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From Overdependence to Independence: European Policy Frameworks for Semiconductor Supply Chain Resilience

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Abstract

This paper explores the European Union's ongoing journey towards greater semiconductor independence in times of supply chain vulnerabilities and rising geopolitical tensions. With a focus on key initiatives such as the European Chips Act or the Critical Raw Materials Act, this paper explores how such policy frameworks can aid in strengthening Europe's position in the global semiconductor industry. This paper's analysis highlights the importance of diversifying the sources for critical raw materials in the semiconductor production, investing in modern manufacturing technologies and fostering a skilled labour force which meet the ever rising standard of the industry. It also identifies the need for closer cooperation & coordination between EU member states and industry partners for the successful implementation of these measures.

The findings suggest that, while complete self-sufficiency and independence remains a distant hope due to the increasingly globalised nature of the industry, the EU's far reaching strategies can significantly reduce the reliance on foreign suppliers. Overall, by balancing policy frameworks, taking into account raw materials, and technological innovation, Europe can move towards a more competitive, resilient and independent semiconductor industry.

Keywords: Semiconductor sovereignty, EU supply chain resilience, European Chips Act, Raw material dependencies

1. Introduction

Semiconductors are the heart and brain of our current technology, they are of utmost importance for a plethora of global industries and are the most crucial component used in powering the devices and various systems we use in our daily life. From smartphones, computers or headphones to military machinery, medical equipment and even rockets these tiny chips, whose physical size often remains within a few millimetres, with gates and transistors even being measures and produced on the nanometer scale, are at the heart of innovation and act as the scaffold for many current and future innovations[1].

Before diving deeper into the economic and geopolitical aspects of the semiconductor industry it is important to understand what these semiconductors are. Semiconductors are essentially materials with conductive properties making them essential for the production of more advanced circuits or chips[2]. The primary component of modern semiconductors is silicon which is one of the most common resources within the Earth's crust and often derived from sands or smaller rocks. Although Silicon is the most important resource the production process further relies on rare metals such as Cobalt, Germanium or Gallium as well as certain gases such as nitrogen, helium and argon[3].

The production of such Semiconductors is highly complex and based on several production steps such as wafer fabrication, lithography and etching. The machines required for the production are not only vastly expensive but also scarce, being produced by only a few firms across the globe, with the most advanced machines being built by ASML, a Dutch company, whose latest machine costs around €350 million and weighs as much as two Airbus A320s[4]. The technological ability of producers in the semiconductor industry is often measured in their ability to minimise the size gate length of transistors on the wafer, with a smaller size allowing for increased density of transistors in a chip. Current production by TSMC and Samsung reaches sizes between 5 nm and 3 nm placing them ahead of the vast majority of the industry which lies at around 20 nm. Overall the complexity of this production process makes this industry into one of the most challenging and resource intensive industries in the world[5].

[1] Katarina Nikolic, Matthew J Forshaw, and Ramon Compañó, "The Current Status of Nanoelectronic Devices," World Scientific, February 1, 2003, https://doi.org/10.1142/s0219581x03001048.
[2] Hwaiyu Geng and Lin Zhou, "How Semiconductor Chips Are Made," 2005, http://arantxa.ii.uam.es/~die/%5BLectura%20ASICs%5D%20How%20semiconductor%20and%20chips%20are%20made.pdf.
[3] Gunnar Halvorsen and Gunnar Schüssler, "Sustainable Silicon Production," September 26, 2003, 495–508, https://doi.org/10.1002/9783527619924.ch80.
[4] Cagan Koc, "ASML Shows off Chipmaking Machine behind AI Shift," Bloomberg.com (Bloomberg, February 9, 2024), https://www.bloomberg.com/news/articles/2024-02-09/asml-shows-off-380-million-165-ton-machine-behind-ai-shift.
[5] Jordan Lorence, "Understanding Semiconductor Technology Nodes: From 10nm to 3nm and Beyond," Mrlcg.com (MRL Recruitment, October 31, 2024), https://www.mrlcg.com/resources/blog/understanding-semiconductor-technology-nodes--from-10nm-to-3nm-and-beyond/.

The Covid-19 pandemic highlighted the vulnerability and fragility of the semiconductor industry, with the rapidly arising distribution issues in its global supply chain[6]. While these disruptions faded into obscurity in tandem with the Covid-10 Pandemic they had the long lasting effect of highlighting the shocking reliance of many nations, especially in Europe, on only a small collection of major producers, most of which operate in East Asia, with Taiwan, South Korea, Japan and China being the predominant producers[7]. While the disruptions of the Covid-19 pandemic faded into obscurity others moved into the spotlight, particularly the rising tensions between China and Taiwan, with Taiwan currently being the world's largest supplier of semiconductors producing well over 50% of the global supply while also being the primary supplier for major western companies like Apple or Qualcomm[8]. The repeated threat of major supply chain disruptions which may even exceed the extends of the Covid-19 Pandemic highlighted the vulnerability of many nations to sustain their domestic demand for semiconductors and sparked various movements within individuals nations and even supranational organisation like the European Union (EU) to strive for improved semiconductor independence, with the goal of enhancing their own economic resilience to such supply shocks[9].

