gaining market share across all sectors and chip types. Thus, the timing and likelihood of economic security risks differ.

Most foundries – the most flexible business model as outlined above – are still highly specialised and cannot easily or quickly switch from the production of one chip to another, even if produced at same process node. Equally, chip design is always based on a specific process node and process technology. Thus, dominating the entire global legacy chip market would require Chinese foundries to be capable of addressing demand within very different and highly specialised market segments.

End-user markets also work differently. It is not just that the solar panel and the legacy chip markets differ. Even when comparing different types of legacy chip market, it is easy to identify critical differences. This means that assessing the risks of emerging strategic dependencies requires an understanding of the factors that shape Chinese market opportunities and constraints. It is only such an analysis that can provide a thorough estimate of the underlying economic security threats to the EU, differentiated by chip type and economic sector.

Factors shaping China's prospects of dominating legacy chip markets

Five factors determine market structure and technological characteristics, and are crucial to understanding the likelihood of economic security risks emerging in legacy chip submarkets. These factors are: concentration of supply, geographical origin of demand, risk of supply shortages, the technological substitutability of a chip, and the duration of the lifecycle of the product in which the respective chip is used. The first three factors shape the market structure; the final two are considered important technological characteristics.

Market structure

The market structure for different types of legacy chips varies. Three indicators are particularly relevant.

1. **Concentration of supply** China's current market share is a primary indicator of China's future prospects. Another factor is the degree to which the supplier market is fragmented. By trend, a fragmented market provides opportunities for the expansion of Chinese firms. Party-state investments of $150 billion between 2014 and 2030 have not been sufficient.[18] China has fallen far short of the national targets set out as part of the Made in China 2025 (中国制造2025) initiative to achieve self-sufficiency in 70% of "core basic parts and components, [and] key basic materials".[19] Currently, China is only producing around 7% of the

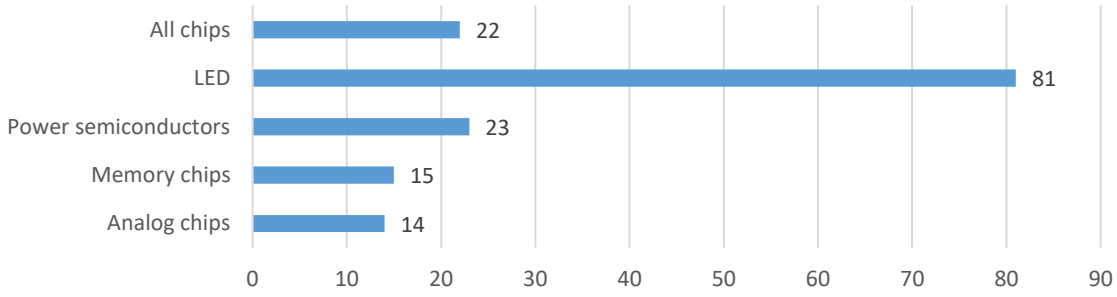
[18] 'SIA White Paper: Taking stock of China's semiconductor industry', *Semiconductor Industry Association*, July 2021 (https://www.semiconductors.org/wp-content/uploads/2021/07/Taking-Stock-of-China%E2%80%99s-Semiconductor-Industry_final.pdf).

[19] '国务院关于印发《中国制造2025》的通知' [Announcement of the State Council on the issuing of "Made in China 2025"], *State Council*, 8 May 2015 (https://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm).

chips it consumes.[20] The actual number is higher, but China exports chips and there are discrepancies between domestic supply and domestic demand. In highly concentrated sub-markets, end-user industries, including Chinese firms, currently still prefer the products of non-Chinese market leaders when meeting customer demand.

A recent analysis shows that the self-sufficiency rate diverges further by chip type, but still remains rather low. For technologically fairly simple LED chips, the self-sufficiency rate is 81%, but China produces less than a quarter of its demand for analog and memory chips, as well as power semiconductors, locally (see Figure 7).[21]

Figure 7: China's estimated self-sufficiency rates for types of semiconductors, 2022/23 (%)
Source: Rhodium Group.



2. **Origin of demand:** Another important factor is the geographic location of the end-user industry that buys the mature node semiconductors. In this context, it is vital to distinguish between two types of demand: the growing demand for Chinese foundries and the increased demand for Chinese chips.

The first type of demand is linked to the price advantages of Chinese foundries. Expanding supply creates price pressures that Chinese foundries can meet. This could result in increased domestic and international demand for Chinese foundry capacity. The second type of demand refers to localisation trends. When Chinese legacy chips achieve a certain degree of quality, companies in the Chinese market might choose to source China-made chips. This might even be the choice where foreign suppliers provide better quality as long as local Chinese semiconductors are "good enough" for their purpose.

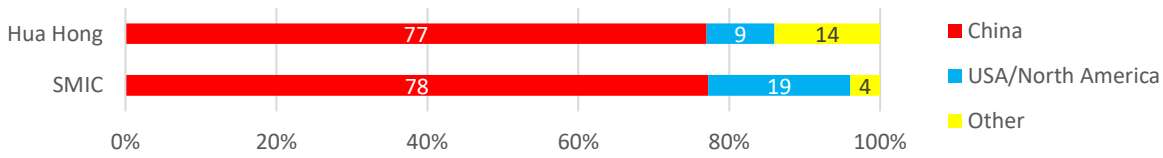
Chinese foundries already mostly serve Chinese customers, as the examples of Hua

[20] Dobberstein, L., 'China will produce one in five of the chips it uses in 2026, says analyst', *The Register*, 19 May 2022 (https://www.theregister.com/2022/05/19/china_chip_production_prediction/).

[21] Goujon, R. et al., 'Thin Ice. US Pathways to regulating China-sourced legacy chips', 13 May 2024 (https://rhg.com/research/thin-ice-us-pathways-to-regulating-china-sourced-legacy-chips/).

