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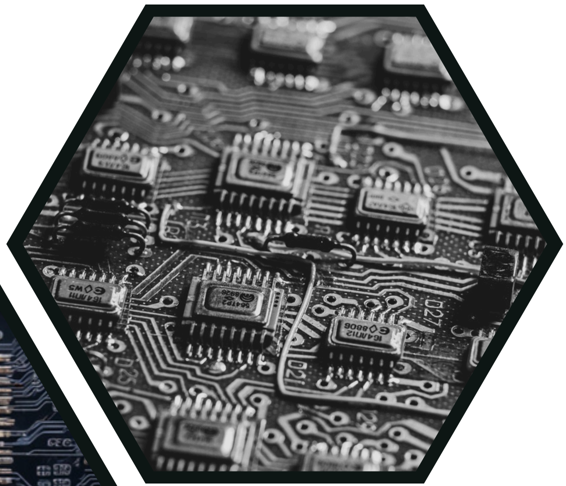

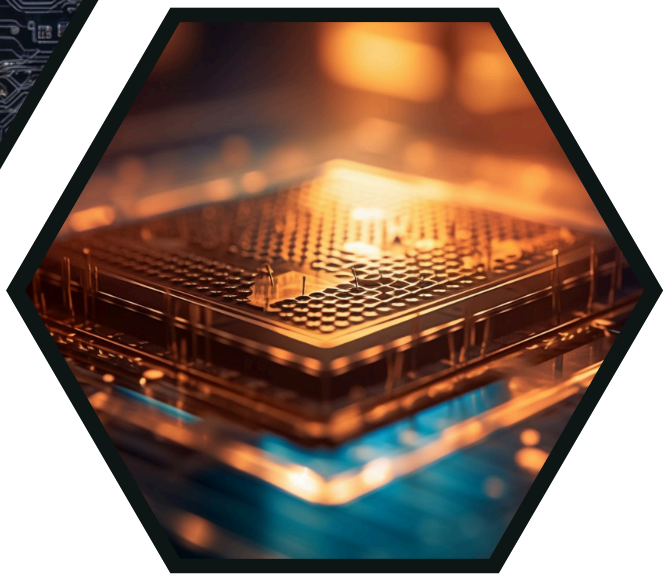

AI ASCENDANCY:

HOW ARTIFICIAL INTELLIGENCE IS SHAPING GLOBAL POWER DYNAMICS

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THE GEOPOLITICS OF THE AI-RELEVANT SEMICONDUCTOR SUPPLY CHAIN

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Executive Summary

The geopolitics surrounding the AI-relevant semiconductor supply chain in 2024 presents significant challenges, including intense competition between China and the US, particularly over Taiwan and its status and technological dominance. The supply chain is global and complex, with numerous actors and bottlenecks, while the demand for and technological advancement of AI semiconductors, which have dual-use capacities, is rapidly growing.

To better understand the future of this critical supply chain, this research has developed four possible scenarios for 2040 based on 100 factors:

1. **Growth in 2040**: The continuation of the current 2024 status quo led to the endurance of Moore's law and contained conflicts.
2. **Instability in 2040**: The semiconductor supply chain collapsed and was severely disrupted amidst global conflict. Technological advancement came to a halt and led the world into a global economic depression.
3. **Transformation in 2040**: Significant changes and advancements in the supply chain and AI-relevant semiconductor technology occurred. This led to a transformation of Moore's law and the emergence of new stakeholders and actors.
4. **Discipline in 2040**: A stagnation in the supply chain and semiconductor technology led to a more dangerous future with competition and a global economic depression.

These scenarios have significant implications for 2024, highlighting trends, weak signals, and potential shocks that may arise in the coming years. To address these challenges and opportunities, stakeholders in the supply chain should consider the following main recommendations for all actors and for International Organisations (Figure 1, p.3).

ALL ACTORS	INTERNATIONAL ORGANISATIONS
1. Cooperation 2. Diversification 3. Regulation 4. Peaceful Resolution of Conflicts 5. Climate Action 6. Capacity Building 7. R&D Investments	1. Initiate Dialogue 2. Active Participation 3. Advocacy 4. Support Climate Action 5. Best Practices 6. Monitoring

Figure 1: Recommendations for different stakeholders

Implementing these recommendations is crucial for ensuring a stable and fair AI-relevant semiconductor supply chain capable of meeting global AI chip demands. The recommendations provide a path to a more sustainable and resilient supply chain with a more diversified approach to ensure long-term efficiency and stability.

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List of Abbreviations

Abbreviation	Full form
AI	Artificial Intelligence
AIS	AI-relevant semiconductors
AMD	Advanced Micro Devices
ASEAN	Association of Southeast Asian Nations
ASML	Advanced Semiconductor Materials Lithography
CHIPS	Creating Helpful Incentives to Produce Semiconductors
EU	European Union
GPU	Graphics processing unit
IO	International Organisation
R&D	Research and Development
SK	South Korea
SPIL	Siliconware Precision Industries Co., Ltd
SSC	Semiconductor Supply Chain
TPU	Tensor processing unit
TSMC	Taiwan Semiconductor Manufacturing Company Limited
UN	United Nations
US	United States

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1. Introduction

The rapid advancement of Artificial Intelligence (AI) is profoundly influencing global power dynamics, with AI's development and deployment heavily dependent on the semiconductor supply chain (SSC). Each stage requires an exceptional level of expertise, cutting-edge technology, and substantial financial investments, especially for AI-relevant semiconductors (AIS).[1] Unlike standard semiconductors, which are designed for general-purpose computing tasks in a variety of electronic devices, AIS are advanced chips optimised for artificial intelligence tasks, such as processing large neural networks and complex algorithms, with advanced features like tensor processing units (TPUs) and graphics processing units (GPUs) to enhance AI performance. This advanced and innovative technology of AI chips makes them challenging to manufacture. The evolution of AI necessitates continuous investment in research and development (R&D) to produce chips capable of handling increasingly complex AI tasks,[2] highlighting the significance of specialised hardware like GPUs and TPUs.[3]

Moreover, the geopolitical implications of the AI-relevant SSC cannot be overstated. Leading countries and corporations in semiconductor technology gain strategic advantages in the AI race and influence global power dynamics. The competitive edge provided by advanced semiconductor capabilities enhances national security, economic growth, and international leadership. Techno-nationalism underscores the strategic importance of maintaining dominance in this critical infrastructure, as control over the SSC is increasingly viewed as essential to a nation's security and economic prosperity. Therefore, understanding and navigating the SSC's complexities and future is crucial for constructing sustainable development strategies. This research delves into how the development and control of the AI-relevant SSC shape global power dynamics, exploring the intersection of technology, economics, and geopolitics in 2040. Thus, it follows the subsequent research question:

What are future scenarios for AI-relevant semiconductor supply chain geopolitics?

Through literature review (chapter 2) and utilising an interdisciplinary foresight method (chapter 3), this research established four scenarios for the geopolitics of the AI-relevant SSC in 2040 (chapter 4). Finally, based on the discussion of the scenarios (chapter 5), it gives recommendations for all actors, especially for international organisations, to support sustainable, peaceful and fair chip access for everyone (chapter 6).

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[1] Bulusu, 'Custom Silicon'.
[2] Carrier, 'The Chip Industry's Reshoring Revolution'.
[3] Rao, 'TPU vs GPU in AI'.

2. Literature Review

To address the research question accurately, this research begins with an overview of the semiconductor industry followed by a description of the supply chain of AIS. Following this, this research delves into the surrounding geopolitics with the aim of understanding the dynamics and bottlenecks in the SSC.

2.1. Overview of Semiconductor Industry

The semiconductor industry has seen a massive evolution in the last decades.[4] Particularly, a critical aspect driving the growth of semiconductors was the formulation of Moore's law in 1965. Gordon Moore observed that the number of transistors in Integrated Circuits doubles approximately every two years, significantly boosting computing power.[5] This has allowed for the fast development of chips that can accommodate larger neural networks and more sophisticated algorithms.[6] However, the physical limitations of traditional transistor scaling present a challenge to the industry and the continuance of Moore's law. The industry is scaling at levels faster than what Moore's law has predicted, thus resulting in uncertainty about the endurance of Moore's law.[7] Several other factors also affect the semiconductor industry, such as geopolitics, climate change, etc.

Additionally, over the last three decades, there has been a significant shift in the manufacturing capacity for semiconductors around the world (Figure 2, p.10).[8] A transition from the United States (US) and Europe-centred production to a more Western Pacific-centred production can be observed. However, this transition is not stable, as the manufacturing capacity is influenced by several factors, including geopolitics, economic factors and regulations governing the sector.[9] Thus, the semiconductor industry is subject to further change in the future.

[4] McDonald, 'A 200-Year Timeline of the Semiconductor Industry'.
[5] Stoner, 'What Is Moore's Law and How Does It Impact AI?'
[6] Carrier, 'The Chip Industry's Reshoring Revolution'.
[7] Dobbos, 'AI Challenges and Collaboration'.
[8] Graham, 'U.S.-China Chip War Nears Moment Of Truth'.
[9] Kaur, 'Why Is Taiwan Leading in Chip Manufacturing, with China in Closing?'

