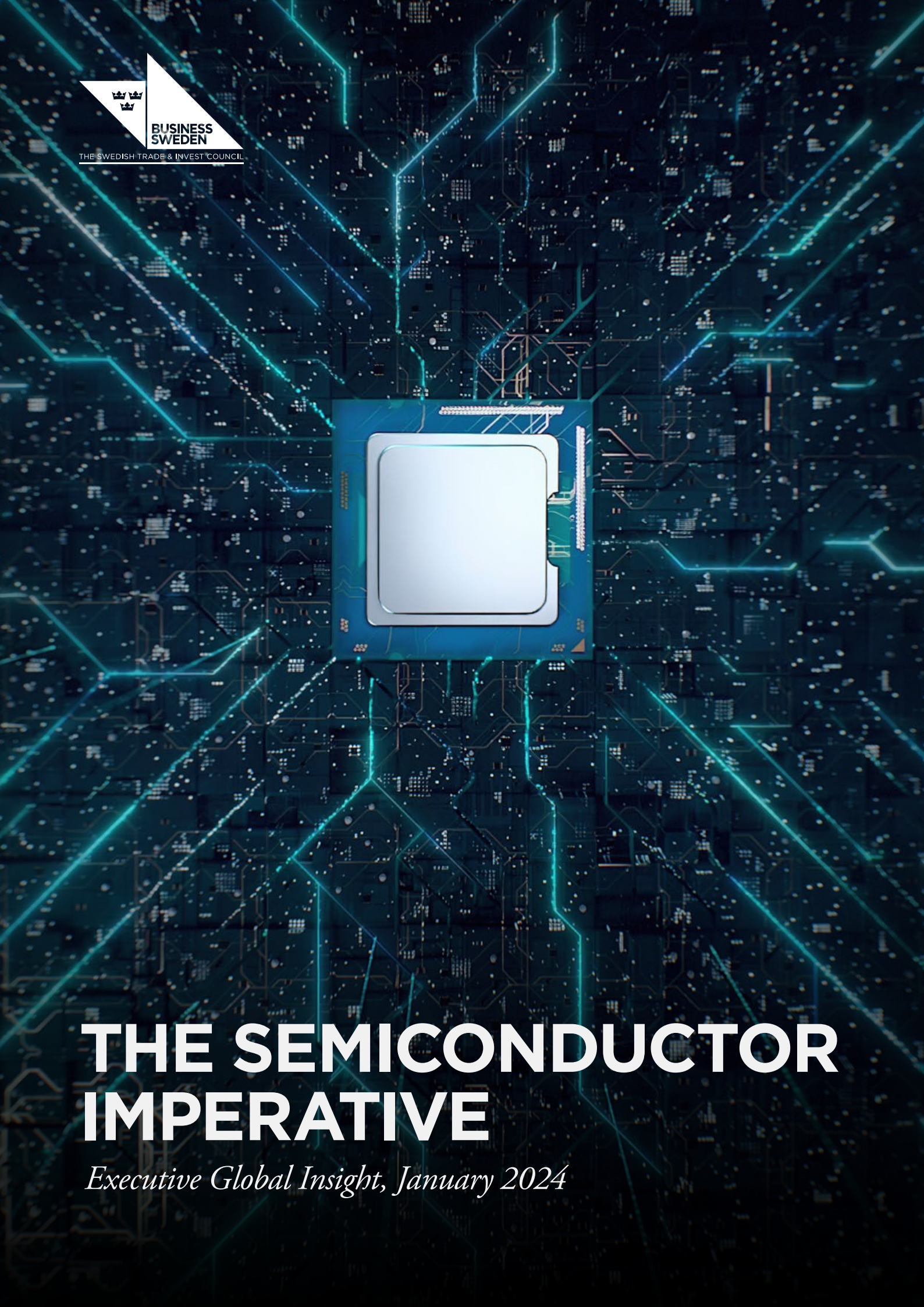

THE SEMICONDUCTOR IMPERATIVE

Executive Global Insight, January 2024

EXECUTIVE SUMMARY

MASTERING THE ART OF RESILIENCE FOR CHIPS

Wherever you look, semiconductors are the common denominator of the green transition. Electric vehicles, renewable energy, smartphone manufacturing, robotics, radar systems, AI and Internet of Things – you name it, they all depend on a steady supply of semiconductors.

We find them in industrial machinery, in the defence sector and in all technology development shaping the future. Ursula von der Leyen, the President of the European Commission, put it in simple terms: "There is no digital without chips". While the semiconductor industry becomes more critical than ever in the digital age, it faces tough challenges ahead.