Hong and SMIC illustrate (see Figure 8). In general terms, China's domestic demand will remain high. One non-public industry study, for example, recently projected that even if all the announced production build-out in China was operational by 2030, an assumption that is unlikely to become reality, it would only meet 90% of domestic demand (up from 37% of supply in 2020). These figures include fabrication in China not only by Chinese companies, but also by foreign-owned fabs.

Figure 8: SMIC and Hua Hong, share of revenue by headquarters location of customer, January to June 2023
Source: company data



3. **Risk of shortages:** Recent chip shortages have led to a global buildout of production capacity. Shortage of supply tends to be an opportunity for new market entries, not least for Chinese firms that have announced significant production buildout. A rapid expansion of supply could create further price pressures. On the one hand, Chinese firms might be better equipped to deal with the resulting price wars, due to party-state support (see Annex 1). On the other hand, China's newly built fabs are not yet fully amortised and therefore less profitable. Furthermore, price wars can affect internal competition between Chinese suppliers and the sub-national entities that back local manufacturers. Many sub-national entities are in financial distress and the degree to which the economic risk of chip manufacturers can still be socialised remains to be seen. Chip shortages should be beneficial to Chinese expansion and increase the risk of new strategic dependencies.

In summary, all three factors linked to the market structure in a given chip sub-segment shape China's prospects of creating critical dependencies. The risk of Europe facing critical dependencies on Chinese legacy chip supply, thereby undermining its economic security, rises in tandem with the following variables:

- Chinese market share in a fragmented market;
- strong domestic Chinese end-industry demand; and
- the risk of chip shortages in the respective submarket.

Technological characteristics

In addition to market structure, two technological characteristics affect the

likelihood of China dominating global legacy chip markets, resulting in critical dependency and European economic security risk.

1. **Substitutability:** Semiconductors can be off-the-shelf products that are easy to replace with the products or another supplier, or highly specialised and tailored to the functionality of a specific product environment. Chips that require complex software programming to fit into products are difficult to substitute. Two distinct features shape the substitutability of semiconductors. First, system designers can develop their technology in ways that allow multi-sourcing of chips and thereby a high degree of substitutability. Second, chip designers may decide to work with various foundries and Outsourced Semiconductor Assembly and Testing firms (OSATs) to diversify supply. The latter, however, is cost-intensive and therefore quite rare.

2. **Product lifecycle:** Consumer expectations diverge greatly across products that use legacy chips. Cars remain on our streets for 10–15 years, while smartphones are often replaced within two or three years. Consumers expect maintenance and spare parts to be provided for their car for much longer than for their phones. Malfunctions in cars can lead to serious accidents, which means that a very low default rate is required. Phones do not need the same reliability. These examples have implications for the demands that legacy chip manufacturers must meet. Long lifecycles of end-products and the need for very high reliability, such as in the automotive and medical device sectors, tend to result in long-term contracts with mature node semiconductor suppliers. In other sectors, such as consumer electronics, by contrast, long-term agreements are much less common.

In many cases, this leads to different standardisation and certification requirements. The degree of standardisation relates to the required tightness, complexity and duration of conformity to standards and related certification. For example, legacy chips that serve safety functions in the automotive industry are highly standardised and certification is particularly tight, as these chips require a close to zero default rate. Every dysfunction could cause a car accident. The certification requirements for consumer electronics are not anywhere close to this.

In summary, the diversity of the technological characteristics of different mature node semiconductors and their applications shape China's prospects of gaining market share and thereby creating a critical dependency. Economic security risks linked to critical dependencies are more likely to emerge:

- where it is easier to substitute a given chip, and
- with shorter product lifecycles or lower certification requirements.

Comparing the risk levels of three legacy chip types

Assessing the degree of economic security risk according to these five factors for a broad range of legacy chip types is beyond the scope of this paper. Instead, this section briefly compares three important mature node semiconductor types to illustrate how divergent market structures and technological characteristics shape the prospects for Chinese firms on global markets. This has profound implications for the economic security risk to the EU.

- **Microcontrollers.** Overall, the risk of rapid and disruptive market share gains for Chinese suppliers of microcontrollers is low (see Annex 2). However, the prospects of Chinese suppliers diverge by market subsegment. For example, Chinese fabrication of microcontrollers for consumer electronics is more likely to gain market share than microcontrollers in the automotive or industrial sectors. Supply market concentration is to China's disadvantage. Demand comes from China and other countries, including Europe. Existing localisation trends have mixed effects. The risk of supply shortages remains significant. Most importantly, microcontrollers are very difficult to substitute because they are software defined and tailored to specific uses. Product lifecycles vary across sectors but significant segments of the market have long product lifecycles and high certification requirements. In sum, the market structure and technological characteristics of microcontrollers mean that the economic security risks of rapidly growing dependencies in this sub-sector are rather low.
- **NAND flash memory chips.** China is well placed to gain market share in NAND flash memory (see Annex 3). Chinese suppliers have a low but rapidly growing share of the global NAND market. Relatively strong domestic demand for memory chips means that localisation trends work to China's advantage. Supply shortages also provide a conducive environment for China's new suppliers. However, existing semiconductor export controls limit the prospects for further innovation, which poses a real obstacle to Chinese ambitions. Nonetheless, NAND flash memory chips at 128 layers will remain relevant for quite a few years to come. The substitutability of NAND flash memory is high and certification requirements low, which favours China. In addition, the lifecycles of many products that use NAND flash memory are short. While these conditions tend to be conducive to China and carry a significant risk of growing dependencies, the EU might be less affected compared to other actors as it has no domestic memory chip producer that could lose market share. The EU's direct consumption of memory chips is low and national security threats are insignificant. China's medium-term prospects are questionable due to US export controls.