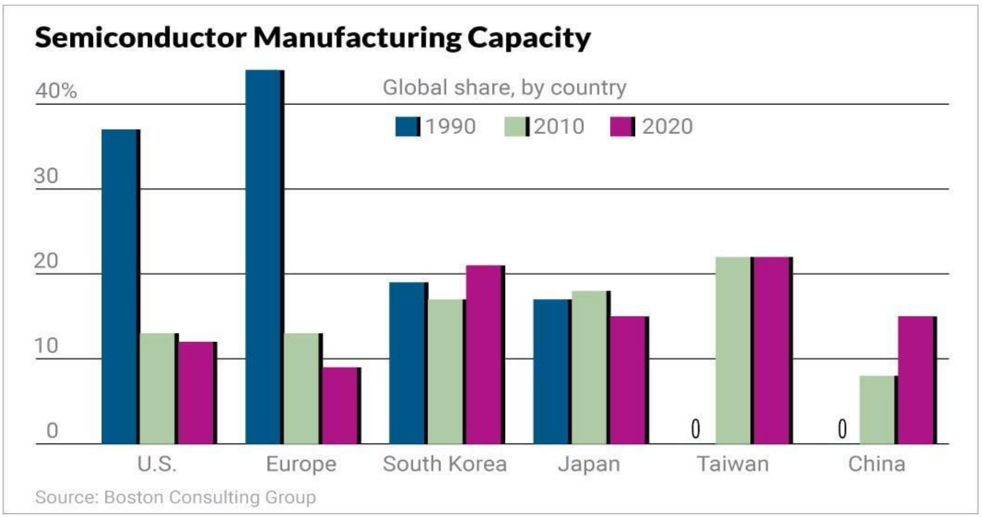

Figure 2: Semiconductor Manufacturing Capacity, a comparison from 1990 - 2020[10]

Figure 3 (p.10) provides some specific insight into the major actors in the different components of the SSC, as this heavily influences the geopolitical dynamics of the SSC. The major actors are the US, Japan, South Korea (SK), the Netherlands in the European Union (EU), and China.[11]

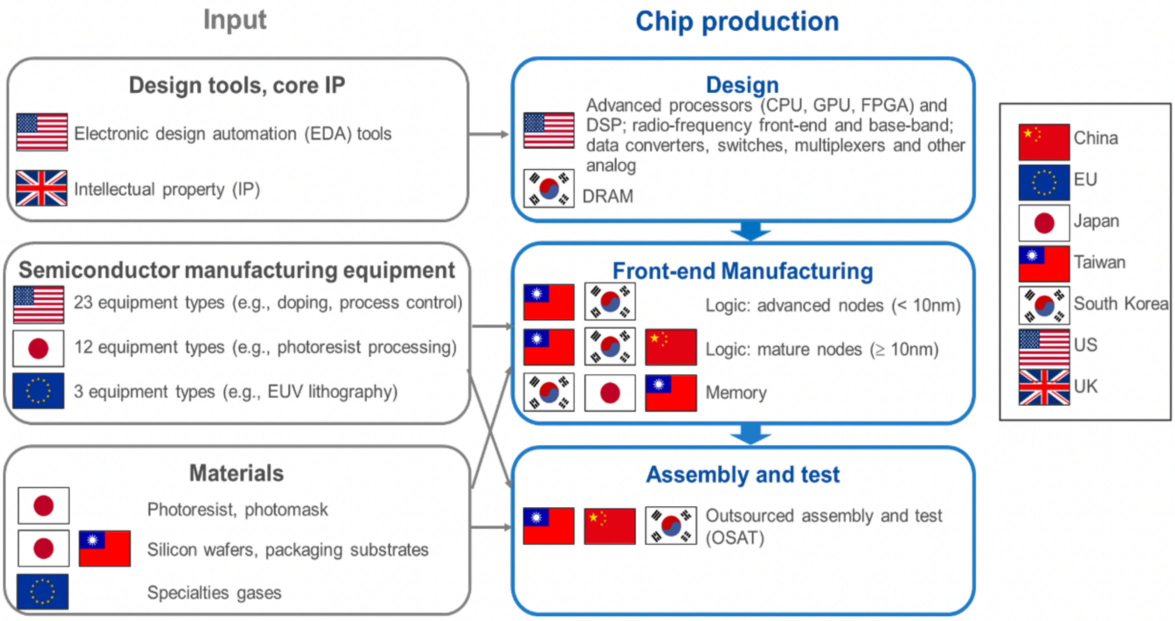

Figure 3: Geographical concentration of the SSC[12]

[10] Batra et al., 'Artificial-Intelligence Hardware: New Opportunities for Semiconductor Companies'.
[11] Thadani and Allen, 'Mapping the Semiconductor Supply Chain'.; Cerutti and Nardo, 'Semiconductors in the EU'.
[12] Cerutti and Nardo, 'Semiconductors in the EU'.

The next part provides a breakdown of the stages of chip production *(design, front-end manufacturing, and assembly & test)*, with specific information on the actors who play a major role in the respective stages, particularly for the AIS.

2.2. AI-relevant Semiconductor Supply Chain

Within the existing sphere of semiconductors, AIS is a niche area, referring to advanced or cutting-edge chips that are optimal for artificial intelligence tasks. This includes ultra-small chips, such as the 3nm chip.[13] This section delves into the supply chain of the AIS.

2.2.1. Design

The US occupies a major role in AIS design. (Figure 4, p.12). Leading companies in the industry located in the US include Apple,[14] Advanced Micro Devices (AMD),[15] Nvidia,[16] Qualcomm,[17] Microsoft,[18] Meta,[19] Google,[20] Amazon,[21] and Intel,[22] with Nvidia holding a dominant position in AIS design.[23] Additionally, the EU, China (Figure 4, p.12), and SK also comprise companies that design chips and are slowly gaining traction.[24] Apart from this, there are other actors and research organisations, such as universities,[25] and specialised labs, investigating new architectures, materials, and algorithms tailored for AI workloads, making significant contributions to advancements in semiconductor design.[26]

[13] Toews, 'The Geopolitics Of AI Chips Will Define the Future Of AI'.
[14] Tarasov, 'Inside Apple's Chip Lab, Home to the Most "Profound Change" at the Company in Decades'; Reuters, 'Apple Plans Mac Line Overhaul with AI-Focused M4 Chips, Bloomberg News Reports'.
[15] Satoh, 'AMD Will Consider "other" Partner Foundries to TSMC: CEO - Nikkei Asia'.
[16] Reuters, 'Nvidia's Dominance in AI Chips Detering Investment in Rival Start-Ups'.
[17] Qualcomm, 'Qualcomm Brings Record-Breaking Generative AI for Devices at Snapdragon Summit 2023 | Qualcomm'.
[18] 'Michelle Cheng, 'Nvidia's Biggest Customers Are Also the AI Chip Maker's Biggest Threat'.
[19] Michelle Cheng.
[20] Bratton, 'Google's New Chips Look to Challenge Nvidia, Microsoft and Amazon'.
[21] Bratton.
[22] Desineni and Tuv, 'High-Value AI in Intel's Semiconductor Manufacturing Environment. White Paper, Intel.'; Wheatley, 'Intel Makes Progress on Advanced Chip Manufacturing Process as It Strives for Relevance in AI - SiliconANGLE'.
[23] Reuters, 'Nvidia's Dominance in AI Chips Detering Investment in Rival Start-Ups'.
[24] Patil et al., 'The Growing Challenge of Semiconductor Design Leadership'.
[25] Zewe, 'MIT Lays Out Strategy To Help the U.S. Regain Its Place as a Semiconductor Superpower'.
[26] Lin, 'In Race for AI Chips, Google DeepMind Uses AI to Design Specialized Semiconductors'.

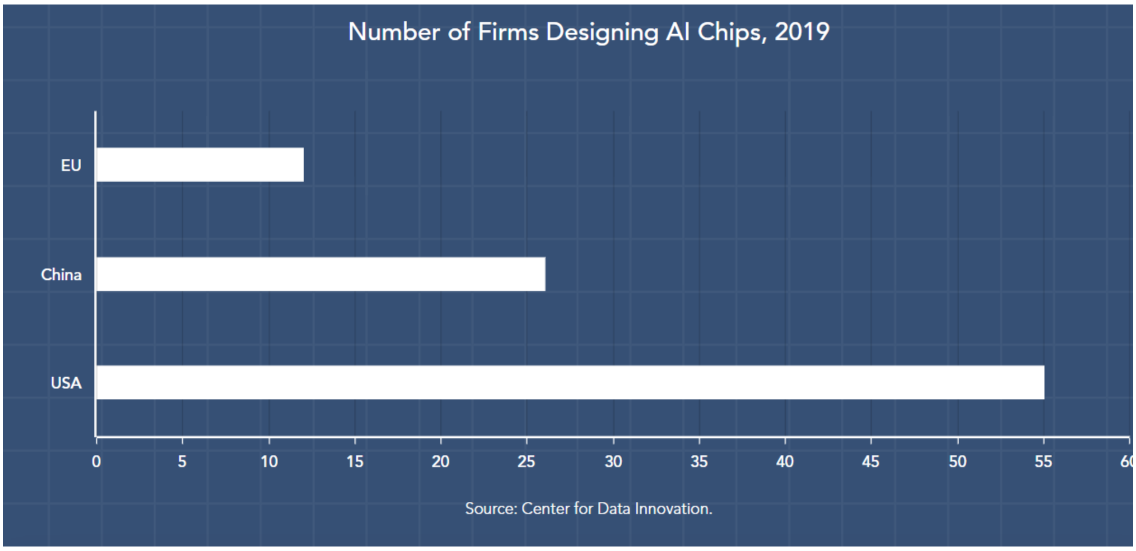

Figure 4: Number of Firms Designing AI Chips, 2019[27]

2.2.2. Front-End Manufacturing

Figure 5 (p.13) presents the several stakeholders involved in this stage of the SSC. Raw materials are typically supplied from China, Japan, the US, and a few European countries.[28] China leads the supply of critical minerals and silicon (Figure 5, p.13). Advanced Semiconductor Materials Lithography (ASML), a Dutch company, supplies 100% of the world's supply of extreme ultraviolet lithography machines, a piece of complex equipment required to build advanced chips.[29] Polymeric material, for example, is used in almost all semiconductor products and is primarily manufactured in Japan, Taiwan, and SK.[30] Furthermore, Taiwan is home to 92% of the world's most advanced semiconductor manufacturing capacity, with the remaining capacity (8%) in SK.[31]

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27 MacroPolo, 'AI Chips'.
28 Mohammad, Elomri, and Kerbache, 'The Global Semiconductor Chip Shortage'.
29 Cronin, 'Semiconductors and Taiwan's "Silicon Shield"'.
30 Cronin.
31 Varas et al., 'Strengthening the Global Semiconductor Value Chain'; Koidan, 'Navigating the Complexities of the Semiconductor Supply Chain'.