The European Union, currently produces roughly 10% of the world's semiconductors, a significant decline compared to the previous decades in which European Companies like Infineon, NXP and STMicroelectronics were significant players in this global market[10]. In response to this rapid decline in market share and with the recognition of the strategic importance of such Semiconductors the EU and its member countries have launched several initiatives such as the Alliance on Processors and Semiconductor Technologies, the IPCEI on microelectronics and communication technologies and most importantly the European Chips Act. While there are various initiatives the European Chips Act stands out in particular with a clear commitment to "reinforce the semiconductor ecosystem in the EU" with the goal of more resilient supply chains and a reduction of foreign dependencies [11]. However the overshadowing and aspirational goal of a 20% global market share by the end of the decade stands out in particular and marks a key step for the EU in reaching their technological sovereignty. These efforts will presumably also have far reaching effects beyond the

[6] Antonio Varas et al., "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era," BCG Global, March 28, 2021, https://www.bcg.com/publications/2021/strengthening-the-global-semiconductor-supply-chain.
[7] Cryille Schwellnus et al., "Global Value Chain Dependencies under the Magnifying Glass," OECD, 2024, https://www.oecd.org/en/publications/global-value-chain-dependencies-under-the-magnifying-glass_b2489065-en.html.
[8] Bradley Martin et al., Supply Chain Interdependence and Geopolitical Vulnerability: The Case of Taiwan and High-End Semiconductors, Rand.org (RAND Corporation, 2023), https://www.rand.org/pubs/research_reports/RRA2354-1.html?utm_campaign=&utm_content=1678728781&utm_medium=rand_social&utm_source=twitter.
[9] Jordan Bish, "A New Dawn for European Chips," Deloitte Insights, n.d., https://www2.deloitte.com/us/en/insights/industry/technology/semiconductor-chip-shortage-supply-chain.html.
[10] European Commission, "European Chips Survey | Shaping Europe's Digital Future," digital-strategy.ec.europa.eu, August 4, 2022, https://digital-strategy.ec.europa.eu/en/library/european-chips-survey.
[11] European Commission , "European Chips Act | Shaping Europe's Digital Future," digital-strategy.ec.europa.eu, 2023, https://digital-strategy.ec.europa.eu/en/policies/european-chips-act.

semiconductor industry, with a more technologically advanced EU economy and industry ensuring competitiveness in rising technologies such as Artificial Intelligence (AI), autonomous vehicles or 5G technology[12].

As the vanguard for this push for technological sovereignty, Germany as the current largest economy in Europe, has taken a somewhat exemplary position in this endeavour. The German government has provided significant subsidies in the industry to attract investments from major semiconductor manufacturers. The largest of these investments facilitated through government subsidies is done by Intel. In exchange for a substantial subsidy of roughly €10 billion Intel announced the construction of a "mega-fab" in Magdeburg, Saxony Anhalt, which would see a total investment of about €30 billion into the country, marking the single largest foreign direct investment in the country's history[13]. And while as of recently this construction has been postponed by 2 years, its completion would significantly contribute to the country`s and the EUs independence. Intel's investment in Germany would also not be the only one, with Global Foundries, Infineon, Bosch, ESMC and even TSMC announcing plans and investments in the country. Other countries such as France and the Netherlands have also increased their efforts in bolstering domestic production, with the Dutch company ASML, which leads in the production of lithography machines, in particular receiving several subsidies for research and development purposes given its vital role in the industry[14].

In spite of the various efforts by the EU and its member states, achieving complete independence in semiconductor production remains a daunting task given the globalised and specialised nature of the industry. For instance Silicon, the primary component of wafers and semiconductors, is to large parts produced by China with Europe being one of its main buyers[15]. The EU has several projects underway which aim increase its production capacity of silicon as part of the Critical Raw Materials Act, from raw extraction like with the Silicium de Provence project (SilPro) in France or the expansion of mines in Spain through ERIMSA and Sibelco to Silicon recovery efforts through circular economy frameworks [16]. With estimates indicating that the European demand will rise to 2 million tonnes of silicon (99.99%) by 2030 such efforts would not suffice in significantly lowering the reliance on foreign imports which in return would weaken extended semiconductor independence despite improvements in the production facilities in the EU[17]. This

[12] European Commission, "European Industrial Strategy," commission.europa.eu, 2022, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en.

[13] Mathis Richtmann and Aline Spantig, "US Intel's Factory Delay Adds to Germany's Economic Woes," dw.com (Deutsche Welle, September 17, 2024), https://www.dw.com/en/us-intels-factory-delay-adds-to-germanys-economic-woes/a-70241739.

[14] Jerome Hull, "Semiconductor Industry in Germany," www.gtai.de, 2023, https://www.gtai.de/en/invest/industries/industrial-production/semiconductors.

[15] Arthur Little, "Strategizing for Growth While Building Resilience in the Rapidly Evolving Industry 2024," 2024, https://www.adlittle.com/sites/default/files/reports/ADL_Localizing_global_semiconductor_2024_0.pdf.

[16] SilPro, Sibelco.com, 2022, https://www.sibelco.com/en/news/sibelco-expands-silica-sand-reserves-in-the-north-of-spain.

[17] European Institute of Innovation and Technology, "EIT RawMaterials Invests in German Silicon Recycling Start Up," EIT RawMaterials - Developing raw materials into a major strength for Europe, September 19, 2023, https://eitrawmaterials.eu/press-releases/eit-rawmaterials-accelerates-green-transition-strategic-investment-silicon-recycling.

pattern repeats itself for other rare metals such as gallium or germanium, required in the production process of advanced semiconductors which are also subject to similar vulnerabilities in terms of supply.