Supply chain complexity, fluctuating demand and geopolitical tensions. These are just a few of the aspects of the business that need to be tackled. In fact, complexity is what characterises every facet of the semiconductor industry, from design to manufacturing and assembly. Any disruption to the chain can have major consequences.

Against the backdrop of rising geopolitical tensions, particularly between the US and China, uncertainty has become the new certainty. Export controls and trade disputes have a negative impact on chips' supply chains, and companies that rely heavily on semiconductors need to anticipate these disruptions. Many companies were hit hard by the recent chips shortage, not least in the automotive sector, and Swedish companies were no exception.

As many other sectors also faced production downtime, the imperative became clear: building resilient supply chains for semiconductors is a matter of safeguarding stability and progress or risking industry-wide disruption.

This report takes the pulse of the latest developments in the semiconductor space and builds on the knowledge and insights presented in Business Sweden's previous Executive Global Insight report *"Rewiring Global Supply Chains"*. We start by taking a deep dive into the global semiconductor landscape and how current trends and challenges may play out in the future.

Our analysis goes one step further in an attempt to uncover how disruption to semiconductor supply chains can ripple out and affect numerous industries. Here, we present a summary of actions that can be taken, narrowed down to three areas that supply chain managers need to urgently prioritise and incorporate into their planning: *risk management, regulatory changes and diversification.*

Lastly, the report provides guidance on how decision-makers can ensure robust and resilient supply chains by exploring essential operational strategies that will enable companies to withstand future disruptions.

BUSINESS SWEDEN
THE SWEDISH TRADE & INVEST COUNCIL

KEY TAKEAWAYS

- Volatile demand, rising geopolitical tensions and new regulations are posing ever-greater risks for the semiconductor industry.
- Semiconductors, or chips, are critical in all technology development supporting the green transition.
- Many Swedish companies have strong positions in high-tech/cleantech industries and are therefore particularly exposed.
- Creating a more resilient strategy for semiconductor sourcing will be crucial for Swedish companies.
- More Western suppliers are entering the market, but semiconductors require a high level of specialisation along a complex value chain.

Executive Global Insight is published by Business Sweden to give Swedish business leaders a regular deep-dive into the most important trends in cross-border trade. The report series helps decision-makers break down risks and opportunities and provides actionable insights, drawn from the knowledge and expertise of Business Sweden's global advisors based in more than 40 markets.

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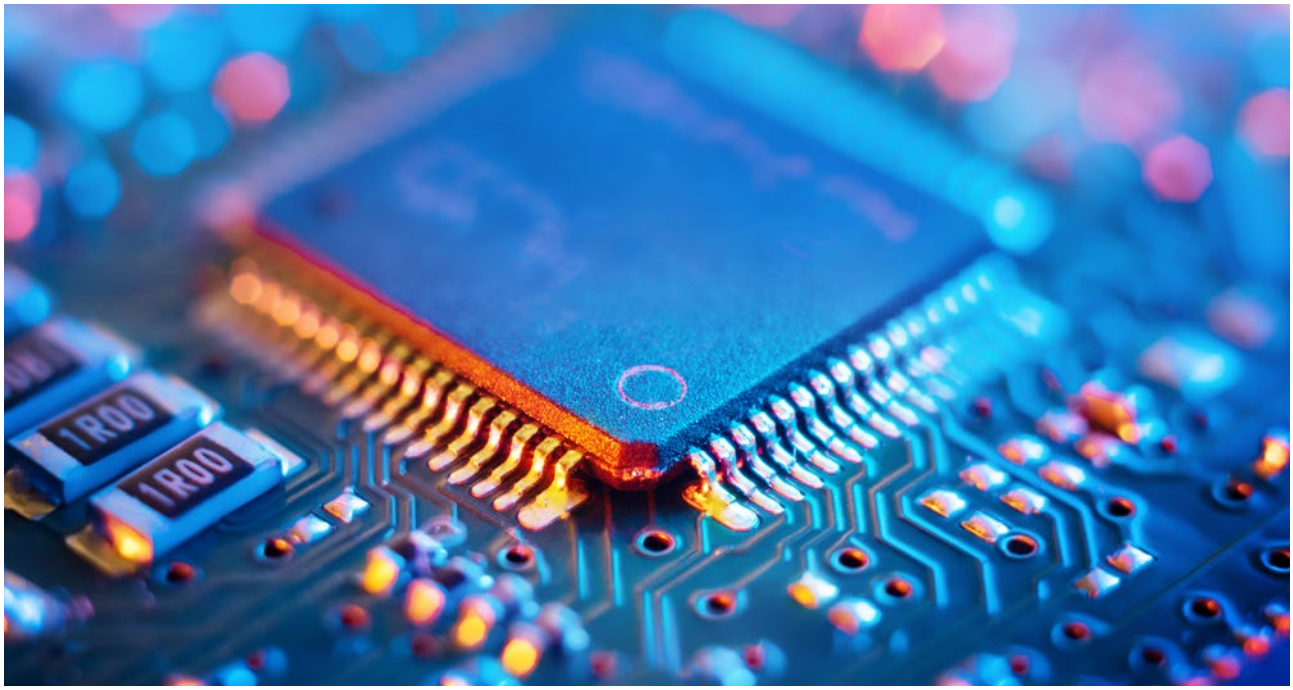