- **Power MOSFET:** The risk of emerging strategic dependencies on Chinese-made power MOSFET is high (see Annex 4). Chinese firms have an expanding market share. Significant domestic demand and localisation, as well as risks of supply shortage present favourable conditions for China. The substitutability of power MOSFETs is very high. In contrast to microcontrollers, power MOSFETs are not software-defined and follow relatively standardised forms. This makes them easy to replace. Certification requirements do not pose a major market entry barrier. The lifecycles of end-user products differ across the sector.

In summary, the risk of major strategic dependencies on China is highest in Power MOSFET and lowest for microcontrollers. China is likely to gain significant NAND flash memory market share, but the EU will be less affected by this and export controls are likely to reduce Chinese prospects in the medium term (see Table 1).

Table 1: Overview of market structure, technological characteristics and resulting risk for the EU across three mature node semiconductor types

Chip type	Market structure			Technological characteristics		**Overall risk**
	Concentration of supply	Origin of demand	Shortage risk	Substitutability	Product life cycles	
Microcontrollers						
NAND flash memory						
Power MOSFET						

Conclusions and policy recommendations

Chinese firms have a strong position in the global mature node semiconductor market. No company in any other country is planning to build out anywhere near as much additional capacity as Chinese firms. It is therefore unavoidable that Chinese companies will pick up a significant degree of the expanding demand. It is anything but a given, however, that the expansion of Chinese supply will result in overcapacity. Many legacy chips markets face the risk of supply shortage rather than overcapacity. Chinese supply meets strong demand from China's end-user industries and most of the additional capacity will be absorbed domestically. China is helping to prevent supply bottlenecks for global and EU industry. The result will be growing dependencies on a strategic good from China.

The resulting economic security risks for the EU are not a consequence of overcapacity. This means that protect measures are unlikely to be effective. Price is only one of several factors that determine China's role in global and European markets. The EU will need to focus on promote and partner tools because protective measures would reduce supply and increase price. The factors

shaping China's prospects are also more complex. Concentration of supply, the origin of demand and the risk of shortages are three key factors, the importance of which differ according to subsector.

Technologically, substitutability and the length of product lifecycles shape how easy it will be for Chinese firms to gain global market share.

Chinese firms are likely to dominate global power MOSFET supply, thereby creating a critical dependency. China's prospects in the NAND flash memory market are also good. However, Europe has no memory chip manufacturer and the EU's direct consumption of NAND flash memory is low. Nonetheless, Europe could suffer indirectly from supply chain disruptions of NAND flash memory, as it imports end-products that contain these chipsets. Critical dependencies on Chinese general-purpose microcontrollers are unlikely to emerge in the short term, mainly because they are not easily substituted.

To better understand the sourcing of legacy chips, the European Commission has launched a survey seeking input from European industry. Participation in the survey is voluntary and it remains to be seen whether the Commission will receive enough information to provide a comprehensive and nuanced assessment that differentiates between legacy chip types. The high degree of division of labour presents a challenge, because the survey would need responses not only from OEMs but also from their tier-1 and tier-2 suppliers. It might be more promising to focus on companies that distribute semiconductors across European economic sectors. These distributors sell roughly one-third of all mature node semiconductors in Europe, which would provide a significant sample size. Robust data complemented by information shared by the United States would provide a solid analytical basis for identifying the most urgent risks. While no substitute for such data, this paper seeks to contribute to the EU's fact-finding exercise.

In a next step, the EU could adopt targeted mitigation measures in specific sub-sectors, instead of hitting all mature node semiconductor markets. With regard to the triad promote, protect and partner, the EU should focus on promote and partner. The demand for legacy chips is expanding. Unless other countries build out their production capacity, Chinese firms will eventually absorb this demand. Protect measures alone will only increase the risk of supply shortages and increase prices in the EU.

The main challenge of promote measures is that they require enormous resources and time, as well as a commitment by end-user industries to accept higher prices. Firms may have an abstract understanding that they need to pay a premium for resilience to geopolitical risks, but in practice it is questionable whether European industry is ready to cover the costs of increased resilience. Under these conditions, the EU should carefully navigate its policy goals. Three objectives could be particularly instrumental in mitigating the resulting economic security challenges.

1. The EU will need to maintain a significant global market share for its companies. This will require securing access to the

domestic Chinese market, because China hosts more than one-third of global industry manufacturing. To this end, the EU should put in place the following policies.

- In its bilateral relations with China, the EU should protest against formal and informal local content requirements, as they seriously diminish the prospects of non-Chinese supply. If unsuccessful, the EU could consider the drastic step of introducing local content requirements for the European sales market in a narrow set of sectors. For example, the EU could require a certain share of chips in cars on European streets to be manufactured in the EU. This would be a radically new course and should only be considered as a last resort.

- The EU could put in place very narrow, targeted tariffs in market niches. Where party-state support distorts markets, anti-dumping and anti-subsidy investigations could result in tariffs. The EU's Foreign Subsidies Regulation could further target company operations within the EU. However, tariffs are likely to be effective only in those niches where a reduction in Chinese market share meets increased capacity from within the EU or third countries. Otherwise, tariffs only increase prices without reducing European dependency.

2. The EU should strive to promote an expansion and diversification of the supply of global legacy chips. To this end, it should consider adopting two sets of policies.

    - Most importantly, the EU should invest more in the diversification of supply by means of a new dedicated funding stream under the Global Gateway as part of the new European Foreign Economic Policy. To reduce dependencies on China, the EU will need to invest in diversification instead of re-shoring. For this, the EU should set up a scheme similar to the International Technology Security and Innovation (ITSI) Fund under the US Chips Act. Since EU chip suppliers are mostly IDMs, the European ITSI fund should also promote cooperation among European end-user industry on legacy chips, in third markets with non-Chinese legacy chip suppliers. To ensure such an instrument is country-agnostic, the EU could make diversification a selection criterion for EU funding.