Europe's strive for independence might have other ulterior motives beyond minimising risks in the supply chain and overdependence. As hinted towards earlier such efforts as outlined above would also have the potential to secure Europe's position in the global technological race, with semiconductors being the foundation of many emerging technologies such as AI, robotics and even quantum computing[18]. Through investments in domestic semiconductor production Europe ensures that it remains on par with the technological innovation and does fall behind other major powers.

Increasingly Semiconductors have moved into the frame of national security concerns. From radar systems or military vehicles to missile guidance systems such as the Javelin system currently in use in Ukraine, semiconductors have become increasingly important if not essential for modern warfare. With recent geopolitical uncertainties the access to semiconductors for use in defence systems has become imperative for nations, akin to a strategic resource which requires secure and reliable access[19].

Overall, Europe's efforts towards semiconductor independence is a crucial economic and strategic move for the European Union and its member states. While complete independence may be unattainable due to the intertwined nature of the global supply chain, significant progress towards a reduction of reliance on foreign suppliers can be made, improving economic resilience. By investing in domestic production capabilities, promoting technological innovation and implementing supporting policies Europe can position itself as an increasingly self-sufficient and competitive player in the global semiconductor industry. The goal of this research is to explore the various strategies employed by the EU and individual countries and evaluate their potential impact on semiconductor independence in both a theoretical and empirical context.

2. Thesis

Achieving greater semiconductor independence is an essential and strategic goal for the European Union and its member states, particularly in light of increasing geopolitical tensions, supply chain disruptions as seen during the COVID-19 pandemic, and the growing significance of semiconductors in modern economies and national security. This paper argues that strengthening supply chain resilience is crucial for the EU to achieve this independence. By enhancing domestic production capabilities, fostering technological innovation, diversifying supply sources, and implementing appropriate policy frameworks, the EU can significantly reduce its dependence on major foreign suppliers, thereby promoting

[18] Kearney, "Europe's Urgent Need to Invest in a Leading-Edge Semiconductor Ecosystem - Article," Kearney, February 2022, https://www.kearney.com/industry/technology/article/-/insights/europes-urgent-need-to-invest-in-a-leading-edge-semiconductor-ecosystem.

[19] Sujai Shivakumar and Charles Wessner, "Semiconductors and National Defense: What Are the Stakes?," www.csis.org, June 8, 2022, https://www.csis.org/analysis/semiconductors-and-national-defense-what-are-stakes.

economic resilience and bolstering both economic and national security. Furthermore, this paper will show how reinforcing supply chain resilience and economic independence is not only a matter of resilience and competitiveness but also a measure to keep Europe at the forefront of technological innovation in emerging technology markets.

3. Literature Review

The semiconductor industry is one of the most important industries of the present and the foreseeable future, being the driving force behind technological advancements and many global industries. The following literature review will aim to provide a a comprehensive review of the existing literature on this topic and will point out several key topics and themes that are relevant for deeper understanding on how the EU can achieve greater semiconductor independence.

The paper by Poli (2023) explores the importance of the EU achieving semiconductor sovereignty, highlighting the need for a higher degree of independence from foreign nations. The paper highlights the EU's dependency on foreign semiconductors and how Covid-19 and the rise of geopolitical tensions exposed the vulnerabilities faced on such an overreliance on foreign suppliers. Particularly the paper underscores how the overreliance on East Asia, particularly Taiwan, limits Europe's capacity to sustain and supply its strategic industries, ranging from telecommunications or energy to the defence industry. The paper emphasises that becoming more independent within the semiconductor industry is not only a matter of economic resilience or becoming more technologically sovereign, but also a matter of geopolitical security in an ever more uncertain world[20].

The issue brief by Khan et al. (2021) takes an in depth look at the complex supply chains of the semiconductor industry, pointing out the current global interdependence at each and every step of the supply chain, from research and development to production and manufacturing. The paper points out the duality of the situation, with nations being highly specialised in certain areas. For instance, the US heavily specialises in research and development, the Dutch company ASML virtually has a monopoly on the most advanced lithography machinery while Germany is a key producer for the required chemicals and gases like helium and argon. Taiwan through its prominent Taiwan Semiconductor Manufacturing Company (TSMC) leads global semiconductor production, predominantly through its advanced fabrication facilities and its logic foundry industry. This stands in contrast to rapid expansion of its production capacity by China which still falls short in the production of more advanced semiconductors, lacking more advanced equipment for the production of more modern and advanced chips. Overall this piece of literature highlights specialities of certain

[20] Sara Poli, "Reinforcing Europe's Technological Sovereignty through Trade Measures: The EU and Member States' Shared Sovereignty," 2023, https://www.europeanpapers.eu/en/system/files/pdf_version/EP_EF_2023_I_013_Sara_Poli_00665.pdf?utm_source.

stages in the production process of advanced semiconductors and highlights how this industry clusters around only a relatively few countries[21].

The paper by Mönch et al. (2018) highlights the complexity of supply chain management pointing out the importance of coordination between different stages of production, extending from the extraction of raw silicon up to the complex packaging processes necessary for secure shipment. The paper stresses the uniqueness of certain aspects of the semiconductor supply chain, which includes the long production process which can extend to several weeks at times, the extraordinarily high capital investments as seen earlier with the ASML lithography machines, and the overall advanced technological processes which require highly skilled personnel. The paper argues that in order to achieve efficiency simply optimizing individual production units would not suffice, rather they emphasise the need for a comprehensive approach, which includes both up- and downstream elements of the supply chain. Additionally the paper points to the significance of semiconductor supply chain management, looking to Europe and showing its need to not only develop production, but also develop expertise and experience in managing the extensive supply chains involved in semiconductor manufacturing. As a tool for this the paper mentions the use of simulation and optimization tools to assist in this management and the decision making process, which according to the authors is an essential aspect in the construction of resilient supply chains[22].