Supply Chain Input	Main Source Countries
Critical Minerals	China is the main source country for many required critical minerals including REEs, Gallium, Germanium, Arsenic, and Copper. The U.S. is highly import-dependent.
Polysilicon	China accounts for 79% of global raw silicon and 70% of global silicon production. The U.S. has just 9% of global silicon production.
Semiconductor Wafers	Global wafer production capacity is in: Japan (56%), Taiwan (16%), Germany (14%), South Korea (10%), and China (<5%). The U.S. has no wafer production capacity.
Photomasks and Photoresists	Photomasks production: Japan (53%), U.S. (40%), and Taiwan (7%) Photoresists production: Japan (90%), U.S. and South Korea (remaining 10%)
Gases and Wet Chemicals	Gases Sources: The U.S., Japan, France, and South Korea control over half of the global supply for the required gases. Wet Chemicals Sources: The U.S., Germany, and Japan control 60% of global supply for the required chemicals.
Manufacturing Equipment	The U.S., Japan, and the Netherlands dominate global production of most equipment and the most advanced machinery. China lacks the capacity to produce most of this equipment.

Figure 5: Summarised assessment of critical inputs in the SSC[32]

2.2.3. Assembly and Test

Japan produces 47% of Taiwan's test equipment, 53% of China's, and 35% of SK's.[33] Thus, Japan leads the world market for test equipment, with the United States coming in second with 35% and SK in third place with just under 11%.[34] Further, more than 60% of the world's assembly, packaging, and testing capacity is centred in China and Taiwan.[35]

In conclusion, the design of AIS is concentrated in the US. Taiwan dominates the production and manufacturing, while China accounts for the majority of the critical minerals required. China's global semiconductor market share is also said to rise[36]

For the purposes of this research, players in the SSC that are important in 2024, such as the US, SK, Japan, Taiwan, and the Netherlands, or private actors like TSMC or ASML, are termed as traditional stakeholders. Their role in the SSC is dominant, with the size of their circle representing their role

[32] 'The Global Semiconductor Supply Chain: Key Inputs'.
[33] Thadani and Allen, 'Mapping the Semiconductor Supply Chain'.
[34] Thadani and Allen.
[35] Semiconductor Industry Association, 'Chipmakers Are Ramping Up Production to Address Semiconductor Shortage. Here's Why That Takes Time'.
[36] 'China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's'.

(Figure 6, p.14). China's role is much smaller compared to that of traditional stakeholders, as represented by the size of their circle (Figure 6, p.14). Furthermore, the other circle, comprising stakeholders such as India and the EU, depicts the other players whose role in the SSC is relatively minor but potentially growing.

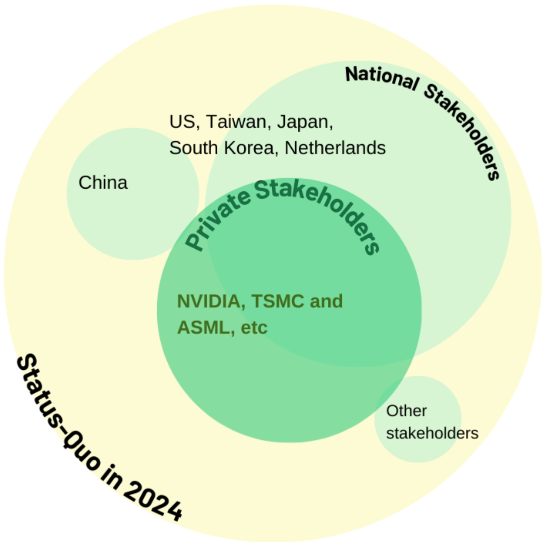

Figure 6: Description of stakeholders (2024)

It is also imperative to note that the dominance of the traditional stakeholders can be traced back to a few private companies. Only three companies worldwide can build advanced chips that are even close to the cutting edge of today's most advanced semiconductor technology: TSMC (Taiwan), Samsung (SK), and Intel (US).[37] Most well-known chip companies, such as Nvidia, Qualcomm, AMD, and Broadcom, are now fabless, meaning they do not produce their own chips. Instead, they rely on foundries like TSMC to manufacture their chips. Figure 7 (p.15) provides insight into what aspects of the SSC these private companies are involved in, with NVIDIA being involved in the design phase and ASML and TSMC in the front-end manufacturing phase. The state of the SSC has also resulted in increased private-public partnerships.[38]

[37] Cronin, 'Semiconductors and Taiwan's "Silicon Shield"'.
[38] Kelley, 'NSF to Helm Nearly $50M Semiconductor Public-Private Partnership'; Ravi, 'U.S. and India Semiconductor Groups Announce Initiative to Strengthen Public-Private Collaboration in Chip Ecosystem'; Wild, 'PPP Is Key to Increasing Capacity in the Semiconductor Industry'.

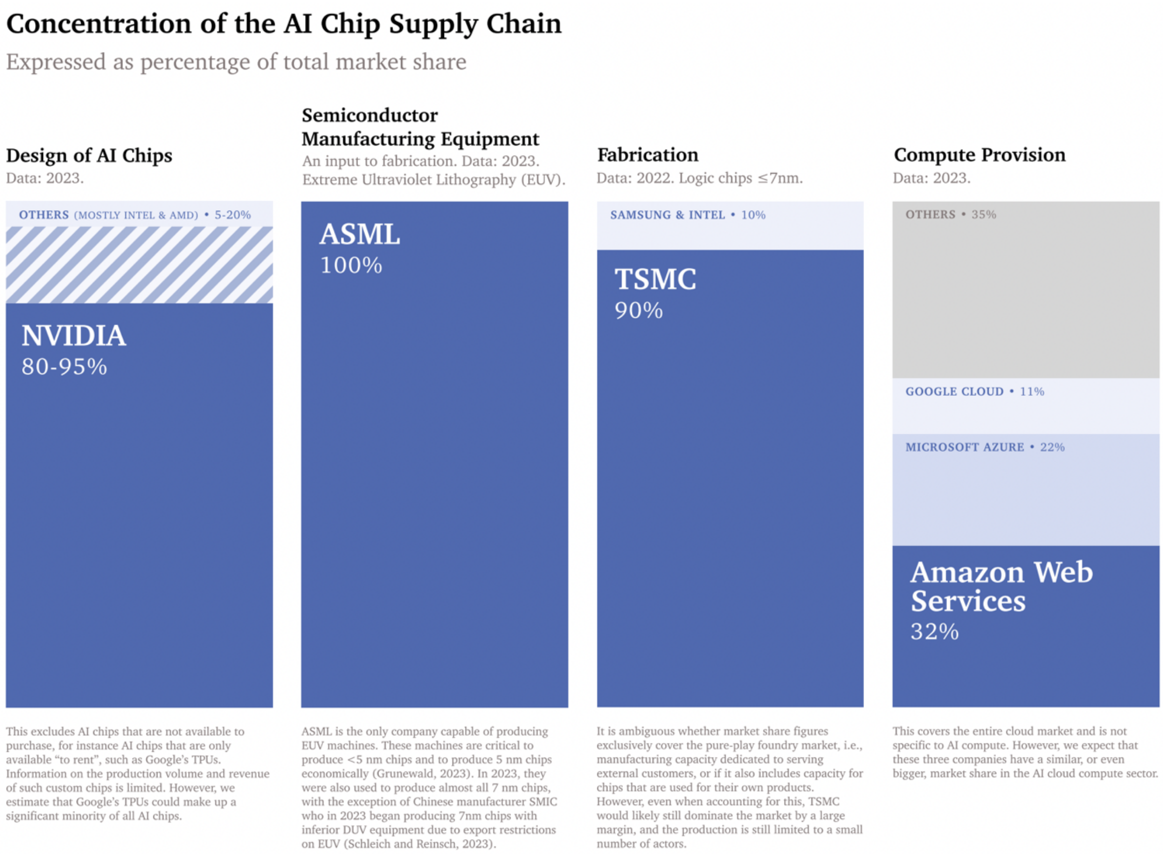

Figure 7: Geographical concentration of the SSC[39]

As seen in Figure 6 (p.14), in 2024, the SSC is still in the hands of private companies, as they are in the driver's seat, as seen by their circle partially outside the circle of their states. They are also partially outside as, while the core technological advancement lies at the hands of private entities, the geopolitics surrounding the AIS leads to increased state interference/influence in the industry. In light of this, the next section delves into the geopolitics surrounding the SSC.

2.3. Geopolitical Dimension of the AI-relevant Semiconductor Supply Chain

This section begins with defining core concepts: geopolitics, critical infrastructure, national security, and techno-nationalism, as these four terms are highly interconnected. Afterwards, this section provides an overview of the main public actors and their engagement and role in the AIS supply chain.

[39] Sastry et al., 'Computing Power and the Governance of Artificial Intelligence'.

2.3.1. Geopolitics and its Connection to Critical Infrastructure, National Security, and Techno-nationalism

Geopolitics analyses the connections between geography and geographic influence on power relations and international relations. A crucial part of geopolitics focuses on industrial capabilities and their relationships to security and the global international system.[40] Therefore, technology and geopolitics are closely connected and influenced by each other. Technology is described as a powerful force that plays a role in defending national sovereignty and geopolitical dominance.[41] The role of AI and computing power in international geopolitical dynamics is especially highlighted.[42]

Due to the geopolitical relevance of technology, the infrastructure linked with the different technologies like energy, telecommunication, defence, and many others are defined as critical by many actors, especially States.[43] For example, the EU describes critical infrastructure as "an asset or system which is essential for the maintenance of critical societal functions."[44] Therefore, destroying critical infrastructure would considerably impact a state's security and citizens' well-being.

AI is crucial for national security based on the significance of critical infrastructure. National security is defined as the preservation of the norms, rules, institutions and values of society against military and non-military threats.[45] As such, national security is tightly linked to stability. In our interconnected world, many discussed national security issues can also be understood as global security problems.