CHANGING TIMES FOR THE SEMICONDUCTOR INDUSTRY

Chips are small but not made easily. Semiconductor manufacturing is a highly complex process consisting of many manufacturing steps requiring a large variety of materials and chemicals, as well as energy and water.

Take for example Taiwan Semiconductor Manufacturing (TSMC), the world's largest contract chipmaker. Its annual electricity consumption accounted for 6 per cent of Taiwan's total energy consumption in 2020, and this is estimated to double by 2025. The company's water consumption in 2021 reached 80 million cubic meters. The risks are obvious. Any water or energy shortage can set back chip production for a perilous amount of time.

Besides this, semiconductor production requires minerals and hazardous chemicals such as cobalt, lithium, gold, and perfluorocarbons (PFCs). And as demand rises in tandem with ever more intricate chip designs, this becomes a difficult but critical circle to square for industry players going forward.

The challenging fact is that all these crucial components rarely are integrated by a single stakeholder, but rather scattered across the globe. Any type of disruption at just one component supplier could affect the entire supply chain of chips and cause imbalance between demand and supply.

As new technologies become the key enabler for the green transition, the semiconductor conundrum facing companies and governments today can hardly be overstated. So, how should Swedish companies begin to address the problem? For one, companies that are exposed to risk need to recognise the reality of the new environment.

Geopolitical tensions, fluctuating demand in an economic downturn, technology advances and frequent natural disasters – these events are all making the supply of chips more volatile. As such, taking proactive measures to ensure a more agile supply of chips can make the difference between success or failure.