    - The EU should further intensify its engagement with European industry, emphasising and substantiating the costs of geopolitical risks. Companies need to incorporate the logic of

"breaking points" when frictions in relations between states increase to a degree that the adversary limits or prohibits the supply of critical resources.[22] The EU should provide data and increase stress testing with industry to illustrate the value of investment in resilience. It will be more commercial to increase resilience than to cope with the potential fallout in cases of a hard decoupling in an escalated crisis.

3. The EU should strive to maintain its technological strengths. However, reverse dependencies will only be realistic in niches, such as in the two examples below.

    - The EU could double down on R&D investment and promote innovative business cases. The EU's strength lies in research and development rather than front-end fabrication. The EU should strive to maintain its strengths in order to maintain market segments where China relies on the EU. The EU could support emerging trends such as open-source silicon and open-source chip design. It could also promote niche markets such as silicon carbide chip development and production. Innovation leadership might not guarantee that China continues to depend on European supply, but would at least maintain an edge over Chinese suppliers in a market niche. Another example could be to promote system integration and advanced packaging. Companies like the German firm, Swissbit, offer innovative NAND memory based on advanced packaging. While none of these cases requires Chinese customers to source European chips, the preservation of such technological strengths is a precondition for Chinese firms continuing to rely on European inputs that could be leveraged.

    - The EU could also actively reach out to European industry to improve IP protection and offer support with its enforcement. Where IP theft is enabling Chinese legacy chip manufacturers, the EU should closely consult with the relevant European industries to coordinate policies on rigorous IP enforcement. EU member states could explore best practices, such as the confidential exchange of information between the European Commission's unit in charge of technology security and European companies. The first concrete case for

[22] Teer J. and Bertolini, M., 'Reaching breaking point: The semiconductor and critical raw material ecosystem at a time of great power rivalry', *The Hague Centre for Strategic Studies*, October 2022 (https://hcss.nl/wp-content/uploads/2022/10/Reaching-breaking-point-full-HCSS-2022-revised.pdf).

investigation could be the possible IP theft of GigaDevice from STMicroelectronics for its 32-series (see Annex 2).

Some policy options are unlikely to be useful. For example, using standardisation and certification requirements as de facto technical barriers to trade is not viable. It could be in violation of World Trade Organisation law and runs counter to the spirit of the European Standardisation Strategy.[23] In addition, it would fail because, in many legacy chip market segments, the EU is not a sufficiently large market to create the gravitational forces it would require.

Similarly, European export controls are unlikely to be effective in curtailing China's mature node semiconductor capacity. Maintenance and the production of spare parts are less complex than is the case with cutting-edge chips, not least because semiconductor manufacturing equipment for older process nodes is already in China in great quantities. China also has plenty of equipment in stock. Memory chips are an exception, but NAND memory does not require particularly sophisticated lithography, just edging. High-end lithography is a European strength but edging is a US strength.

Outbound investment screening could even backfire. Joint ventures such as the one between Sanan and STMicroelectronics do not serve the EU's geopolitical agenda. However, hindering such cooperation is unlikely to slow China's advance significantly, would increase prices in the short term and reduce the market share of European legacy chip suppliers in China. This is not to dismiss the utility of an outbound investment screening instrument altogether. However, it would be likely to create significant damage in the field of mature node semiconductors.

[23] 'An EU strategy on standardisation. Setting global standards in support of a resilient, green and digital EU single market', *European Commission*, 1 February 2022 (https://ec.europa.eu/docsroom/documents/48598).

Annexes

1.1

Annex 1: Chinese party-state support for the country's semiconductor industry

China uses various means to support its domestic semiconductor industry.

- **Equity investment:** State-backed equity funds, most prominently the China Integrated Circuit Industry Investment Fund ("Big Fund", 国家集成电路产业投资基金), provide enormous financial resources. Between 2014 and 2019, the Big Fund raised $23 billion; in 2019, it launched a second phase starting with an investment of $29 billion. The Big Fund's investments have made it a major shareholder in several Chinese semiconductor firms (see Table 2).[24] No less than 43% of the registered capital in the Chinese semiconductor industry is directly or indirectly owned or controlled by the Chinese party-state.[25] Reuters has reported that a third phase of the Big Fund was launched in 2023.[26] Industry insiders question Reuters' assertion but have identified a more decentralised strategy (see below). Throughout the past decade, the Big Fund's activities have been complemented by at least 14 sub-national government investment funds with a combined volume of at least $45 billion (as of 2020).[27]

Table 2: Share of Big Fund in major Chinese semiconductor firms
Source: ***Financial Times***

English name	Chinese name	Share of Big Fund
Semiconductor Manufacturing International Corporation (SMIC)	中芯国际集成电路制造有限公司	32%
Hua Hong (Wuxi) Semiconductor	华虹半导体有限公司	29%
Yangtze Memory Technologies Corporation (YMTC)	长江存储科技有限责任公司	24%
Unisoc	紫光展锐	14%

- **Subsidies:** China's semiconductor industry also profits from direct subsidies from central and sub-national governments. In the period 2020–22, the income statements of 76 publicly traded Chinese semiconductor companies registered $3.2 billion in government grants.[28] The total amount of subsidies is higher because major semiconductor firms such as YMTC are not publicly traded.

[24] White, E. And Li, Q, 'China's Big Fund corruption probe casts shadow over chip sector', *Financial Times*, 29 September 2022 (https://www.ft.com/content/8358e81b-f4e7-4bad-bc08-19a77035e1b4).

[25] 'Taking stock of China's semiconductor industry', *Semiconductor Industry Association*, 13 July 2021 (https://www.semiconductors.org/taking-stock-of-chinas-semiconductor-industry/).