The paper by Wei Xiong et al. (2024) adds further detail to the issues faced by the semiconductor industry, particularly the issues of supply chain shocks as seen during the Covid-19 pandemic. The authors emphasise the necessity of more resilient supply chains and the need for a decentralised network to mitigate such disruptions. The paper explores the high degree of vulnerability exhibited by the semiconductor supply chain and points out its vulnerability and how this vulnerability has been underscored by the Covid-19 pandemic and the Russian-Ukraine crisis. The paper then proceeds to explore previously mentioned strategies which aim to promote resilience and names examples such as a more diversified manufacturing base, increased international collaboration and the use of advanced technologies like AI and advanced data analytics to enhance the "visibility" of the supply chain with the goal of predicting future shocks and disruptions. The authors point out the need of such strategies to ensure long-term stability in the semiconductor industry, especially in Europe where nations attempt to distance themselves from East-Asian partners and build more resilient and independent supply chains[23].

[21] Saif Khan, "The Semiconductor Supply Chain," Center for Security and Emerging Technology, January 2021, https://cset.georgetown.edu/publication/the-semiconductor-supply-chain/.
[22] Lars Mönch et al., "Modelling and Analysis of Semiconductor Supply Chains," International Journal of Production Research 56, no. 13 (April 25, 2018): 4521–23, https://doi.org/10.1080/00207543.2018.1464680.
[23] Wei Xiong, David D Wu, and Jeff, "Semiconductor Supply Chain Resilience and Disruption: Insights, Mitigation, and Future Directions," International Journal of Production Research, August 13, 2024, 1–24, https://doi.org/10.1080/00207543.2024.2387074.

The European Chips Act (ECA) Analysis by Villoslada Camps and Saz-Carranza (2023) looks at Europe's strategy of trying to strengthen its semiconductor industry through several different lenses, including the fundamental motivation, structure and challenges its current strategy might entail. The ECA act, which was introduced in response to the Covid-19 pandemic and rising geopolitical tensions, aims to bring Europe's semiconductor market share from 10% to 20% by 2030. The Authors specifically highlight the reliance on East Asia and the US for the production of advanced semiconductors, while also pointing out the EU`s strength in Semiconductor design and the production of advanced semiconductor machinery, specifically through ASML in the Netherlands. However the paper points out several challenges which the EU might face in its quest for a self-reliant semiconductor industry such as high costs, a limited suitable workforce, and most notably a lack of established semiconductor foundries able to produce the latest semiconductor designs. The authors conclude that while the ECA is certainly an ambitious project, it must still be seen as the first step and major step in its drive towards reducing semiconductor reliance[24].

Figura (2023) explores the potential of Europe within the global semiconductor industry by pointing out its specialization in research, design and the production of advanced machinery / equipment. Key to the paper is the idea that Europe should strike a balance between its ambitious production targets and leveraging its existing, aforementioned strengths. Figura critiques the current efforts of creating and supporting new and more advanced fabrication facilities, instead suggesting a broader approach which spans the wider semiconductor supply chain including R&D, Raw materials and the production of machinery. Hence Figure builds upon existing frameworks of the EU by providing a different approach, which leverages existing strengths of the EU within the semiconductor industry[25].

While the existing research provides valuable insight into the complexity of the semiconductor industry some gaps can be identified. Research exploring this topic predominantly explores the dynamics of the industry's supply chain, specifically the evident overreliance on foreign suppliers and the related vulnerabilities. While other research like Mönch et al (2018) focuses on other related topics like achieving efficiency in this supply chain, while failing to look at other factors influencing the EU's ability to achieve its aspirational goals. The general trend appears to be that the literature does not address how this extensive knowledge can be applied within the specific environment present in the EU, with reference to its current capabilities and other geopolitical and economic context. This paper aims to address the gaps in this research by focusing on the existing policy frameworks already implemented or in the process of being implemented by the EU, such as the ECA Act or the Raw Materials Act, and how such policies are able to increase production capacity while also fostering deeper collaboration between members and ultimately enhancing the EU's resilience. By utilizing

[24] Joan Camps and Angel Saz-Carranza, "The European Chips Act: Europe's Quest for Semiconductor Autonomy," 2023, https://www.esade.edu/faculty-research/sites/default/files/publicacion/pdf/2023-09/Chips_Act_ESADE.pdf.
[25] Jannis Figura, "An Assessment of the European Microchip Industry and Its Expansion Strategy," Horizon Insights 6, no. 1 (March 1, 2023), https://doi.org/10.31175/hi.2023.01.

insights gained from previous research in combination with an analysis of the EU's policy frameworks this paper aims to contribute to the overall understanding of how Europe will be able to reduce its reliance on foreign suppliers, working towards a more self-sufficient and independent semiconductor industry.

4. Policy Review

In its quest to achieve semiconductor independence Europe has already implemented many frameworks and policies which contribute towards that goal. Many of these policies have been relatively recently implemented with their effectiveness still being unclear and only open to estimation and predictions at this point in time. This section will aim to make such estimations and predictions based on current information.