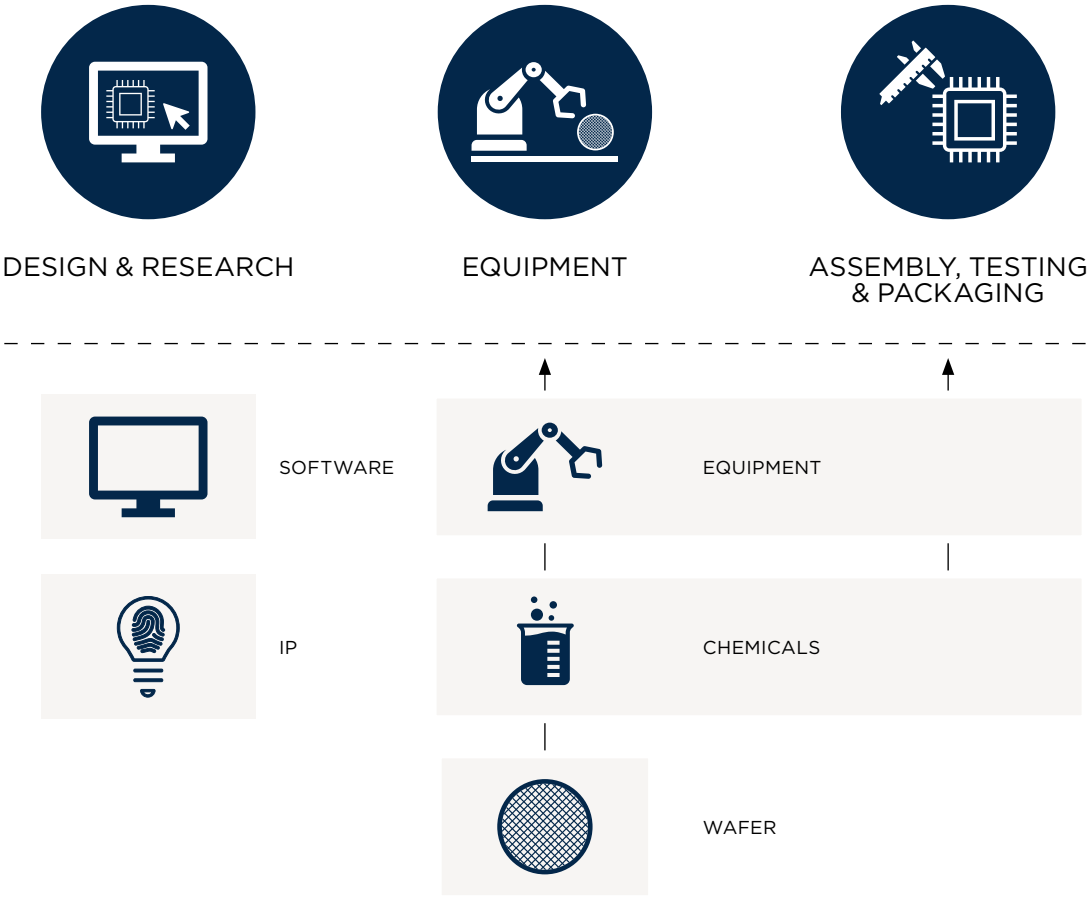
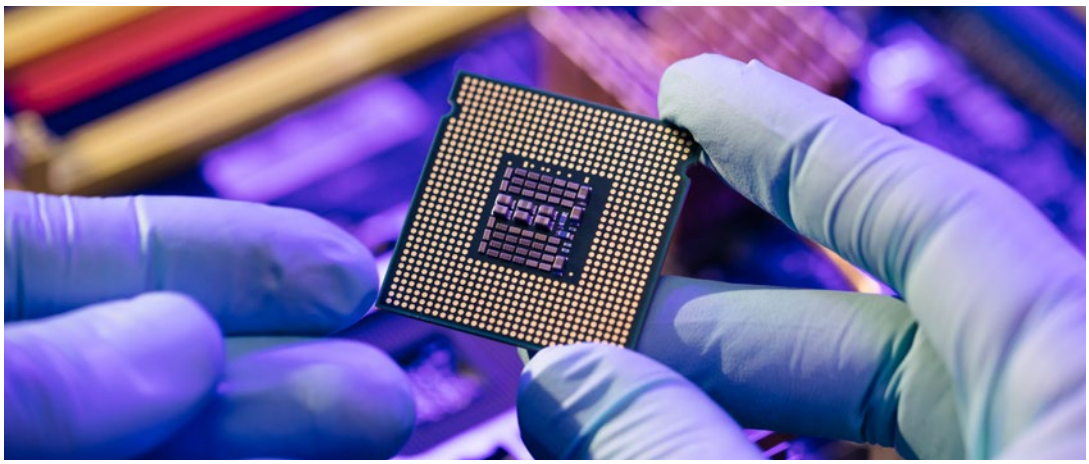


Figure 1. The Global Semiconductor Value Chain – Kleinhans & Dr. Baisakova, 2020, P6 – Stiftung Neue Verantwortung, used under CC BY-SA



TACKLING A SCATTERED VALUE CHAIN

Semiconductor manufacturing is a capital-intensive business that puts heavy requirements on time and specialisation along the entire value chain, which can be divided into three main phases: design and research, wafer fabrication (front-end) and assembly, testing and packaging services (back-end).

While the US is strong in intellectual property and chip design, it still heavily relies on partners for manufacturing and the extreme ultraviolet (EUV) machinery required for these technologically advanced processes. The leading front-end manufacturing hubs for the most advanced fabrication capabilities are owned and run by a few global players in places including Taiwan, South Korea, China and Japan. Meanwhile, emerging and labour-intensive economies have leveraged their cost advantages and put focus on back-end production processes.

The semiconductor supply chain is today determined by key players such as Intel, Samsung and Texas Instruments, who have seized positions across the market. Fabless design companies such as Apple, Nvidia and Qualcomm working in collaboration with foundry service providers like TSMC, GlobalFoundries and UMC became a main model in the mobile computing era. This model enabled foundry service companies like TSMC and Samsung to become technological frontrunners of strategic importance in the global economy.

So far, chip manufacturing has been hit by various forms of disruption, ranging from demand fluctuation to geopolitical conflicts and natural disasters. Changing behaviours during the pandemic made it increasingly difficult for companies to predict market demand. This meant that industries with complex supply chains based on heavy outsourcing and just-in-time manufacturing struggled to balance their inventories. Due to the supply shortage, competition became fiercer and many companies began stockpiling chips to secure their production.

Russia's invasion of Ukraine halted half of the world's neon output for chips. And just last February, NXP, Samsung and Infineon fabrication plants were forced to shut down operations due to an ice storm which caused power shortages in Texas, setting back production for months. Impact from similar extreme weather events may occur and should therefore be taken into consideration.