[26] Zhu, J. et al., 'China to launch $40 billion state fund to boost chip industry', *Reuters*, 5 September 2023 (https://www.reuters.com/technology/china-launch-new-40-bln-state-fund-boost-chip-industry-sources-say-2023-09-05/).

[27] Lee, J. and Kleinhans, J.-P., 'Mapping China's semiconductor ecosystem in global context. Strategic dimensions and conclusions', *Stiftung Neue Verantwortung*, June 2021 (https://www.interface-eu.org/storage/archive/files/chinas_semiconductor_ecosystem.pdf).

[28] Hsaio, J. 'Chinese government grants for semiconductors concentrate on pure-play foundries', *DigiTimes*, 3 October 2023 (https://www.digitimes.com/news/a20231002VL202/china-chips+components-government-semiconductors.html).

- **Other direct and indirect financial support:** Chinese semiconductor firms are further profiting from investments in semiconductor plants,[29] loans at favourable interest rates from state-controlled banks,[30] the sale of land below market value,[31] tax exemptions, tax breaks and reduced tariffs,[32] or financial support for Chinese semiconductor customers, to name just a few examples.[33]

Corruption investigations,[34] investment inefficiencies and US policies targeted at preferential treatment for the Chinese semiconductor industry[35] have led to a restructuring of the party-state's support for the industry.[36] A new "Small Leading Group" led by Ding Xuexiang (丁薛祥), a loyalist to President Xi Jinping, member of the Standing Committee of the Politburo and Vice Premier, now oversees the sector. China

[29] 'China chipmaker SMIC gest state funds for US$2.35 b plant', *The Business Times*, 18 March 2021 (https://www.businesstimes.com.sg/startups-tech/technology/china-chipmaker-smic-gets-state-funds-for-us2.35b-plant); Shihua, T., 'Chinese chipmaker Hua Hong to set up $6.7 billion wafer JV', *Yincai Global*, 19 January 2023 (https://www.yicaiglobal.com/news/chinese-chipmaker-hua-hong-to-set-up-usd67-billion-wafer-jv); 'China's SMIC plans $8.87 bn investment for new chip plant in Shanghai', *TelecomLead*, 3 September 2021 (https://telecomlead.com/telecom-chips/chinas-smic-plans-8-87-bn-investment-for-new-chip-plant-in-shanghai-101519).

[30] 'SIA White Paper: Taking stock of China's semiconductor industry', *Semiconductor Industry Association*, July 2021 (https://www.semiconductors.org/wp-content/uploads/2021/07/Taking-Stock-of-China%E2%80%99s-Semiconductor-Industry_final.pdf); Ito, S., 'The Chinese government's financial support for the semiconductor industry: further strengthening support despite dilemma', SSU Working Paper 6, *University of Tokyo*, March 2022 (https://ifi.u-tokyo.ac.jp/en/wp-content/uploads/2022/03/SSU_WP_SIto_EN20220214.pdf). Between 2014-18, four Chinese semiconductor companies received no less than $4.85 billion favourable loans. 'Measuring distortions in international markets: the semiconductor value chain', *OECD*, 12 December 2019 (https://www.oecd-ilibrary.org/trade/measuring-distortions-in-international-markets_8fe4491d-en;jsessionid=LV0s2_HKJxTAW4hsHTEVNDbC2a3HeAYGHU1pDQfe.ip-10-240-5-68).

[31] 'Measuring distortions in international markets: the semiconductor value chain', *OECD*, 12 December 2019 (https://www.oecd-ilibrary.org/trade/measuring-distortions-in-international-markets_8fe4491d-en;jsessionid=LV0s2_HKJxTAW4hsHTEVNDbC2a3HeAYGHU1pDQfe.ip-10-240-5-68); 'SIA White Paper: Taking stock of China's semiconductor industry', *Semiconductor Industry Association*, July 2021 (https://www.semiconductors.org/wp-content/uploads/2021/07/Taking-Stock-of-China%E2%80%99s-Semiconductor-Industry_final.pdf).

[32] State Council of the PRC, '国务院关于印发新时期促进集成电路产业和软件产业高质量发展若干政策的通知 [Circular of the State Council on the issuance of several policies to promote the high-quality development of the integrated circuit industry and software industry in the new period], 27 July 2020 (https://www.gov.cn/zhengce/content/2020-08/04/content_5532370.htm); Ito, S., 'The Chinese government's financial support for the semiconductor industry: further strengthening support despite dilemma', SSU Working Paper 6, *University of Tokyo*, March 2022 (https://ifi.u-tokyo.ac.jp/en/wp-content/uploads/2022/03/SSU_WP_SIto_EN20220214.pdf).

[33] In 2023, for example, the city of Guangzhou committed around $21 billion in support for Chinese chip consumers to eliminate dependencies from foreign suppliers. Chang, C., and Liu, J., 'De-Americanize': How China is remaking its chip business', *New York Times*, 11 May 2023 (https://www.nytimes.com/2023/05/11/technology/china-us-chip-controls.html).

[34] Shen, X., 'Former chip guru at Tsinghua Unigroup pleads guilty in corruption trial after Beijing's anti-graft push', *South China Morning Post*, 29 September 2023 (https://www.scmp.com/tech/policy/article/3236315/former-chip-guru-tsinghua-unigroup-pleads-guilty-corruption-trial-after-beijings-anti-graft-push).

[35] Nyam, F., 'China vs. US tech war, China to use new strategy', *GizChina*, 31 December 2022 (https://www.gizchina.com/2022/12/31/china-vs-us-tech-war-china-to-use-new-strategy/).