5.1 European Chips Act (ECA)

One of the most significant policy frameworks which has been mentioned earlier on is the European Chips act. This policy framework sets €43 billion into motion with the goal of not only bringing the EU`s semiconductor landscape up to date, but also increasing its overall volume. The ultimate goal is a 20% market share of the global semiconductor market, marking an increase of roughly 10%, by 2030 with the additional focus on making EU supply chains more resilient and less receptive to external shocks and disruptions. The European Chips act essentially consists of 3 Pillars, making up an extensive framework which aims to foster innovation and increase production[26].

First of these pillars, referred to as the "Chips for Europe Initiative", focuses on the transfer of knowledge "from lab to fab" essentially trying to close the gap between theoretical innovation and practical manufacturing and production by combining funds from private and public investors. As part of this pillar just short of €10bn are mobilised for the creation of new information networks and competence centres where innovative technologies can be tested and improved through support structures with the additional goal of attracting new talent through easier access to the required facilities. Overall this first pillar, which aims for complete introduction by 2027, appears to be an effective policy aiming to establish a foundation for future research and innovation within the semiconductor industry and although its effects might only be found in the future given the complexity of the industry, its product and general time-intensitivity of research and development, it still is a solid start[27]. However, given that the EU is already trailing behind countries like South Korea and Taiwan who similarly invest large sums in such frameworks, the question must be asked if this is not only enough for the EU to bridge the technological gap, but also if 2027 is a realistic timeframe.

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[26] European Commission, "European Chips Act," commission.europa.eu, 2022, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en.

[27] European Commission, "European Chips Act: The Chips for Europe Initiative | Shaping Europe's Digital Future," digital-strategy.ec.europa.eu, 2023, https://digital-strategy.ec.europa.eu/en/factpages/european-chips-act-chips-europe-initiative.

The second pillar, which goes unnamed, aims to create a framework which fosters investments and increases production capacity within the EU, with the goal of ultimately improving supply chain resilience. In order to achieve this the EU aims to introduce two kinds of facilities, first of which being Integrated Production Facilities (IPF`s). These IPFs are vertically integrated production facilities, essentially these manufacturing facilities are partially self-sufficient in their production process by including every major step from lithography to etching and packaging. These facilities would produce essential equipment and components used in semiconductor manufacturing within the European Union to improve supply chain resilience due to increased control over it. An example of such a vertically integrated facility would be STMicroelectronics which actively attempts to make its supply chain more resilient through vertical integration as seen in their latest Silicon Substrate manufacturing facility in Italy[28].

The second type of facility the EU plans to introduce are Open EU Foundries (OEF`s), such foundries would allocate large parts of their production capacity to the production of chips from other companies or third parties in general, in particular companies which do not have access to their own fabrication facilities. The underlying goal of such, "first of its kind", facilities is to enhance the semiconductor ecosystem of the EU, lowering the barriers of entry of fabless firms into the semiconductor market, attracting more investments into the industry. The addition of a priority component in such facilities for new innovative chip designs adds to the EU`s goal of fostering innovation. While the EU does not specifically plan its own construction of such facilities, existing facilities may offer their services under this scheme by complying with certain criteria such as: Promoting Innovative designs, dedicating parts of their capacity to other firms and by ensuring functional separation by guaranteeing confidentiality[29]. As of writing this paper only a select few manufacturers' facilities have been recognized as OEF`s, including X-Fab Silicon Foundries and GlobalFoundries, both of which located in Germany and STMicroelectronics located in Italy[30].

The IPF`s and OEF`s included in the second pillar stand out as "first of their kind" within the EU and facilities or manufactures which meet the specifications of these two frameworks are granted simplified administrative processes within the EU and early access to pilot lines. Additionally during supply chain disruptions such facilities may be required to produce products underproduced during disruptions to enhance resilience. Overall the second pillar of the European Chips Act (ECA) stands as an exemplary policy which aims to open the doors for many smaller manufacturers who might have innovative designs, but may not have the vast funds associated with the production of semiconductors. One

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[28] European Commission, "European Chips Act: Security of Supply and Resilience | Shaping Europe's Digital Future," digital-strategy.ec.europa.eu, 2023, https://digital-strategy.ec.europa.eu/en/factpages/european-chips-act-security-supply-and-resilience.
[29] Belga, "The Brussels Times," Brusselstimes.com, 2024, https://www.brusselstimes.com/1189264/eu-microchips-commission-approves-an-open-foundry-in-germany.
[30] SiliconSaxony, "European Chips Act: Germany Is Leading the Way. Now It Is up to Europe. - Silicon Saxony," Silicon Saxony, November 13, 2023, https://silicon-saxony.de/en/european-chips-act-germany-is-leading-the-way-now-it-is-up-to-europe/.

concern with OEF`s may be the existence of some degree of inequality between nations, as such facilities tend to cluster around more economically prosperous member nations and could still opt to produce for the highest bidder making it harder for very small innovative design firms to produce their chips.

The third pillar of the ECA aims to establish a coordination mechanism between the EU member states and the EU Commission. This pillar aims to foster collaboration between members, monitoring the supply chain for the industry, predict shortages within this supply chain and aims to provide a framework for crisis response. Additionally this pillar introduces the establishment of the European Semiconductor Board (ESB) which consists of representatives of each member state and the commission, overseeing the implementation of the ECA while also advising and monitoring other related initiatives. While this pillar and its policies are smaller than the previous two it is by no means less important. The policies under this pillar highlight the EU`s willingness to learn from its mistakes in the past as seen during the chip shortages during the Covid-19 Pandemic and at the start of the Russia-Ukraine war and improve upon them. However it is quite unfortunate to see that current drafts of this pillar do not specifically mention more extensive collaboration with industry specialists and companies or the establishment of private advisory channels of communication, although this pillar is still in its early stages and may have omitted certain specifics[31].