Both the strategic value and future risks facing the industry have put semiconductors firmly in the spotlight, and discussions are closely linked to the new economic and strategic strategies that are emerging across the globe. Acquiring specialised capabilities can drive innovation and reduce interdependence in the semiconductor supply chain.

ASML, with its concentration of core components in the complex supply chain, vividly illustrated the strategic advantage of having unique technological expertise in the production and deployment of the Extreme Ultraviolet (EUV) lithography technology. This is used to print the most intricate layers on chips and is essential when manufacturing the most advanced chips. Unfortunately, it will be extremely challenging for most players along the semiconductor value chain to achieve multiple specialisation capabilities.

CHIPS AT THE HEART OF GEOPOLITICAL TENSIONS

The semiconductor industry has been politicised because it is a key enabler in all technological advancement. Besides the challenges the industry is already facing, intentional disruption in the supply of chips or chip-related components can be used as leverage by competing geopolitical powers.

Several of the largest chip players are based in the US and China, and over the past year, the US has escalated its semiconductor export control to China. Between August 2022 and early 2023, the US aligned with Japan, The Netherlands, and other countries to launch a series of multilateral measures to limit China's possibility of developing its own cutting-edge chips, especially logic chips at 14nm and below. This was done by cutting China's access to electronic design automation software, high-performance computing chips procurement, software and chip manufacturing

equipment and tools. More recently, in August 2023, the US restricted investment from US firms and investors into China's cutting-edge technology.

According to US-led export controls, the non-restricted areas can still be used by Chinese semiconductor companies to expand. However, any OEM considering using Chinese-made chips will have to also be aware of the risk of US entanglements. Growing concerns around supply chain dependency on China were further exposed as the US implemented additional controls on 7 October 2023 regarding high-performance computing and cutting-edge logic chips.

Heightened tensions are here to stay for the foreseeable future. There is no clear off-ramp for the escalating tensions between the US and China. The US is alarmed by China's move to adopt advanced civil-use technology to sharpen its military capabilities.

Meanwhile, there has been no indication that the Chinese government is going to change any of its current policies on self-reliance despite US pressures and sanctions. The US-led restrictions targeting China will push both central and local Chinese governments and companies to do a trade-off when it comes to deciding where to invest their money, talent, and time, to counteract the chip suppression from Washington. "Self-reliance" will probably be the first priority for the central government of China to promote the Chinese chipmakers, but the interdependence and complexity of semiconductor value chains make it challenging for any country to become completely self-sufficient, especially for developing cutting edge chips.

Recent actions taken on the Chinese side caused somewhat of a shock as they challenged the effectiveness of US sanctions. In July 2023, China launched new regulations for export control of gallium and germanium, two essential metals for chip manufacturing where China dominates the market as it accounts for 80 per cent and 60 per cent of global production respectively.

In early September 2023, Huawei's newly launched phone Mate 60 Pro marked a breakthrough in the use of 7-nanometer processors which were made by Semiconductor Manufacturing International Corporation (SMIC) from China.

Current developments are raising a series of questions. How will China's counter measures affect global semiconductor manufacturing? Will the US implement more measures against China? And how will this bilateral competition impact other countries and their specialisation in the value chain?

Will all of these events artificially raise the operating costs of the global semiconductor industry, or force non-US or non-Chinese companies to pick side? It is still too early to predict any final outcome, but it is clear that proactively planning for a more resilient chip supply strategy will be crucial for Swedish companies.

PORT OF SHANGHAI

A SHIFTING LANDSCAPE: THREE KEY TRENDS

Against the backdrop of rising geopolitical tensions and growing demand for advanced chips, the global semiconductor industry is facing change on three major fronts.

1. PUSH TOWARD REGIONALISATION AND FRIENDSHORING

The regionalisation of production is accelerating as companies across the globe rethink their sourcing strategies. With governments worldwide pushing to secure the supply of chips, the semiconductor industry is very much leading this trend as they increase their capacity investments close to home and in "friendly" markets.

Due to the high complexity and strong inter-dependencies in the semiconductor value chain, "friend-shoring" has become an increasingly favoured strategy. At the same time, as more and more companies take steps to secure their supply, there is a risk of over-supply in the market. And striking the right balance is not easy due to the cyclical nature of semiconductor demand, coupled with the issue that fabrication plants need to run at full capacity to remain profitable.