[36] Triolo, P., 'A new era for the Chinese semiconductor industry: Beijing responds to export controls', *American Affairs*, Vol. 8, No 4, 2024 (https://americanaffairsjournal.org/2024/02/a-new-era-for-the-chinese-semiconductor-industry-beijing-responds-to-export-controls/).

has increased its investment in basic research available to select commercial entities as part of a new approach to promoting public-private partnerships.[37] Open-source hardware such as RISC-V is another focus of China's efforts. Central to this new approach is Huawei (华为) and its close alliance with SMIC.[38]

Annex 2: Microcontrollers

Microcontrollers are tiny computers on a single chip, which are largely software defined. Microcontrollers have a broad range of applications. They perform measurement, sensing and controlling functions in consumer electronics, cars, energy grids, hospitals and numerous other sector-specific technologies. Almost all microcontrollers are legacy chips, although a small proportion of cutting-edge microcontrollers are produced on 20 nm or even 7 nm process nodes.

Market structure

The *concentration of the microcontroller supply market* is not to China's advantage. None of the five leading suppliers, which control 82% of the market, is headquartered in China (see Figure 9).[39]

In contrast, around 30% of global *demand for microcontrollers originates* in China.[40] The market was worth $25 billion in 2023 and is expected to grow to roughly $73 billion by 2033.[41] Chinese consumer electronics and home appliance providers are among the key drivers of this expansion in demand. Localisation trends linked to US export controls and China's self-reliance policy are likely to favour Chinese suppliers in the strong domestic market but limit Chinese prospects in foreign markets.[42] Since the demand for

[37] '加强半导体基础能力建设 点亮半导体自立自强发展的"灯塔"[Strengthening the basic semiconductor capacity to light up the semiconductor self-reliance and self-improvement of the development of the 'lighthouse' (of semiconductor self-reliance)]', *Chinese Academy of Sciences*, 16 February 2023 (https://mp.weixin.qq.com/s/m-WzjLux4HQDtYyYKra22w); Liu, Q., 'China gives chipmakers new powers to guide industry recovery', *Financial Times*, 21 March 2023 (https://www.ft.com/content/d97ca301-f766-48c0-a542-e1d522c7724e).

[38] Triolo, P., 'A new era for the Chinese semiconductor industry: Beijing responds to export controls', *American Affairs*, Vol. 8, No 4, 2024 (https://americanaffairsjournal.org/2024/02/a-new-era-for-the-chinese-semiconductor-industry-beijing-responds-to-export-controls/).

[39] Kleinhans, J.-P. et al, 'Running on ice. China's chipmakers in a post-October 7 world', *Rhodium Group*, 4 April 2023 (https://rhg.com/research/running-on-ice/).

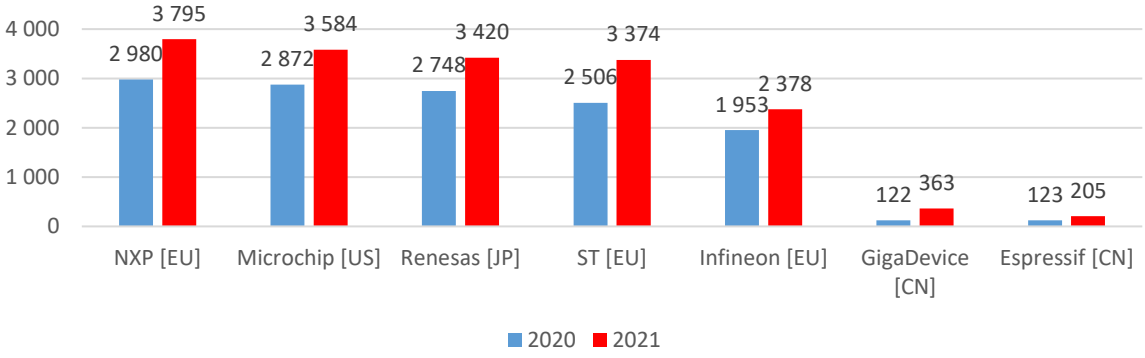
[40] '2031 microcontroller market size. Demand and consumption by top country', LinkedIn, 14 January 2024 (https://www.linkedin.com/pulse/2031-microcontroller-market-size-demand-consumption-xs5yf).

[41] 'Microcontroller market outlook (2023 to 2033)', *Fact.MR*, June 2023 (https://www.factmr.com/report/4556/microcontroller-market).

[42] Kleinhans, J.-P. et al, 'Running on ice. China's chipmakers in a post-October 7 world', *Rhodium Group*, 4 April 2023 (https://rhg.com/research/running-on-ice/).

microcontrollers is also high outside China, including in the EU, localisation trends will have mixed results for China's prospects.

Figure 9: Leading microcontroler suppliers (2020 and 2021, in $ billion) and their Chinese competitors, source: Rhodium Group.



The supply of microcontrollers will continue to be tight and *shortages* remain likely.[43] The widely reported cases of STMicroelectronic's 32-series competition with supply of China's GigaDevice (兆易创新) and Geehy (极海半导体) has created significant price pressures. However, since GigaDevice's 32-series is only sold on the domestic Chinese market, probably due to the lack of enforced patents held by STMicroelectronic in China, the effects are limited to China.

Technological characteristics

Microcontrollers are highly dependent on specialised software and therefore difficult to *substitute*. The better the software stack, the easier it is for developers to program the microcontroller. Customers tend to trust their suppliers because they know the microcontrollers and the respective software stack. Ripping and replacing microcontrollers is difficult because interoperability tends to be low. Exceptions to this dynamic are the GigaDevice GD32-series and Geehy's APM32-series. These microcontrollers are directly interchangeable with Europe's STMicroelectronics' STM32 but have limited availability outside the Chinese market.