AI has recently gained an important place in national security as it is used in modern military systems and network-driven warfare. Several states consider AI and other emerging technologies to be the focal points of the next great power competition, with the possibility of changing the global balance of power.[46]

Because of their use in AI tools, semiconductors are particularly significant for national security, economy and economic innovation. Furthermore, they have strong defence capabilities as they are included in nearly every modern weaponry.[47] The fact that many military-used semiconductors can also

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[40] Deudney, 'Geopolitics'.
[41] Khan et al., 'Geopolitics of Technology', p.458.
[42] Popescu, 'The Geopolitical Impact of the Emerging Technologies', p.7,14.
[43] 'Critical Infrastructures'.
[44] 'Critical Infrastructure'.
[45] Osisanya, 'National Security versus Global Security UN Chronicle'.
[46] Kasapoğlu and Kırdemir, 'Wars of None'; 'National Security'.
[47] Grimes and Du, 'China's Emerging Role in the Global Semiconductor Value Chain', p.2; Peters, 'Semiconductors, Geopolitics and Technological Rivalry: The US CHIPS & Science Act, 2022', p.3; Sierra, 'When the Microchips Are Down'.

be used for civil purposes gives them a dual-use capacity, further complicating the issue.[48] Consequently, semiconductors are necessary for every modern economy and state-of-the-art military.

Securing access to semiconductors is of vital interest to many states. As already discussed, the SSC, especially for the AIS, has many chokepoints and is dominated by a few companies and countries. These bottlenecks are making the SSC extremely vulnerable. On top of that, global shipping lanes are vulnerable as they can easily be disrupted. A disruption at any point in the SSC would have dire consequences for the international economy.[49] Despite this vulnerability, no attempt exists to govern it globally to strengthen its resilience. The current shots in this direction are primarily about the governance of AI applications.[50]

Therefore, nation-states, which are policy-making entities, have a renewed interest in the development of AIS. The connection between geopolitics, technology and security can lead to techno-nationalism. This term describes the link between technological innovation and capabilities, as well as national security, economic prosperity, and social stability. Connected with geopolitics, techno-nationalism explains that nations want to attain a competitive technological advantage to use this power for global gains. Therefore, techno-nationalism could fracture the international system. As a part of the high-tech sector, AI is also a segment of techno-nationalism. Consequently, many states are balancing national interest with the growth of the AI industry.[51]

In this highly contestant environment, it is no surprise that there is the potential for geopolitical conflict between states. However, techno-nationalism also leads to another issue: Inequality. In short, rapid technological development can reinforce international and, to some extent, domestic inequalities, creating new challenges.[52]

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[48] Donnelly, 'Semiconductor and ICT Industrial Policy in the US and EU', p.8; 'Securing Semiconductors'.
[49] Mark and Tiff Roberts, 'United States–China Semiconductor Standoff'; Sierra, 'When the Microchips Are Down'; Popescu, 'The Geopolitical Impact of the Emerging Technologies', p.8; Martin et al., 'Supply Chain Interdependence and Geopolitical Vulnerability The Case of Taiwan and High-End Semiconductors', vi-vii.
[50] 'Global AI Governance Initiative'. AI Safety Summit, 'The Bletchley Declaration by Countries Attending the AI Safety Summit, 1-2 November 2023'; 'Global AI Governance Initiative'.
[51] Capri, 'Techno-Nationalism: What Is It And How Will It Change Global Commerce?'; Park, 'Shifted Paradigm in Technonationalism in the 21st Century', p.2.
[52] Popescu, 'The Geopolitical Impact of the Emerging Technologies', p.13.

2.3.2. The US-China Rivalry and its Implications

The US-China rivalry is currently at the centre of attention. Those two nations, having a long and complex relationship, are known for clashing over different issues. One dynamic that can be observed is China's attempt to challenge the dominance of the US in the world.[53]

For Beijing, AI is the foundation of the future military, economic and geopolitical power, thus declaring semiconductors a top priority. Estimations suggest that China invested $50 billion in 2021 in its domestic semiconductor production, leading to rapid growth in its production and development. Its goal is to challenge the US dominance, enhance the resilience of this critical infrastructure, and reduce the dependence on US technology and vulnerability.[54]

This growth was seen as a severe threat to the US national security and its dominance.[55] AI is a crucial technology for the US to enable continued US military superiority over China.[56] The US has recently attempted to block China's advancement in the semiconductor sector with various acts, export control, and sanctions. With the CHIPS and Science Act of 2022, the Biden administration invested $52.7 billion in its domestic semiconductor production to strengthen the resilience of the SSC and reduce its vulnerability.[57] With a whole batch of export controls and sanctions, the US de facto cut off access to cutting-edge AIS for China and blocked the Chinese ability to produce them.[58]

The US also works closely with key partners in the sector, like the EU, the Netherlands (mainly ASML), Japan, SK, and Taiwan, to convince them to align with US interests instead of China's interests. Sometimes, as in the ASML case, with success, further strangling the Chinese ability to build domestic semiconductors. This led to a devastating blow in the Chinese semiconductor industry, especially for AIS. Furthermore, these export controls are not only focused on China but also on other hostile perceived nations. These US actions are motivated by national security and techno-nationalism.[59]

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[53] 'Timeline'; Wain, '12 - The U.S. Position in the South China Sea'; Scobell, 'The South China Sea and U.S.-China Rivalry', p.201.
[54] Allen, 'China's New Strategy for Waging the Microchip Tech War'; Miller, *Chip War: The Fight for the World's Most Critical Technology*; Peters, 'Semiconductors, Geopolitics and Technological Rivalry: The US CHIPS & Science Act, 2022', p.1; 'China's Military Strategy'; Grimes and Du, 'China's Emerging Role in the Global Semiconductor Value Chain', p.2.
[55] 'Funding for International Partnerships Through the CHIPS Act'.
[56] Allen, 'China's New Strategy for Waging the Microchip Tech War'.
[57] 'FACT SHEET'.
[58] 'Public Information on Export Controls Imposed on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC)'; Mark and Tiff Roberts, 'United States–China Semiconductor Standoff'.
[59] Allen, 'China's New Strategy for Waging the Microchip Tech War'; Kaur, 'Is There Really a Chip 4 Alliance?'; Miller, *Chip War: The Fight for the World's Most Critical Technology,* p.315; 'Funding for International Partnerships Through the CHIPS Act'.

The US-China rivalry and its fallout on the technology sector heavily impact the global SSC as both states are weaponising it.[60] Both states started this "Chip War", as described by Miller.[61] They began investing heavily in their domestic chip production as they tried to circumvent the many bottlenecks by decoupling the other rival from the SSC. They attempt to secure this critical technology with domestic and a more diversified supply chain and semiconductor production.

Since many bottlenecks of the SSC are currently under US control, the US measures are effective in slowing down China's development in the sector.[62] However, the vast number of subsidies and investments – not just in the US and China but worldwide – has the potential to change the dynamics rapidly.[63]

2.3.3. Conflict in Taiwan and its Implications

One main bottleneck of the SSC is Taiwan. With its unchallenged dominance, Taiwan is a crucial partner for all AI-aspiring states. However, the question of Taiwan's legal status could disrupt the SSC and end in a conflict, as the US's reaction to a forceful Chinese attempt to reunite with Taiwan is challenging to predict. A war in the Taiwan Strait, even a blockade of Taiwan, would devastate the global SSC and economy.[64]

With the concentration of semiconductor production in the Western Pacific, regional actors like Taiwan, SK and Japan are also very active. All three invest in their SSC sector to strengthen their global leverage and diversify their supply chain to reduce vulnerability by actively decoupling from China. However, their actions sometimes result in tensions between partners, as evident by the conflict in 2019 between Japan and SK over exporting chemicals critical for semiconductor production from Japan to SK. However, techno-nationalism in the semiconductor sector is a global phenomenon: The EU and India are also trying to diversify their SSC and protect their production from the ongoing conflict between China and the US by significantly investing (EU: $43 billion, India: $10 billion) in their domestic production, and hence are considered as emerging players. As part of that, many states try to attract major semiconductor producers. In the case of TSMC, Germany, Japan, and the US were successful, as

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[60] Bown, 'How the United States Marched the Semiconductor Industry into Its Trade War with China', pp.349-350; Miller, *Chip War: The Fight for the World's Most Critical Technology,* p.316.
[61] Miller, *Chip War: The Fight for the World's Most Critical Technology,* p.316.
[62] Miller, p.315.
[63] Park, 'Shifted Paradigm in Technonationalism in the 21st Century', p.6; Peters, 'Semiconductors, Geopolitics and Technological Rivalry: The US CHIPS & Science Act, 2022', p.3.
[64] Chou, 'A Discussion on Geopolitical Risk of Taiwan Semiconductor Industry', p.1; Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.336-338; Sacks, 'Will China's Reliance on Taiwanese Chips Prevent a War?'.

the company now builds semiconductor factories in these countries. One current challenge for all public actors is the balance between the US sanctions against China and China itself, as there is a significant dependency on US security guarantees and the Chinese semiconductor market.[65]

In conclusion, the global SSC is substantially weaponised and dominated by techno-nationalism, with the main rivalry between the US and China setting the tone. Many states are trying to diversify their SSC and reduce dependencies by investing in domestic AIS production. By doing so, they can also reduce the pressure on the US and China to engage in their conflict. The last few years have shown a change from an economic and private to a security and public-driven SSC.[66] However, it is unclear how long the public actors can afford such high investments.[67] Additionally, as established above, the SSC is dominated by a few players in the different stages of the SSC: Design (US), production (Taiwan, SK), tools (Netherlands), critical minerals and resources (China, Japan), etc. There are also other actors involved who play key roles in this process. Any disruption to their work would affect the SSC, leading to uncertainty and chaos in the industry. Therefore, a comprehensive foresight of the geopolitical dynamics could help companies and politicians navigate this fast-changing environment.

3. Methodology

3.1. Scope of the Research

Chapter Two builds a progressive narrative that demonstrates the volatility in the AIS supply chain. The existence of many stakeholders and the entanglement among them implies that the future of AIS development and its implications on society are hard to predict. Given the extensive application of AIS, this project recognises the necessity to address the following research question using a foresight method:

What are future scenarios for AI-relevant semiconductor supply chain geopolitics?