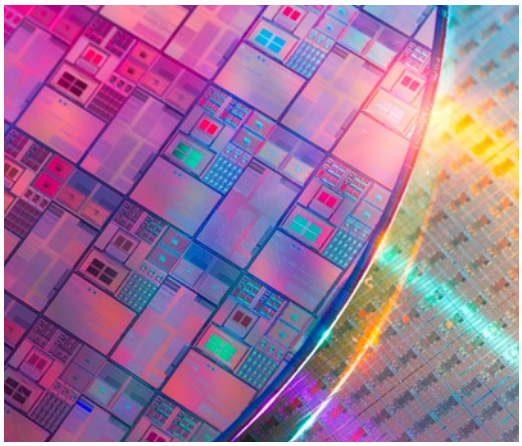
2. NEW RELATIONSHIPS BETWEEN SUPPLIERS AND CUSTOMERS

As a result of the chips shortage, the balance of power between semiconductor manufacturers and their customers changed. More frequently, companies were willing to commit to long-term non-cancellable contracts in addition to paying a premium and provide deposits to secure future supply. In the wake of this, companies saw the need to formulate new procurement strategies based on closer collaboration directly with the chip suppliers to improve reliability and transparency. With chip capacity growing at a rapid pace, it remains to be seen if the power balance will shift back in the future.

3. SPOTLIGHT ON SUSTAINABLE MANUFACTURING

There is no doubt that semiconductors play a crucial role in enabling the green transition. However, the semiconductor industry today faces many challenges when it comes to reducing its environmental impact. The manufacturing process requires large amounts of energy and water in addition to the use of various harmful chemicals.

Not unlike other resource intensive industries, the semiconductor industry is accelerating its move towards more energy and resource-efficient manufacturing practices. Sweden is home to many leading companies who provide climate-smart solutions that reduce emissions and resource consumption. With the ongoing build-out of capacity through establishment and expansion of fabrication plants around the world, the opportunities for these companies are endless.



RAMPING UP CHIPS CAPACITY IN THE WEST

The supply shortage during the pandemic and rising geopolitical tensions prompted fierce competition – pushing companies to stockpile chips. But Western countries are hard at work building up a homegrown supply chain.

Companies in both China and the West turned to stockpiling of chips during the past few years to safeguard their production. Today, chip manufacturers across the globe are rapidly expanding their capacity through expansion and establishment of new fabrication plants.

Governments in all corners of the world have recognised the economic and strategic importance of securing semiconductor supply chains, and they are now busy allocating investments closer to their home markets in the name of sovereignty, resiliency and increased competitiveness.

THE US AND EUROPE SHIFT INTO HIGH GEAR

In July 2022, the US Chips Act was signed into law which provides approximately USD 52 billion in government subsidies for research and production of semiconductors in the United States. A year later, in July 2023, the European Union adopted the EU Chips Act to reduce vulnerabilities and dependencies on foreign actors, with a view to double its global market share from 10 per cent to 20 per cent by 2030. Similar initiatives have been introduced in markets such as Taiwan, South Korea, China, India, and Japan.

Taking a closer look at Europe, there has been a surge of semiconductor investments in recent years. According to a recent statement by Ursula von der Leyen, President of the European Commission, the European Union has attracted investments of more than EUR 90 billion in the semi-conductor industry since the announcement of the EU Chips Act in February 2022.

The most significant investment was announced a month later in March 2022 when Intel revealed their plans for several large-scale investments in Europe along the entire semiconductor value chain. The most substantial being a EUR 17 billion investment to build two first-of-a-kind fabrication plants in Magdeburg, Germany. In 2023, the company expanded its investment to over EUR 30 billion, which also comes with a revised commitment of EUR 10 billion in

subsidies from the German government.

In August 2023, TSMC announced their first large scale investment in Europe to build a chip plant in Dresden, Germany. The company will invest USD 3.5 billion together in a joint venture with Bosch, Infineon and NXP under the name European Semiconductor Manufacturing Co. (ESMC). The total investment exceeds USD 10 billion and includes support from both the European Union and German government.

After this announcement, Thierry Breton, Single Market EU Commissioner, stated there are now 68 semiconductor technology projects across the EU. It remains to be seen if the EU's efforts are enough to reach its target of 20 per cent market share by 2030. Competition is mounting as countries across the globe are allocating significant resources to securing their own capacity.

IMPACT ON SWEDISH COMPANIES

Sweden, a frontrunner in the green and digital transition, has a strong position in sectors such as energy, transport, advanced manufacturing, and ICT. In large part, the competitiveness of Sweden's industries stems from a continuous focus on innovation and technological development. This also makes many Swedish companies increasingly dependent on chips.