The *lifecycles of products* using microcontrollers differ greatly according to economic sector. The sector with the highest demand, the automotive sector, has long product lifecycles, as has the fourth largest sector, medical devices. However, almost 25% of microcontroller demand stems from consumer electronics with short product lifecycles.[44] The high divergence among microcontrollers allows only limited unitary standards. The role of certification differs depending on application. The automotive sector has high safety certification requirements. Defect rates for modern vehicles are in the range of 10 defective parts per billion.[45]

[43] 'Semiconductor shortages, is there an end?', *Z2Data*, 28 September 2022 (https://www.z2data.com/insights/semiconductor-shortages-is-there-an-end).
[44] 'Microcontroller market size, share & COVID-19 impact analysis by product type', *Fortune Business Insights*, 9 September 2024 (https://www.fortunebusinessinsights.com/microcontroller-market-106430).
[45] Meixner, A., 'Auto chipmakers dig down to 10ppb', *Semiconductor Engineering*, 8 March 2022 (https://semiengineering.com/auto-chipmakers-dig-down-to-10ppb/).

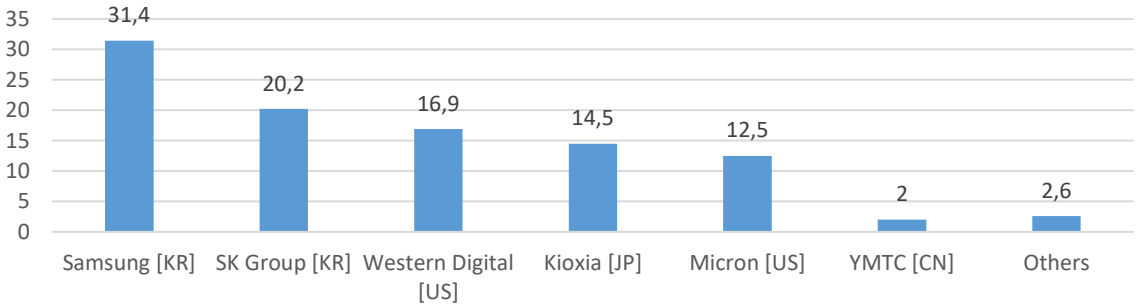
Annex 3: NAND flash memory

NOT-AND (NAND) flash memory chips are chips for "long-term" memory that are indispensable to any device that runs software. NAND flash memory chips at 128-layers are produced by the newer machinery of legacy process nodes, mostly 20 nm and 28 nm.

Market structure

Chinese companies have low but rapidly expanding *market shares*. China's leading NAND producer, YMTC, controls around 2% of global market share (see Figure 10).[46] This does not sound like much, but the company was only founded in 2016. The highly concentrated market is controlled by five big companies. YMTC's development has profited from the fact that NAND memory production is highly capital intensive, has low profit margins and is more volatile than other semiconductor markets. Between 2016 and 2021, NAND memory manufacturers had either the highest or the second highest costs for semiconductor manufacturing equipment of all front-end industries. Demand for memory chips evolves more quickly to the latest generations; "legacy" memory capacity is rather short-lived in the market. Thus far, YMTC has profited in this difficult market environment from Chinese state financial support and from the scale of China's national economy. With the help of China's Big Fund, as well as two investment funds in Hubei province, Tsinghua Unigroup (紫光集团有限公司) founded YMTC with massive state backing and developed the company into one of the most competitive NAND chip suppliers with production capacity at 232-layers.

Figure 10: Revenue Ranking for NAND flash manufacturers 3Q23 in per cent, source: TrendForce



Despite the high domestic *demand* for memory chips and a vibrant localisation trend, China's medium-term prospects are questionable.[47] Restrictions on exporting cutting-edge semiconductor manufacturing equipment to China challenge the prospects of a market for short-lived legacy chips. If rigorously enforced, the export controls by the US, Japan and the Netherlands will make it very difficult for YMTC to innovate further and compete on international markets.

[46] 'Market anticipates a 50% price surge for NAND flash in short-term', *TrendForce*, 29 December 2023 (https://www.trendforce.com/news/2023/12/29/news-market-anticipates-a-50-price-surge-for-nand-flash-in-short-term/).

[47] Wang, E., 'Strict restrictions imposed by US CHIPS Act will lower willingness of multinational suppliers to invest; Chinese semiconductor development will be limited for next decade, says TrendForce', *TrendForce*, 14 April 2023 (https://www.trendforce.com/presscenter/news/20230414-11644.html); 'YMTC could abandon market for 3D NAND flash by 2024 following US government's decision to place it on entity list, says TrendForce', *TrendForce*, 16 December 2022 (https://www.trendforce.com/presscenter/news/20221216-11503.html).

The risk of memory chip *supply shortages* supports the expansion of newcomers. However, in the medium term, NAND memory demand will move to higher performance levels that Chinese suppliers will not be able to meet if export controls are comprehensively enforced.[48]

Technological characteristics

NAND memory chips are highly interchangeable by design. These chips are easy to rip and replace so *substitutability* is high.

Most products that require NAND flash memory have short *product lifecycles*. These are primarily consumer electronics such as laptops, mobile phones and servers. However, this means that export controls could result in the competitiveness of Chinese NAND memory chips being short-lived. The high substitutability is the result of a high degree of standardisation. The decisive international technical standards were developed in the Joint Electron Device Engineering Council (JEDEC) and the Open NAND Flash Interface Workgroup (ONFI). Certification is not particularly demanding and does not pose a significant barrier to market entry for Chinese suppliers.

While several factors indicate a risk of growing dependency on Chinese NAND flash memory supply, the EU is likely to be relatively unaffected. Europe has no memory chip manufacturer and therefore no market share to lose. The direct consumption of memory chips in Europe is also low.[49] NAND chips also hardly threaten European national security. The risk of hardware backdoors or kill switches in NAND flash memory is negligible. Shortages of NAND flash memory supply would, however, impact Europe indirectly as it would lead to shortages in all kinds of devices that use NAND flash memory chips.