Foresight research involves two steps: first, monitoring and recognizing factors that could lead to future changes, and second, formulating and recommending appropriate strategies to manage these changes.[68]

[65] Mohammad, Elomri, and Kerbache, 'The Global Semiconductor Chip Shortage', p.480; Department of Information Services, 'Taiwan boosts semiconductor industry support following US export controls on China'; 'European Chips Act'; Khemka, 'India's Prospects in the Global Semiconductor Manufacturing Race | Council on Foreign Relations'; Kumar, 'The US-China Chip War and Prospects for South Korea-India Semiconductor Cooperation', p.1; Mochizuki and Lee, 'TSMC Eyes Third Japan Chip Plant with Cutting-Edge 3 Nanometer Tech'; Park, 'Shifted Paradigm in Technonationalism in the 21st Century', pp.1, 6-7; European Council on Foreign Relations, 'Europe's Digital Sovereignty'.
[66] Donnelly, 'Semiconductor and ICT Industrial Policy in the US and EU', p.2.
[67] Sauga, 'The new cold war'.
[68] Iden, Methlie, and Christensen, 'The Nature of Strategic Foresight Research'.

The first step seeks potential answers to the question of "what might happen" to change the dynamics of the AIS supply chain; the second step aims to provide a decision on "what and how will we solve it".[69] For the first step, our literature review spotted signals of the main categories of stakeholders as well as the overarching structures and dynamics of the geopolitics of the SSC. Considering the interconnectedness of our stakeholders, this project keeps a comprehensive scope of stakeholders to construct four future scenarios in a time frame of 16 years (till 2040). For the second step, our project formulates recommendations based on the four possible futures.

3.2. Introduction of Foresight Methodology

Foresight research is a method of deploying an interdisciplinary approach to understand and explore potential future scenarios to better assess the challenges that might lie ahead. During our literature review, we identified the main categories of stakeholders in the AIS industry that needed to be considered, including multinational technology companies, AIS factories, political entities, universities and research centres, and other international actors. As literature and news exhibit the current state of global geopolitics around AIS, there is a gap in understanding the future challenges and opportunities in the AIS industry. This project analyses the foresight trajectory based on tensions and cooperation among the aforementioned stakeholders while considering the possibility of new stakeholders and events that might drastically affect the geopolitics of the AIS supply chain.

A collective futuristic image needs to be challenged and consulted by various stakeholders. To enable the involvement of different stakeholders, this project gathered information about the industry and common concerns through attending international conferences and lectures,[70] as well as through interviews, desk research and a feedback round. By utilising a wide range of sources, the research was also able to reduce biases and to be sensitive to impacts on the less represented groups while focusing on the dominance of semiconductor-producing countries and companies.

3.3. Structure of the Research

This project conducted qualitative research, including conducting oral interviews and desk research. The structure of our study is displayed in the following steps:

[69] Conway, 'An Overview of Foresight Methodologies'.
[70] The team attended multiple panels and moderated a discussion at the AI House in Davos during the World Economic Forum 2024 and the presentation at the University of Basel by Dr. Josie-Marie Perkuhn "Ein hundertjähriger Brennpunkt? Angespannte globale Beziehungen um die Insel Taiwans" on March, 21st 2024.

1. **Horizon scanning (October 2023 - April 2024)**
   a. Data collection:
      i. Through conducting a literature review and attending conferences (such as the AI House at the World Economic Forum Annual Meeting 2024), this project enhanced the overview of the current situation of the AIS supply chain and identified key stakeholders. This knowledge base was also valuable in building a shared context with intersubjective testability that facilitates interviewing different perspectives.[71]
      ii. Through semi-structured interviews of experts, this project was able to connect different sources of information and explore assumptions, as interviews are also effective for gathering insights into decision-making and other processes.[72] Semi-structured interviews allowed us to structure the conversations while encouraging an open discussion. Each interviewee was asked to answer the same three overall questions:
         1. ***Mega Trends in the AI-Relevant Semiconductor Supply Chain**: What are the enduring mega trends shaping the future of the AI-relevant semiconductor supply chain and its geopolitical landscape, based on your area of expertise?*
         2. ***Observation of Weak and Emerging Signals**: From your vantage point, do you detect any weak or emerging signals within the sector that could influence its trajectory?*
         3. ***Potential Shocks and Improbable Events**: What improbable events or shocks do you foresee that could significantly impact the geopolitics of the AI-relevant semiconductor supply chain?*

         By keeping the questions broad, the research team enabled the interview partners to discuss their areas of expertise. In all cases, the interviews developed into an open conversation, allowing the attendees to ask follow-up questions to explore the topic more broadly. Despite this open approach, this project was aware of biases and underlying assumptions in the interviews that could influence the presented views.

[71] Valaskakis, 'Notes on Relativity in Future Studies'.
[72] Badache, Kimber, and Maertens, *International Organizations and Research Methods*.

iii. The project was able to gain a variety of interview partners. Overall, the project team conducted interviews with 17 people who are based in Australia, Belgium, Ireland, Japan, the Netherlands, SK, Switzerland and the US. Our interview partners have a wide range of professional backgrounds, ranging from EU officials to business people. The biggest group is comprised of scholars, mainly political scientists/IR (7) or with a technical (2), economics (2), or defence (1) background. Some of those scholars work for UN agencies or other International Organisations (IOs).[73] All but one interview was conducted as oral interviews.

iv. To complete our horizon scanning, we conducted a thorough desk research by consulting 78 other resources.[74] Additionally, we used information from the presentations during the World Economic Forum Annual Meeting in Davos from January 15th-19th, 2024 and at the University of Basel by Dr Josie-Marie Perkuhn "*Ein hundertjähriger Brennpunkt? Angespannte globale Beziehungen um die Insel Taiwans*" on March, 21st 2024.

b. Completion of the horizon scanning. After finishing the first step of the horizon scanning, we sorted this comprehensive and wide range of information into megatrends, weak signals, and potential shocks. Here, the research team sometimes re-classified given information from the interviews and used their judgement. In total, we classified 45 factors as megatrends, 40 as weak signals and 15 as potential shocks.[75] Thus, the research categorised exactly 100 factors used for the next step, scenario building.

2. Scenario building (April 2024 - May 2024)

a. Creative scenario building: Four possible future scenarios of the geopolitics of the AIS supply chain in 2040 were constructed for this study. To ensure comprehensive and creative scenarios, the three research team members built different scenarios using three approaches based on the factors found during the horizon scanning. The first approach involved randomly selecting weak signals and shocks. Afterwards, they were connected to the megatrends, and the scenarios were constructed. To generate conditions with less influence from personal bias, ChatGPT was utilised to produce a random combination of megatrends, weak signals and shocks. The second approach was a weighted one based on those factors that were the most often mentioned during the interviews. There, a system based on the hypothetical increase and decrease of intensity of the megatrends, weak

[73] The full list can be found in the Annexe of this document.
[74] The full list can be found in the Annexe of this document.
[75] A link to the full Excel list with detailed distribution and sources can be found in the Annexe of this document.

signals and shocks was utilised to have different combinations and, thus, different scenarios. The last approach used was Dator's four futures.[76] By using as many factors as possible, a growth, a collapse, a discipline, and a transformation scenario were built. The growth scenario is the most positive with an overall positive development, the collapse the most negative, considering the most negative shocks, while discipline stays between those two. Transformation is the scenario with the most change in the system by acknowledging many weak and emerging signals. Afterwards, the different outcomes were compared, and the final four scenarios were constructed based on previous scenarios. One aim was to use as many factors as possible for the final four scenarios. During this process, we adopted the guidelines proposed by Durance and Godet, 2010: Pertinence, coherence, likelihood, importance, and transparency.[77] This multilevel and guided approach to scenario building enabled a creative process with the widest possible variety of scenarios.

3. **Evaluation of Scenarios and Recommendations (May 2024 - June 2024)**
   a. Deepening understanding: The four final scenarios were presented to experts (mainly former interview partners) who acted as a focus group for the first results. This enabled the project to get feedback and comments on the part of the scenarios, which allowed us to enhance them further.
   b. Recommendation formulation: After finishing the scenarios, the research team formulated recommendations for AIS supply chain actors and specifically for the project partner, Swisscom, IOs (mainly based in Geneva), and the Swiss government. However, given the interconnectedness of the AIS supply chain, our recommendations can be applied by a wide range of stakeholders and actors and are therefore sorted between recommendations for all actors and those that are tailored to IOs.

3.4. Research Limitations

A foresight study always comes with its methodological limitations. Being aware of those limitations enables us to reduce the impact of them.

Given the complexity and the fast-changing nature of the AI-relevant SSC, a certain degree of simplification is needed. Tens of thousands of companies are involved in producing one AIS[78] and the

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[76] Dator, 'Alternative Futures at the Manoa School'; '4 Scenarios to Imagine the Future'.
[77] Durance and Godet, 'Scenario Building'.
[78] Thadani and Allen, 'Mapping the Semiconductor Supply Chain'.

tools and resources needed with numerous bottlenecks and geopolitical implications. Furthermore, this process involves potentially hundreds of border crossings, making it even more complicated. Therefore, we adopted a broad perspective to answer the research question about the geopolitics of the AIS supply chain and the sophisticated nature of this study should be kept in mind as it also leads to future research questions on the nuances of the SSC.

Moreover, the research team, in certain topics, lacked the technological expertise to understand the complex production processes behind the chips. Additionally, access is a further limitation. The research team was sometimes not able to gain access to some key governments (such as China or the US) or companies (TSMC or Nvidia). We filled this gap with our broad scope of interview partners and desk research.

4. Four Scenarios for 2040

All 100 factors mentioned above were used to construct the four final scenarios. On average, 37 out of 45 megatrends, 30 out of 40 weak signals and 9 out of 15 shocks are used. Table 1 (p.25) and Figure 8 (p.26) show how many megatrends, weak signals and shocks were used for each of the four scenarios. The complete list with detailed distribution of factors across scenarios can be found in the Annexe. Figures 9 to 12 are constructed to visualise each scenario, with different circles' sizes indicating the importance of different national and private stakeholders in 2040. A Swiss flag is used to show Switzerland's role in the global dynamic clearly.