One of the industries that has been hardest hit by the chip shortage, both globally and in Sweden, is the automotive industry. Sweden stands out in a global context as one of the countries where the automotive industry has the greatest impact on the economy, in terms of employment and production output. The Swedish automotive industry consists of approximately 1,000 companies and 72,000 employees. Net sales amounted to SEK 385 billion before the pandemic and the industry's contribution to GDP was 2.2 per cent.

Automakers in both Sweden and other parts of Europe have experienced major production challenges over the last couple of years. The disruptions in chip supply caused by lack of components due to shortage of chips resulted in production stops, increased delivery lead times, and a failure to fill orders. During a few months in 2020 and 2021, the Swedish automotive industry experienced a 25 per cent drop in production volumes. The result over time was financial losses, personnel cuts and dissatisfied customers.

The shortage forced many companies, not only in the automotive sector, to redesign components and reorganise their production processes, leading to increased costs. As this is not considered a sustainable approach going forward, companies are now considering different options for how they can reduce the effects of future chip shortages.

It's important to note that the challenges don't differ between Sweden and other European countries, and so they should be viewed in a European context.

EIGHT STEPS FOR BOOSTING RESILIENCE IN THE SEMICONDUCTOR SUPPLY CHAIN

Semiconductors have a broad value chain (spanning from design and materials to equipment, manufacturing, and commercialisation) that relies on specialised competences based on the comparative advantages of different markets around the world.

It is equally essential for governments and companies globally to work jointly towards a more resilient semiconductor supply chain to enable continuous leaps in industrial development. To mitigate the apparent risks and vulnerabilities along the value chain, governments and industry players will have to collaborate more closely to address questions related to geographies, technologies, capital, and talent.

While the semiconductor shortage from the pandemic now has stabilised somewhat, delivery times remain a challenge for many Swedish companies. At the same time, it is clear that industry players have adapted their approach and are showing a level of increased flexibility. Companies in the semiconductor space have developed a better understanding of sourcing and also improved communication between suppliers and customers to tackle challenges.

That being said, actions need to be taken to mitigate the frequent disruptions that occur in this volatile and sensitive industry. In short, companies need to develop their defense mechanisms. But how you do create more agile and resilient operational processes?

In today's new reality, all companies that are dependent on a steady and reliable supply of semiconductors need to make a self-assessment of their readiness to tackle risks, based on the eight-step framework presented below.

RECOMMENDATIONS TO DE-RISK THE SUPPLY CHAIN

1. Monitor risk exposure due to regulatory frameworks and the potential consequences in terms of impact from export controls on sales and market share. One of the most widely discussed events on the regulatory front, with far-ranging impacts, is the CHIPS Act in the US which has been launched to bolster 'Made in America' initiatives.

Based on this and other regulatory changes, develop mitigation strategies that can eliminate the risk of supply chain disruptions, for example by putting more focus on localisation, multiple sourcing and friendshoring.

2. Enhance business continuity planning (BCP) to strengthen your ability to deliver regardless of potential disruptive events and to be able to respond to external factors in a swift and agile way. Companies affected by the semiconductor industry's ups and downs should have a well-developed understanding of the geopolitical risks involved (e.g. with Taiwan, or the ongoing trade wars) and proactively work with mid- to long-term BCP across multiple tiers.

This is primarily achieved through proactive build-up of knowledge and understanding of your suppliers' suppliers to be able to assess the risks of the whole supplier base and de-risk accordingly. This is especially important for highly sensitive tech supply chains such as semiconductors.

3. Understand and prioritise the role of partnerships across the value chain in the new global environment. This requires closer collaboration between stakeholders in the semiconductor supply chain than ever before and includes increased share of in-housing by OEMs, or development of strategic alliances (including M&As) across all three tiers of the supply chain.

4. Identify components and materials from high-risk geographies and adopt a dual/multi-source strategy to mitigate supply risks to withstand geopolitical turbulence, given that even small disruptive events can have a major impact. While adopting this strategy may be more costly, it has proven to be an invaluable tool to safeguard a steady supply at all times.

RECOMMENDATIONS TO COUNTERACT OPERATIONAL VOLATILITY

5. Invest in advanced tools such as AI and data analytics to improve visibility and predict disruptions so you can proactively respond and quickly take action well ahead of time.

6. Rethink and prepare dual-design of products to avoid reactive redesign caused by chip disruptions since reactive redesign costs more than pragmatic dual design up-front. This strategy is not only essential to counteract supply disruption, but also to avoid rising product costs which may be influenced by an increase in semiconductor prices.