Annex 4: Power MOSFET

Power metal-oxide-semiconductor field-effect transistors (Power MOSFETs) are the most widespread type of power semiconductors. They are widely used in many products in consumer electronics, and in radio-frequency applications, transport technology and the automotive sector.

Market structure

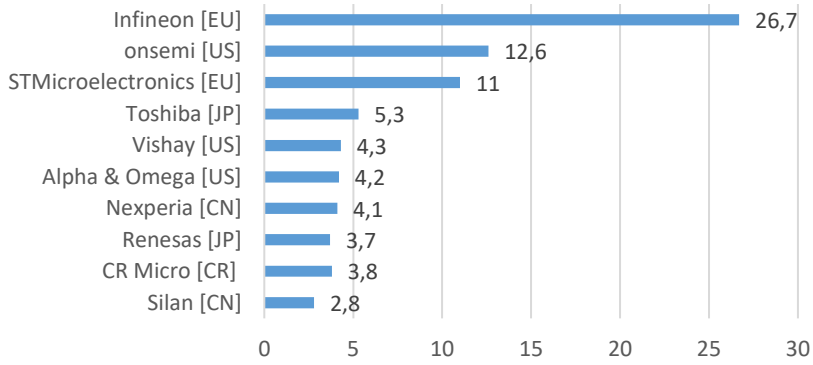
China has a growing *market share* in power MOSFETs.[50] The ten largest power MOSFET providers control 78% of the global market. Three of these companies are Chinese, with a combined market share of 10.4% (see Figure 11).[51] In the wider power semiconductor market (including other types of power semiconductors, such as insulate-gate bipolar transistors), Chinese suppliers are even less important. Nexperia is the only Chinese-owned company (headquartered in the Netherlands) in the global top 10 suppliers, with a market share of 2.7% (see Figure 12). Chinese power MOSFET suppliers are well

[48] 'After memory price hike, shortages emerge in some products?', *TrendForce*, 12 December 2023 (https://www.trendforce.com/news/2023/12/12/news-after-memory-price-hike-shortages-emerge-in-some-products/).
[49] 'Economic analysis of the EU and international semiconductor ecosystem', *ICOS*, 12 December 2023 (https://icos-semiconductors.eu/wp-content/uploads/2024/07/Public-Version-ICOS-Deliverable-2.1.pdf).
[50] 'Insight into the 2024: China MOSFET industry competition pattern and market share', *Yicai Global*, 11 February 2024 (https://www.yicaiglobal.com/star50news/2024_02_11665665818605492634 6).
[51] Fourth quarter FY 2023. Quarterly update', *Infineon*, 15 November 2023 (https://www.infineon.com/dgdl/2023-11-15+Q4+FY23+Investor+Presentation.pdf?fileId=8ac78c8b8b657de2018bcea7a6f50033).

positioned to gain market share. For example, Silan is expanding its capacity with additional production capacity in Xiamen and Hangzhou.[52]

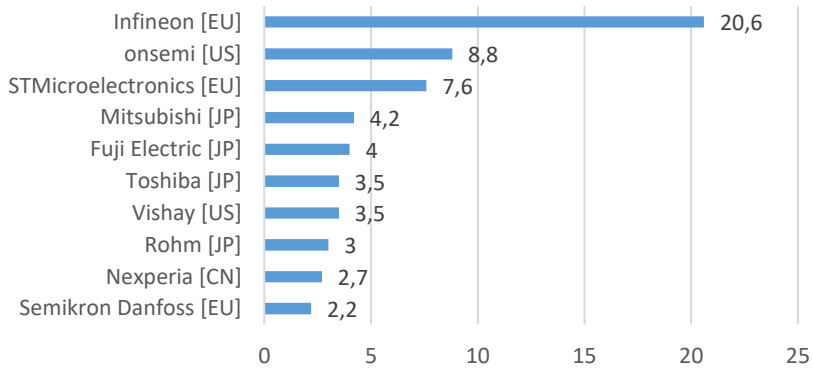
China has strong *demand* from many of the end-user industries of power MOSFETs, such as consumer electronics and vehicles. Chinese power MOSFET suppliers benefit from localisation trends. US export controls have no impact on power MOSFET because even 130 nm process nodes are frequently used to produce power MOSFETs.

Figure 11: Global market shares by percentage of the ten leading power MOSFET suppliers, 2022
Source: Infineon, based on Omdia data.



The *risk of supply shortages* further favours Chinese newcomers to the global power MOSFET market.[53]

Figure 12: Global market shares in per cent of ten leading power semiconductor suppliers (2022)
Source: Infineon, based on Omdia data.



Technological characteristics

Power MOSFETs are easy to *substitute* with the supply of a competing manufacturer.

The *lifecycles* of products that use power MOSETs differ according to application. However, a significant proportion of the market (especially consumer electronics) has short product lifecycles, which provides favourable conditions for further market expansion of Chinese companies. Just like NAND, power MOSFETs are standardised by JEDEC. There is no indication that certification is a major barrier to market entry for newcomers to power MOSFETs.

[52] Dahlgren, D., 'China is beefing up its wafer capacity', *Evertiq*, 16 November 2023 (https://evertiq.com/news/54720).

[53] 'FPGA and power MOSFET shortage will continue in the second half of the year', *EinPresswire*, 7 March 2023 (https://www.einpresswire.com/article/620595981/fpga-and-power-mosfet-shortage-will-continue-in-the-second-half-of-the-year); Ho, J. and Strom, E., 'Power MOSFET, diode suppliers expect demand recovery in 2024', *DigiTimes*, 9 August 2023 (https://www.digitimes.com/news/a20230808PD212/diode-force-mos-technology-mosfet-power-components-power-mosfet-power-supply.html).

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