5.2 The Second Important Project of Common European Interest in Microelectronics (IPCEI)

Another major initiative launched by the European Union is the IPCEI which carries the motto "Safety, Security, Sustainability and Sovereignty". This initiative is similar in nature to the ECA in that it attempts to catch up to foreign semiconductor companies on which the EU has become reliant on. The second IPCEI built upon its predecessor which was able to raise €8bn in public funding, and aims to support existing projects, from research and development up to the introduction of new semiconductor technologies in the manufacturing part of the supply chain. The initiative focuses on 4 main components of the semiconductor value chain which complement each other: AI-enabled processors, sensors, high frequency electronics and power electronics. These chips are an essential resource for other rapidly advancing industries like the Artificial Intelligence, Automotive and telecommunication industry and serve a vital role in the defence industry [32].

Essentially the project aims to fund these four areas of semiconductor manufacturing, with Germany and its existing and growing semiconductor industry being the main target for this initiative for the time being, although other countries

[31] European Commission, "European Chips Act: Monitoring and Crisis Response | Shaping Europe's Digital Future," digital-strategy.ec.europa.eu, 2023, https://digital-strategy.ec.europa.eu/en/factpages/european-chips-act-monitoring-and-crisis-response.

[32] European Commission, "Press Corner," European Commission - European Commission, 2023, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3087.

like France, Italy and the Netherlands are included just on a smaller scale given the relatively smaller but growing semiconductor industries[33].

Overall this policy framework adds to the comprehensive approach implemented by the European Union with the objective of making the EU a semiconductor leader in terms of innovation, production and most importantly resilience. However the scope of this initiative could be considered limited, given that it focuses on Germany, something that has been observed earlier in parts of the ECA, leading to further disparities between member states in the semiconductor industry

5.3 Critical Raw Materials Act

The CRM Act, which has been superficially explored earlier in this paper, differs from the previous policy frameworks which heavily focused on the Research and Development and production components of the semiconductor industry and instead looks towards the start of the industry supply chain, the raw resources[34]. The essential inputs for semiconductor manufacturing are first and foremost silicon and some precious metals like Gallium and Germanium as well as certain gases like Nitrogen, Argon and carbon tetrachloride. The essential gases are to large parts produced in Germany in its vast chemical industry and the required metals are sourced from relatively secure sources with shocks in these resources not being the main concern of EU policy makers. However the main issue lies with Silicon, which is mainly sourced from China, which currently produces around 70% of the world's supply raising concerns given the potential for geopolitical tensions or export limitations[35].

The CRM act aims to bring more of this production to its own shores to meet and secure the growing European demand which is expected to reach 2 million tonnes by 2030. In order to achieve this several projects are underway like in Spain and France as well as the implementation of a more closed circular economy approach given the ability to recycle Silicon.

Some of these projects include Spain's investments in collaboration with private partners into silicon processing facilities in the Asturias region, aiming to produce 300,000 tonnes of silicon annually by 2028 through a €500 million investment, significantly contributing to the EU`s future demand. Similarly in France under the CRM several companies

[33] European Semiconductor Industry Association, "European Semiconductor Industry Association ESIA Welcomes the Approval of the Second IPCEI on Microelectronics" 2023, https://www.eusemiconductors.eu/sites/default/files/uploads/ESIA_PR_IPCEI-Approval_2023.pdf.

[34] European Commission, "Critical Raw Materials Act," single-market-economy.ec.europa.eu, 2023, https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en.

[35] Statista, "Major Countries in Silicon Production 2019," Statista, 2023, https://www.statista.com/statistics/268108/world-silicon-production-by-country/.

have come together to establish new processing plants near Bordeaux with an EU supported investment of €350 million and a projected annual output of 200,000 tonnes by 2027[36].

Additionally the act also involves the introduction of partnerships with Non-EU members in an effort to diversify the supply of this integral component. For instance there are negotiations with Norway and Canada with the aim of establishing long-term silicon supply agreements, referencing the countries stable economies and green mining practices[37].

By combining all of these efforts the CRM act and the EU aim to contribute to stable and resilient supply chains which aim to reduce reliance on uncertain non-EU sources of silicon fostering resilience and self-reliance.

5. Determining Factors

So far this paper has explored various investments into the semiconductor industry, of both public and private origin, however the success of such investments may depend on a variety of factors like skilled labour availability, average energy costs and regulatory concessions / support. For instance the high energy costs in Europe which still linger around since the Covid-19 pandemic are a significant concern for semiconductor manufacturers. Drawing the comparison, the average price for electricity for industrial use in the EU is around €0.14 per kWh while in China the average lies around $0.089 kWh and in the US around $0.07 kWh, highlighting a significant competitive disadvantage[38].

Additionally many EU member nations are just now experiencing a growing interest in STEM fields in their labour force, with the last 5 years seeing increases in STEM degrees obtained in several member nations, however this still falls short to the US or many Asian nations which have supported such career prospects for close to a decade now, resulting in a comparatively lower skilled labour work force as off now which needs to grow together with the EU`s semiconductor ambitions[39].