Labels	Megatrend	Weak Signal	Shock
Growth	42	34	4
Instability	33	23	14
Transformation	32	30	6
Discipline	40	31	13

Table 1: Summary of each scenario's factor composition

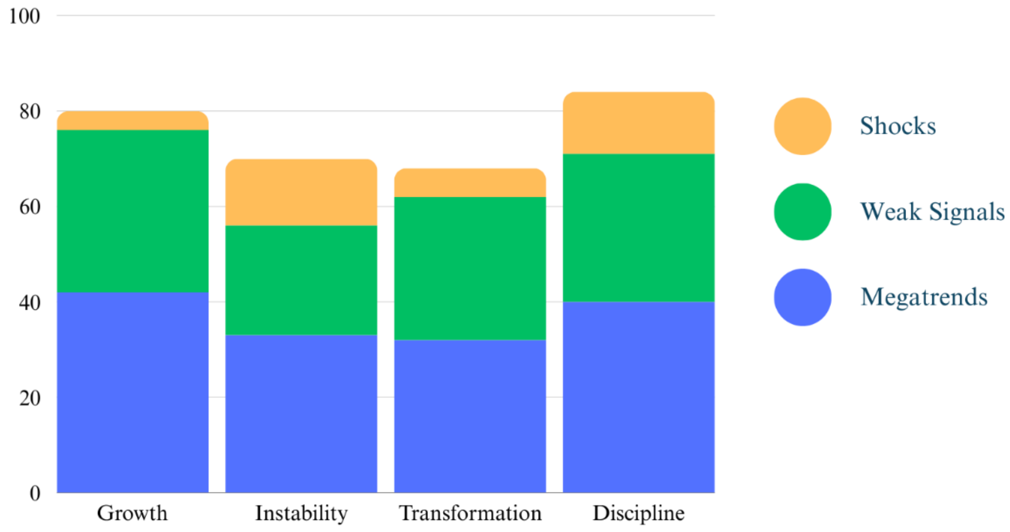

Figure 8: Summary of each scenario's factor composition

Scenario 1: Fragmented Interconnectivity: Growth in 2040

Cooperation, Development and Stability

Main Characteristics

1. *The SSC has transformed, with more states having a role than in 2024, as the demand for AIS is growing. However, the traditional stakeholders from 2024 continue to retain their dominant positions in their respective areas, maintaining the status quo from 2024.*
2. *There is greater cooperation amongst states to address issues affecting the world and, more specifically, the SSC, despite the continuing tensions over Taiwan as the status quo from 2024 is still persistent.*
3. *The SSC is stable and resilient, focusing more on sustainable development and technological advancements.*

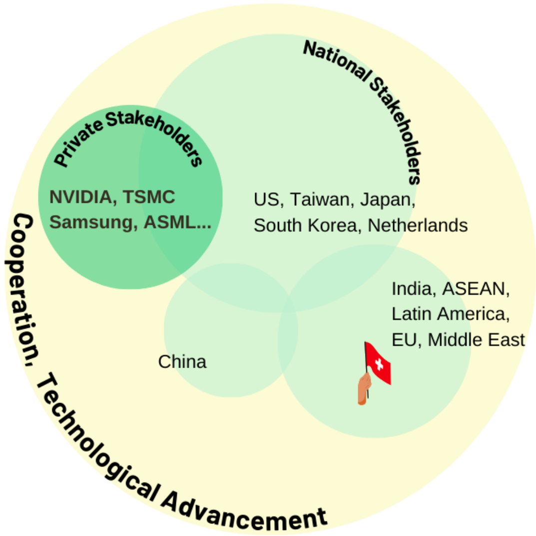

Figure 9: Description of stakeholders for Scenario 1

The AIS industry has seen a massive evolution, probably similar to all other aspects of life in 2040. The demand for semiconductors has sky-rocketed, with continued consumption in all regions of the world,[79] particularly a drastic increase in low-income states. The dynamics in the SSC have undergone some transformation, leading to a more diversified supply chain.[80] This is because there have been attempts by several states to domesticate the SSC and shift different elements of it, such as design, production, etc., away from the few regions it was centred in 2024.[81] However, interdependencies among states remain,[82] as de-coupling of the SSC is very complicated, and it is still impossible for one jurisdiction to be able to host the whole AIS supply chain.[83]

[79] Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp. 328-329.
[80] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.95; Seohee Park, online interview, 12 March 2024; Séamus Grimes, online interview, 7 March 2024; Dongyoun Cho, on-site interview, 13 March 2024.
[81] Federico Mantellassi, on-site interview, 13 March 2024; Isabella Cerutti and Michela Nardo, online interview, 30 April 2024; Bunde, Eisentraut, and Schütte, p.101.
[82] IR Scholar in the US, online interview, 2 April 2024; IR Scholar in Geneva, online interview, 26 March 2024; Bunde, Eisentraut, and Schütte, p.101.
[83] Mark and Tiff Roberts, 'United States–China Semiconductor Standoff'; Macaulay, 'EU Has "No Chance" of Chip Independence. Nor Does Anybody Else'; IR Scholar in the US, online interview; EU Official, online interview, 8 April 2024; Florian Jaton, online interview, 2 April 2024.

To delve into some details, the status quo in 2040 remains similar to 2024 (Figure 9, p.27). The dominance of the traditional stakeholders, such as Nvidia and Intel, among others in the US,[84] TSMC in Taiwan, Samsung in SK, Rapidus in Japan and ASML in the Netherlands continue, as seen by the large size of their circle (Figure 9, p.27).[85] While there have been several technological breakthroughs in the field of semiconductors, those breakthroughs were mainly a result of the efforts of the traditional stakeholders, leaving China, Switzerland, and other emerging players still behind, as seen by the size of their circle (Figure 9, p.27).[86] Thus, the US sanctions and export controls were effective in hindering rapid Chinese developments.[87]

The US was also able to shift some of the AIS production, especially manufacturing capacities, from East Asia to the US and EU.[88] While China has not been able to catch up with the US, its position has seen a transformation from 2024 to a stronger focus on AIS and notable innovation.[89] Despite being unable to overcome the US technological dominance, emerging players such as the EU,[90] India,[91] ASEAN,[92] the Middle East,[93] and Latin America[94] were able to enhance their positions in the SSC, as seen by their circle (Figure 9, p.27). This has further increased fragmentation and interdependencies among states, as the SSC involves more players at the moment. This fragmentation and diversification

[84] Hille et al., 'US Missing Pieces of AI Chip Puzzle despite TSMC's $65bn Bet'; Perrault and Clark, 'AI Index Report 2024 – Artificial Intelligence Index'; IR Scholar in Japan, online interview, 3 May 2024; EU Official, online interview; Shawn Donnelly, online interview, 26 April 2024; Michael Frank, online interview, 5 March 2024.

[85] EU Official, online interview; Frank, online interview; Cerutti and Nardo, online interview; Carrara et al., 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study'.

[86] Miller, *Chip War: The Fight for the World's Most Critical Technology,* p.323; Grimes, online interview.

[87] Frank, online interview; Grimes, online interview; Devonshire-Ellis, 'US Chip Sanctions on China: Analysis and Implications'.

[88] 'Semiconductor Supply Chain Update'; Hille et al., 'US Missing Pieces of AI Chip Puzzle despite TSMC's $65bn Bet'.

[89] IR Scholar in Geneva, online interview; Mantellassi, on-site interview; Grimes, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?'; Cerutti and Nardo, 'Semiconductors in the EU'; Patel, Ahmad, and Xie, 'China AI & Semiconductors Rise'.

[90] Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.331 - 332; EU Official, online interview; Florian, online interview; Donnelly, online interview; Cerutti and Nardo, online interview.

[91] IR Scholar in Geneva, online interview; Cerutti and Nardo, online interview; Tripathi, 'The Global Race For AI Chips Intensifies. Where Does India Stand?'.

[92] IR Scholar in Geneva, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', pp.59 - 61; Cho, on-site interview; Sandy Chong, online interview, 25 April 2024.

[93] Goodrich, 'Silicon Valley Should Carefully Assess Its AI and Semiconductor Dealings in the Middle East'.

[94] Cardenas, 'Post-AMLO? The North American Semiconductor Opportunity'; 'Opportunities in South America for Semiconductor Manufacturing'; 'Mexico and Brazil Dither as Chip Supply Chains Are Reforged'.

also reduced tensions between the US and China,[95] and the lack of escalation of tensions over Taiwan, as the status quo from 2024 remains. This has further resulted in the maintenance of the stability of the SSC.[96] This also results in states not having to align themselves with China or the US. In contrast, the existing alliances between states continue to remain, for example, between the US and EU,[97] Brazil and China,[98] etc.

The broader context of geopolitics and the state of affairs in 2040 also contribute to the stability of the SSC. This is because while threats and challenges such as conflicts, techno-nationalism, cyber-attacks, talent shortages, climate crises and natural disasters[99] remain pertinent, states have effectively responded to these threats, underscoring the importance and effectiveness of resilience and preparedness. There is a stronger focus on sustainable development when compared to 2024, with a renewed focus on alternative tools, such as alternative lithography tools[100] or alternatives to silicon (such as gallium chips) in the production of semiconductors,[101] and sustainable modes of production, including the conversation of energy and water resources.[102]

Additionally, the broader trend toward AI technological development, such as quantum computing relevant to AI applications,[103] newer designs for chips, etc and AI development remains.[104] This is because Moore’s law, which refers to exponential growth in computing power, has been kept, even

[95] Reinsch, ‘Secretary Raimondo Goes to China’.
[96] EU Official, online interview; Florian, online interview; IR Scholar in the US, online interview; Mark and Tiff Roberts, ‘United States–China Semiconductor Standoff’; Macaulay, ‘EU Has “No Chance” of Chip Independence. Nor Does Anybody Else’.
[97] Cerutti and Nardo, online interview; EU Official, online interview; Jeremy Mark, online interview, 12 March 2024; Miller, *Chip War: The Fight for the World’s Most Critical Technology,* p.333; Benson, Mouradian, and Sicilia, ‘Transatlantic Cooperation on Semiconductors and AI in 2024’; Geschwindt, ‘Intel, Germany Strike Record €30B Deal for Chip Mega-Factory’.
[98] ‘Mexico and Brazil Dither as Chip Supply Chains Are Reforged’; Reuters, ‘Brazil Paves Way for Semiconductor Cooperation with China’; Nacucchio, ‘The High-Tech Industry in Latin America’.
[99] Cerutti and Nardo, online interview; EU Official, online interview; IR Scholar in Geneva, online interview; Park, online interview; Mark, online interview; Defence Scholar in Japan, online interview, 27 March 2024; Miller, *Chip War: The Fight for the World’s Most Critical Technology.* p.340.
[100] EU Official, online interview; Florian, online interview. ; IR Scholar in the US, online interview.
[101] ‘New Superatomic Semiconductor Material Could Reshape Chip Manufacturing Forever’.
[102] Frank, online interview; IR Scholar in the US, online interview; Grimes, online interview; Rammayya Krishnan, online interview, 15 February 2024.
[103] Donnelly, online interview.
[104] Mark, online interview; Krishnan, online interview; MacroPolo, ‘AI Chips’.

though it has reached a physical limit.[105] There is also successful AI regulation[106] due to the collaborative efforts of states in Geneva, negotiating and ratifying the AI Accord Protocols. This has led to the responsible use of AI and, therefore, AIS. The SSC continues to remain crucial for security. Still, it is not further weaponised by sanctions and export controls by states, leaving mostly private companies in the driver's seat (Figure 9, p.27), with their circle being outside of that of their states. Thus, this contributes to the stability of the SSC, as well as the state of geopolitics in the world.