7. Increase your company's readiness to adopt contingencies such as allocating an additional budget to cover the costs from reshaping the current chip supply chain, and to remedy the loss of customers and reputational impact by disrupted supply and reliability.

8 Ensure traceability and sustainability along the entire semiconductor value chain by deploying Product Lifecycle Management tools (PLM) and considering circularity when sourcing and procuring chips, bearing in mind that end-of-life of semiconductors will be an instrumental new opportunity for companies globally.

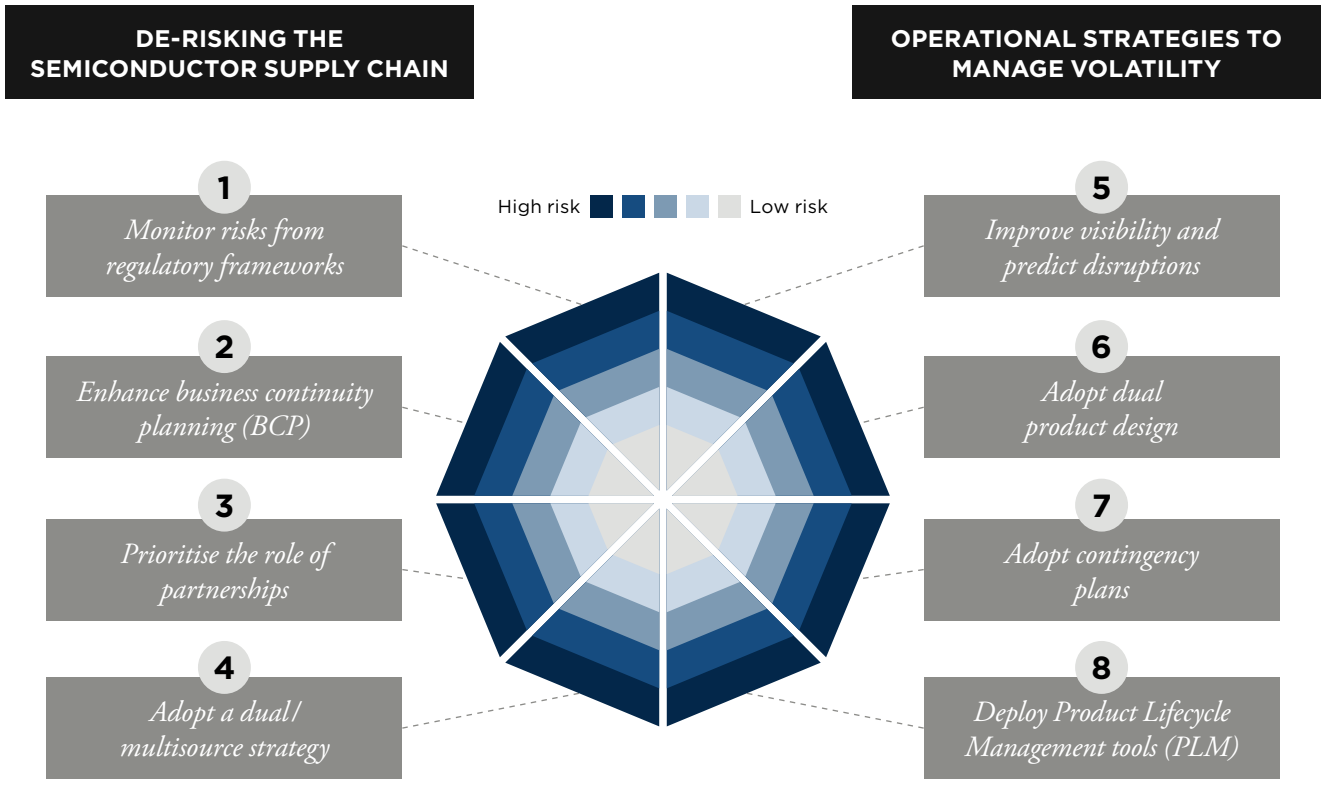


Figure 2

BUSINESS SWEDEN CAN SUPPORT YOU

Business Sweden's green tech specialists have helped many Swedish companies, of different sizes and in diverse sectors, to maximise the impact of their strategies in the global green shift.

We can help you improve your risk management, sales and operations planning (S&OP), procurement, sustainability performance, logistics and distribution – and provide hands-on support for localisation, M&A and 'Make or buy' (MoB) decisions.

With a unique mandate from the Swedish government and the business sector, our global team offers strategic advice and practical support in more than 40 markets worldwide.

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