These are certainly not the only determining factors for the effectiveness of investments in the semiconductor industry, however they highlight the fact that pure investments may not be sufficient in addressing the EU′s overdependence on other foreign semiconductor producers indicating that the EU needs to act on other related issues like the electricity prices to add to their competitiveness and independence.

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[36] Florent Allais, Honorine Lescieux-Katir, and Jean-Marie Chauvet, "The Continuous Evolution of the Bazancourt–Pomacle Site Rooted in the Commitment and Vision of Pioneering Farmers. When Reality Shapes the Biorefinery Concept," EFB Bioeconomy Journal 1 (November 2021): 100007, https://doi.org/10.1016/j.bioeco.2021.100007.

[37] NorSun, "Silfab Solar and NorSun Set Agreement for Supply of Solar Silicon Wafers from NorSun's Planned USA Factory," Norsun.no, 2023, https://www.norsun.no/artikler/norsun-and-silfab.

[38] Statista, "Industrial Electricity Prices by Country 2024 | Statista," Statista, 2024, https://www.statista.com/statistics/1369634/business-electricity-price-worldwide-in-selected-countries/?utm_source.

[39] Brendan Oliss, Cole McFaul, and Jaret Riddick, "The Global Distribution of STEM Graduates: Which Countries Lead the Way?," Center for Security and Emerging Technology, November 27, 2023, https://cset.georgetown.edu/article/the-global-distribution-of-stem

6. Case Study

7.1 Germany

Throughout this paper Germany has stood out as somewhat of a figurehead in the EU's quest to achieve semiconductor independence by increasing its production capabilities. A major part of its seemingly correct trajectory towards this goal is Intel's substantial investment in the country, supported by the German government with a subsidy of roughly €10bn. Although recently delayed by 2 years given internal financing issues faced by Intel the plans are not off the table and construction of the new mega-fab complex in Magdeburg is to continue as planned, bringing with it an investment of €30bn into the country and the semiconductor industry. The facility will not only produce chips of the latest designs with chips up 3nm currently being planned, but will also add 3,000 jobs to the German semiconductor industry as well as 10,000 indirect jobs[40]. Additionally the facility is expected to attract more talent towards the industry, being placed between several of Germany's states which produce the highest number of STEM graduates as well as the general centrality of Germany relative to the rest of the EU. The completion of this factory would mark a major milestone in the process of achieving independence and building up supply chain resilience by favouring domestic production within member states[41].

However Intel is not the only manufacturer, others include GlobalFoundries, Infineon, Bosch, ESMC and even TSMC. The Taiwanese company TSMC stands out in particular as its $3.5bn investment into the country highlights a growing interest in the European Semiconductor industry even for a company which currently is the world's largest manufacturer of semiconductors[42]. Therefore, by offering subsidies, strategic locations and regulatory support Germany stands as an example of how other member nations attract investments into the country in order to increase production capacity and semiconductor sovereignty.

Germany's approach which included financial incentives, simplified bureaucratic processes and increased collaboration between the private industry and the government, stands out as an effective approach in attracting semiconductor players and investors. Such an approach which favours incentives and investments to attract major companies could be implemented in other member states, allowing them to benefit economically and contribute to the overall resilience of the EU's semiconductor industry.

[40] Intel, "FactSheet Germany Overview of the Planned EU Semiconductor Manufacturing Facility in Magdeburg," 2022, https://download.intel.com/newsroom/2023/manufacturing/20230110_Factsheet_1_Magdeburg_EN.pdf.
[41] MDR, "Intel-Ansiedlung: Subventionen Wichtig Für Europas Halbleiterindustrie | MDR.DE," Www.mdr.de, June 18, 2024, https://www.mdr.de/nachrichten/deutschland/intel-ansiedlung-eu-chips-act-100.html.
[42] GTAI, "TSMC Breaks Ground, Secures Subsidy for German Plant," Gtai.de (GTAI, August 20, 2024), https://www.gtai.de/en/meta/press/tsmc-breaks-ground-secures-subsidy-for-german-plant-1813224.

Nevertheless, the country still faces some significant hurdles which it has to overcome in its path towards semiconductor independence, from high labor costs, rising energy prices and the country's notorious bureaucracy, these challenges have to be overcome to foster continuous investments and maintain current investments.

7.2 Netherlands

The Netherlands are a peculiar case within the semiconductor industry through its domestic company ASML who is the world's most advanced producer of lithography machines and the world's sole producer of advanced extreme ultraviolet (EUV) lithography machines. These machines are the backbone of the industry, being essential for the manufacturing of advanced chips produced by leading manufacturers like TSMC, Samsung or Intel[43]. ASML's strategically superior position in this field gives the EU a significant advantage due to easier access to the machinery.

The Dutch government has continuously provided financial support to the company in the past few years as well as favourable regulatory conditions in order to assist ASML in maintaining its cutting edge leadership in its somewhat niche market segment, enabling the company to become a foundation of large parts of the greater semiconductor industry[44].

However, relying only on a single company like ASML for such an integral component of the production process brings with it some risks which can be mitigated as any hindrance in the production process of ASML could have far reaching effects. Additionally ASML is only able to produce a small amount of machines with varying degrees of complexity, with the company producing just over 400 machines in 2023 for the global market, with only a few of those machines being the most advanced (EUV's)[45]. Overall the EU should most likely look to promote other similar manufacturers of machinery within the EU and could adopt a similar approach to the Dutch government by offering financial incentives and regulatory favours to new market entrants in an effort to promote diversity across several member states and companies.