Scenario 2: Meltdowns and Damage: Instability in 2040

Disruption, Conflict and Securitisation

Main characteristics

1. *The semiconductor industry is disrupted and unable to meet the demand in 2040, leading to a severe economic depression.*
2. *Several conflicts and natural disasters plague the SSC, and states grapple with the consequences.*
3. *The SSC continues to be weaponised by states, though they are unable to secure their domestic supply entirely by themselves.*

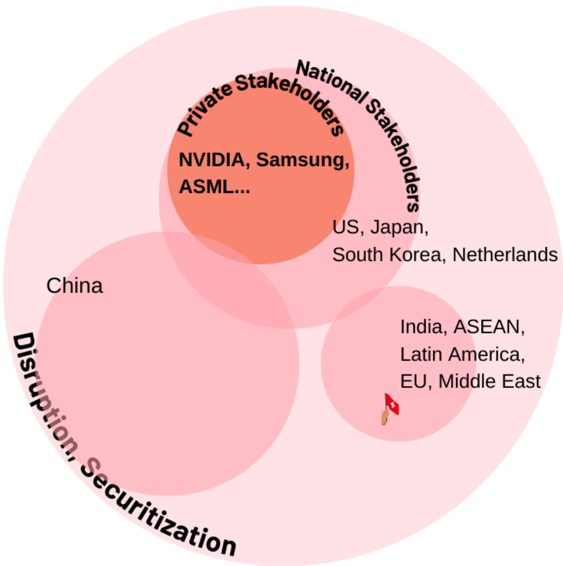

Figure 10: Description of stakeholders for Scenario 2

[105] Rosenbush, 'Pro Take: Going Beyond Moore's Law; Semiconductor Innovation Continues, But It Is Tougher'; Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.348 - 349*;* EU Official, online interview; Jaton, online interview; IR Scholar in the US, online interview; IR Scholar in Geneva, online interview.
[106] Mantellassi, on-site interview; Panel discussion "AI in Peace and Conflict" AI House WEF Davos 15.01.2024.

The state of affairs in 2040 is severely bleak, with fractured geopolitical relations impacting the SSC. The decades have seen an evolution in the SSC, with demand drastically increasing in several parts of the world.[107] However, unlike scenario one, the industry cannot meet these needs due to disruptions to the SSC.

From a broader context, the geopolitical tensions in the Taiwan Strait have escalated to a blockade,[108] leading to the SSC in smithereens and severe techno-nationalism, as TSMC's capabilities in Taiwan were severely impacted. The situation is further exacerbated by natural disasters and the consequences of climate change,[109] which states have been unable to address collectively. All of this has resulted in chaos across the world as states continue to scramble to safeguard their territories and supply chains,[110] which has led to a severe global economic depression.[111]

Narrowing in on the SSC reveals that the efforts of several states, such as the US and China, towards decoupling and domestication have failed.[112] However, fragmentation,[113] as a result of such attempts, thwarts the possibility of bringing stability to the SSC.[114]

While the enduring dominance of the traditional stakeholders, such as Intel and Nvidia, among others in the US, in designing chips remains, they also have the increased ability to produce AIS.[115] Similarly,

[107] *Miller, Chip War: The Fight for the World's Most Critical Technology,* pp.328 - 329.
[108] Frank, online interview; Grimes, online interview; IR Scholar in the US, online interview; Mark, online interview; Donnelly, online interview; IR Scholar in Japan, online interview; Defence Scholar in Japan, online interview; Presentation at the University of Basel by Dr. Josie-Marie Perkuhn "Ein hundertjähriger Brennpunkt? Angespannte globale Beziehungen um die Insel Taiwans"; Miller, p.341.
[109] Cerutti and Nardo, online interview; EU Official, online interview; IR Scholar in Geneva, online interview; Park, online interview; Mark, online interview; Defence Scholar in Japan, online interview; Miller, p.340.
[110] Cerutti and Nardo, online interview; EU Official, online interview; IR Scholar in Geneva, online interview; Park, online interview; Mark, online interview; Defence Scholar in Japan, online interview; Miller, p.340.
[111] Mark, online interview.
[112] Mantellassi, on-site interview; Cerutti and Nardo, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.101.
[113] EU Official, online interview; IR Scholar in Geneva, online interview; Grimes, online interview; Mantellassi, on-site interview; Park, online interview; Bunde, Eisentraut, and Schütte, p.101.
[114] EU Official, online interview; IR Scholar in Geneva, online interview.
[115] Hille et al., 'US Missing Pieces of AI Chip Puzzle despite TSMC's $65bn Bet'; Perrault and Clark, 'AI Index Report 2024 – Artificial Intelligence Index'; IR Scholar in Japan, online interview; EU Official, online interview; Donnelly, online interview; Frank, online interview.

ASML in the Netherlands maintains its position,[116] along with Rapidus in Japan and Samsung in SK. These can be seen (Figure 10, p.30), with the size of their circle representing their role. China has substantially developed its role, creating new frontiers in AIS, also as seen by the size of its circle (Figure 10, p.30).[117] These are also, in part, a result of the failed sanctions imposed by the US to curb China's access to technology, which have backfired and have only further exacerbated development in China.[118] These developments occur parallel to the growth of emerging players such as the EU,[119] India,[120] ASEAN,[121] Latin America,[122] the Middle East,[123] and Switzerland. However, they have not managed to create a massive impact on the SSC to catch the lost capacities from the disruption of the supply chain caused by conflicts, climate change, and efforts of traditional stakeholders to domesticate the SSC, as seen by their comparatively smaller circle (Figure 10, p.30). At the same time, the increased tensions and conflicts between China and the US continue to escalate[124] with further and more semiconductor sanctions,[125] and other states have the challenging task of aligning themselves with

[116] EU Official, online interview; Frank, online interview; Cerutti and Nardo, online interview; Carrara et al., 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study'.
[117] Frank, online interview; Cerutti and Nardo, online interview.
[118] Frank, online interview; Grimes, online interview; Kharpal, 'China Making More Advanced Chips — but Beijing Still Faces Challenges'; Carrara et al., 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study'.
[119] Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.331 - 332; EU Official, online interview; Jaton, online interview; Donnelly, online interview; Cerutti and Nardo, online interview.
[120] IR Scholar in Geneva, online interview; Cerutti and Nardo, online interview; Tripathi, 'The Global Race For AI Chips Intensifies. Where Does India Stand?'.
[121] IR Scholar in Geneva, online interview; Cho, on-site interview; Chong, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', pp.59 – 61.
[122] Goodrich, 'Silicon Valley Should Carefully Assess Its AI and Semiconductor Dealings in the Middle East'.
[123] Cardenas, 'Post-AMLO? The North American Semiconductor Opportunity'; 'Opportunities in South America for Semiconductor Manufacturing'; 'Mexico and Brazil Dither as Chip Supply Chains Are Reforged'.
[123] Reinsch, 'Secretary Raimondo Goes to China'.
[124] IR Scholar in Geneva, online interview; Guevara, 'U.S. and China Race for Latin America's Semiconductors'; Hille et al., 'US Missing Pieces of AI Chip Puzzle despite TSMC's $65bn Bet'.
[125] Frank, online interview; Grimes, online interview; Devonshire-Ellis, 'US Chip Sanctions on China: Analysis and Implications'.

China or the US, as non-alignment is more difficult in 2040.[126] Thus, alliances such as those between the US and the EU,[127] as well as Brazil and China[128] , continue.

The SSC continues to be impacted heavily by climate change, leading to a scarcity of resources required, such as energy and water.[129] While there is a drive towards sustainable development,[130] there has yet to be a massive transformation in the development and utilisation of alternative tools and materials,[131] as well as the preservation of resources. These factors have resulted in chaos, further intensifying competition between states.

The years have seen increased development of technology such as quantum computing,[132] though nothing sufficient enough to be relevant to AI. The broader trend towards the development of AI remains.[133] However, Moore's law on chip production reaches its end[134,] and there is no alternative that guides the semiconductor industry. The conflict in the Taiwan Strait adds to the inability to have alternatives to Moore's law. The absence of regulation has resulted in a higher probability of chips being utilised in a dual-use capacity.[135] In this dangerous situation, states try to gain more control over the SSC as techno-nationalism rises, which further fuels tensions among states.[136] These factors have led to severe fragmentation and disruption of the SSC, as semiconductors, particularly AI-relevant ones, have become even more central to security concerns,[137] as they are weaponised by states who try to

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126 EU Official, online interview; Krishnan, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', pp.59- 61; Nova, 'APEC Ministers Reach Agreement to Reduce Dependence on Semiconductors from China'.

127 Cerutti and Nardo, online interview; EU Official, online interview; Mark, online interview; Miller, *Chip War: The Fight for the World's Most Critical Technology,* p. 333; Benson, Mouradian, and Sicilia, 'Transatlantic Cooperation on Semiconductors and AI in 2024'; Geschwindt, 'Intel, Germany Strike Record €30B Deal for Chip Mega-Factory'.

128 Reuters, 'Brazil Paves Way for Semiconductor Cooperation with China'; 'Mexico and Brazil Dither as Chip Supply Chains Are Reforged'; Nacucchio, 'The High-Tech Industry in Latin America'.