Overall the Dutch model which includes specific R&D funding, supporting regulatory frameworks and a clear focus on keeping up with the most advanced technologies, shows a successful strategy which other countries could try to imitate. By protecting and supporting existing companies like ASML while also promoting market entry with favourable policies, the Netherlands show how such policies can be used to bolster the EU's overall semiconductor capabilities.

7. Policy Recommendations

[43] Katie Tarasov, "ASML Is the Only Company Making the $200 Million Machines Needed to Print Every Advanced Microchip. Here's an inside Look," CNBC, March 23, 2022, https://www.cnbc.com/2022/03/23/inside-asml-the-company-advanced-chipmakers-use-for-euv-lithography.htm

[44] Toby Sterling, "Dutch Will Spend $2.7 Billion on Improving Infrastructure to Keep ASML," Reuters, March 28, 2024, https://www.reuters.com/world/europe/dutch-government-launch-plan-keep-asml-netherlands-2024-03-28/.

[45] Peter Westberg, "Quartr," Quartr.com, 2024, https://quartr.com/insights/company-research/asml-architecting-earths-most-complex-machines.

Building on the previous analysis of the EU policy frameworks which have been discussed above, this paper will offer several policy recommendations which not only address the production capacity of semiconductors but also the industry's broader environment, including skilled labour, infrastructure and raw materials.

8.1 Upstream Supply Chain for Raw Materials

While the EU's Critical Raw Materials initiatives have been a good start for the EU in diversifying their supply and promoting domestic extraction further efforts will be necessary to meet the rapidly growing demand for semiconductor related raw materials.

Policymakers should consider expanding on existing long-term supply contracts with other countries with high ESG standards, as seen previously with Norway and Canada, to ensure reliable access to raw resources like silicon and other production critical resources.

Additionally further support and investment in recycling or circular economy initiatives may prove fruitful in not only adding an additional channel of supply, but may also support environmental initiatives by recovering silicon and rare metals from end of life electronics and industrial by-products. Certain tax-incentives or standardized guidelines for recycling may prove helpful in fostering such initiatives and ultimately improving the circular nature of the semiconductor raw materials supply chain.

Furthermore, based on lessons learnt during the Covid-19 pandemic, this paper recommends the stockpiling of production critical resources by private companies to create a buffer against short-term supply chain disruptions.

8.2 Domestic Production Capabilities & Infrastructure

While there is an array of incentives to expand EU-based semiconductor foundries there is still room for policies to complement such incentives. For instance, this paper would recommend that policymakers further support the formation of semiconductor clusters where research facilities, foundries, raw material suppliers and logistics are located in close proximity to another to benefit from shared infrastructure such as larger energy networks as well as having a generally larger talent pool.

Furthermore this paper recommends a general shift in focus to more advanced technologies through a focus in investments in 3nm and below production nodes or similar advanced technologies like compound semiconductors, in an effort to avoid falling behind in terms of technological capabilities.

Additionally policymakers should create incentives for small to medium sized foundries and R&D centres to avoid having only a handful large ones in wealthy member states. This would aid in reducing the risk of over-concentration while also promoting balanced development across member states.

8.3 Skills and Talent

A significant determinant for the EU's endeavours is the availability of skilled labour. In order to address this, member states and the EU as a whole should create incentives for STEM education or similar associated programs. This may include specific scholarships, apprenticeships, internships or fostering collaborations between universities and the industry which could ensure that the educational curricula remain up to date with the ever developing industry standards.

In addition EU policymakers should consider streamlining visa processes for experienced professionals in order to expand the talent pool within the EU. Such a policy could potentially lead to an acceleration in growth of both the talent pool, and the industry as a whole.

8.4 Risk Management

Having observed the effects of the Covid-19 pandemic and the rising political tensions around the world, the EU should consider implementing some sort of warning system which would not only actively gather data but also attempt to monitor the supply chain in real time with the goal of identifying potential vulnerabilities. This would allow for early detection of shocks which may adversely affect production, allowing for proactive measures to be taken.

Furthermore, as the EU expands its domestic production capabilities efforts should be made to continuously attempt to diversify the supply of critical resources which may not be as available in Europe. Some degree of interdependence with reliable partners may even aid in mitigating the impact of potential future supply shocks.

8.5 Policy Recommendation Conclusion

The policy recommendations above provide a broad approach to improving the resilience and competitiveness of the EU semiconductor industry. By providing stable access to raw materials, improving domestic production, increasing the talent pool and improving risk management, the EU can reduce its vulnerability and dependence on other nations while also strengthening its position in the global semiconductor industry. As a whole these measures support self-sufficiency, innovation and even sustainability which can protect the EU's economic, technological and strategic interests.

8. Conclusion

This paper has explored the EU's journey towards greater semiconductor independence, highlighting the many and interconnected challenges on this journey such as raw materials, production capacity, talent and risk management. While the current overreliance of the EU on foreign suppliers, specifically in East Asia, cannot be overcome within a year or so, the combination of various strategies and policy frameworks such as the ECA or CRM Act show commitment towards this aspirational goal.

Efforts such as fostering research and innovation, integrating production facilities and developing the workforce demonstrate that the EU has shifted towards a broader approach which covers the extensive semiconductor industry. However, the success of such initiatives requires addressing other challenges such as the high energy costs, uneven distribution of investments across members and outdated technologies.

By refining its policies, forging international partnerships and shifting towards advanced and sustainable technologies and practices, the EU will be able to move closer towards its goal of a self-sufficient, resilient and competitive semiconductor industry.

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