129 IR Scholar in the US, online interview; Frank, online interview; Grimes, online interview; Krishnan, online interview.

130 Frank, online interview; IR Scholar in the US, online interview; Grimes, online interview; Krishnan, online interview.

131 EU Official, online interview; Jaton, online interview; IR Scholar in the US, online interview.

132 Donnelly, online interview; Mark, online interview.

133 Mark, online interview; Krishnan, online interview; MacroPolo, 'Big Picture: AI Chips'.

134 Rosenbush, 'Pro Take: Going Beyond Moore's Law; Semiconductor Innovation Continues, But It Is Tougher'; Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.348 - 349; EU Official, online interview; Jaton, online interview; IR Scholar in the US, online interview; IR Scholar in Geneva, online interview.

135 Donnelly, online interview.

136 Donnelly, online interview.

137 Mantellassi, on-site interview; Park, online interview.; IR Scholar in the US, online interview.

enhance their control over the SSC[138] (Figure 10, p.30), with states being in the driver's seat as private players are within their control. In Geneva, some states seek support from the UN, hoping for an end to the conflicts. However, there is not a satisfactory outcome, as geopolitical challenges hinder effective solutions.

Scenario 3: Technological Advancements and Change: Transformation in 2040

Collaboration, Resilience and Diversification

Main characteristics:

1. *Global technological advancement drives diversification and specialisation in AI-relevant semiconductor production and the supply chain, enabling new stakeholders to emerge.*
2. *In light of rapid development and changing domestic approaches, the tension among the US, Taiwan, and China has become less intense, and all parties prioritise developing through collaborations.*
3. *More international cooperations happen, addressing shocks and further stabilising the SSC.*

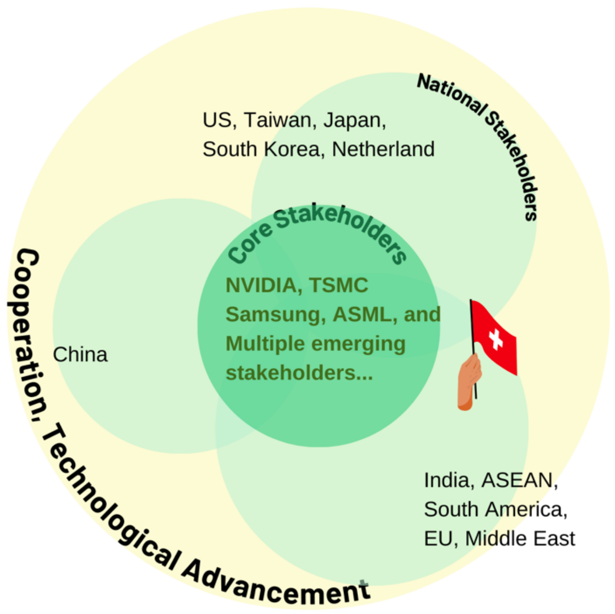

Figure 11: Description of stakeholders for Scenario 3

[138] Mantellassi, on-site interview.

In a world of rapid innovation and collaboration, the semiconductor industry in 2040 will experience a period of unprecedented growth. This stimulates new ways of utilising AI, such as Artificial General Intelligence. Due to simultaneous technological advances and breakthroughs in semiconductor technologies, such as room-temperature superconductors[139], there is a fast-growing demand for semiconductors,[140] especially from low-income states.[141] New technology not only advances AI applications, such as AI and space exploration,[142] but also advances chip production, such as the gallium nitride[143] technology. As semiconductors lie in the pillar of technological progress, they also become even more central to geopolitical competition.[144]

The geopolitical landscape has transformed as the US and China built better connections and increased trade.[145] This had a stabilising effect on chip production. Furthermore, changing leadership and politics in China[146] and the US[147] favour the reduction of tensions and techno-nationalism. This also led to a decrease in sanctions.[148] Consequently, the subsidy race[149] around the SSC is reduced and states no longer compete in investing in their semiconductor industry, leaving private companies and researchers in the driver's seats, as suggested by the central big circle (Figure 11, p.34). Furthermore, Taiwan and China established better cross-strait relations. Even though other geopolitical conflicts,[150] natural disasters,[151] pandemics[152] and further disruptions[153] occurred, they were quickly contained. At the same time, climate change is addressed successfully, and the semiconductor industry has shifted its focus

[139] Zhang, 'Room-Temperature Superconductors'.
[140] Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.328 - 329.
[141] Krishnan, online interview.
[142] Cerutti and Nardo, online interview; Chong, online interview.
[143] EU Official, online interview; IR Scholar in Geneva, online interview; Mantellassi, on-site interview; Mark, online interview; Krishnan, online interview; Capaccio, 'Pentagon Seeks Supply of Chip-Mineral Gallium After China Curbs Exports'.
[144] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.101.
[145] Reinsch, 'Secretary Raimondo Goes to China'.
[146] Mark, online interview.
[147] Donnelly, online interview.
[148] Paul, 'The Sanctions against China Will Continue until Morale Improves'.
[149] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.96.
[150] Mark, online interview; Defence Scholar in Japan, online interview; Frank, online interview; IR Scholar in the US, online interview; Grimes, online interview; Miller, *Chip War: The Fight for the World's Most Critical Technology,* p.341.
[151] EU Official, online interview; IR Scholar in Geneva, online interview; Park, online interview; Cerutti and Nardo, online interview; Miller, p.340.
[152] EU Official, online interview; IR Scholar in Geneva, online interview; Cerutti and Nardo, online interview.
[153] Cho, on-site interview.

further to sustainable development over short-term efficiency.[154] In addition, new sources of raw materials and[155] new technology enable more effective use of water and energy.[156] This new environment gives some states, such as some of ASEAN, a more critical role.[157]

The semiconductor industry had adapted Moore's Law positively,[158] by utilising technological advancement and better cooperation. Due to the specialisation of production among different regions,[159] talent shortage[160] is also effectively addressed. The US supports this trend by continuing to deploy friendshoring by seeking partnerships and offshoring by leveraging global resources.[161]

As Figure 11 (p.34). indicates other emerging players, such as the EU, collaborate with traditional stakeholders in producing AI chips,[162] thus holding a stronger position[163]. At the same time, Brazil and China established deeper corporations[164] in producing advanced chips. Traditional stakeholders like SK, Japan, and the Netherlands hold their advanced position,[165] while ASEAN,[166] the Middle East,[167] Latin America[168], and Russia[169] emerge as new hubs of the SSC. The growing international investments and coexistence of both traditional and emerging players enable a successful diversification, specialisation and depolarisation of the SSC.[170]

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[154] Chong, online interview; International Labour Organization, 'Regional Study on Green Jobs Policy Readiness in ASEAN'.
[155] Chong, online interview.
[156] IR Scholar in the US, online interview; Frank, online interview; Grimes, online interview; Krishnan, online interview.
[157] 'Semiconductor Market Size & Share'.
[158] Cerutti and Nardo, online interview.
[159] Miller, *Chip War: The Fight for the World's Most Critical Technology,* p.340.
[160] Mantellassi, on-site interview; Donnelly, online interview; Frank, online interview.
[161] Rojas et al., 'Reshaping Supply Chains to Improve Economic Resilience'.
[162] Cerutti and Nardo, 'Semiconductors in the EU'.
[163] 'Semiconductor Supply Chain Update'.
[164] 'Mexico and Brazil Dither as Chip Supply Chains Are Reforged'; Reuters, 'Brazil Paves Way for Semiconductor Cooperation with China'; Nacucchio, 'The High-Tech Industry in Latin America'.
[165] EU Official, online interview; Frank, online interview; Cerutti and Nardo, online interview; Carrara et al., 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study'.
[166] IR Scholar in Geneva, online interview; Chong, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.61.
[167] Goodrich, 'Silicon Valley Should Carefully Assess Its AI and Semiconductor Dealings in the Middle East'.
[168] Cardenas, 'Post-AMLO? The North American Semiconductor Opportunity'; 'Opportunities in South America for Semiconductor Manufacturing'.
[169] Lincoln, 'Ukraine-Russia Sector Considerations'.
[170] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.101; Grimes, online interview; Park, online interview; IR Scholar in Geneva, online interview; EU Official, online interview.

Traditional stakeholders, such as TSMC and Nvidia, formulate effective corporations,[171] thus increasing the US domestic manufacturing capacity, and China keeps its position in the industry. Even though China had a stronger focus on innovating smaller and faster AIS, it was not able to catch up with US technology.[172]Overall, with the efforts of emerging players that diversified the SSC and reduced bottlenecks, the US-China rivalry was reduced. Thus, sanctions and governmental influences are needed less in this new and effective SSC.[173] Even though the SSC is still central to national security,[174] it is not weaponised, and there is no concern about the dual-use capacity of chips.[175] This is the case because AI and, with it, AIS regulation progresses and is successful.[176]

Meanwhile, Switzerland plays a larger role in the SSC in innovating AIS technology, facilitating communications and pushing for global regulations for the use of AI and AIS production. Under the collective effort of states, as well as IOs, a shared guideline for AI application and AIS production is deployed during the "Geneva 2040 AI Convention", further stabilising the SSC.

Scenario 4: Turmoil and Stagnation: Discipline in 2040

Polarisation, Conflict and Depression

Main characteristics:

1. *Several stakeholders try to respond to geopolitical conflicts, resource scarcity, and the dual-use capacity of AIS by engaging with more competition.*
2. *The US-China chip rivalry becomes heightened as the SSC becomes polarised and fragmented, and China catches up to the technological advancements of the US.*
3. *Stagnation in technological advancement in the AI and semiconductor industry has led to an economic depression worldwide.*

[171] Mantellassi, on-site interview; Mark, online interview.
[172] 'TSMC's Q1 Revenue Rise Beats Market Expectations on AI Boom'; Patel, Ahmad, and Xie, 'China AI & Semiconductors Rise'.
[173] Patel, Ahmad, and Xie, 'China AI & Semiconductors Rise'.
[174] Mantellassi, on-site interview; Park, online interview; Cho, on-site interview; Donnelly, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.99.
[175] Donnelly, online interview.
[176] Mantellassi, on-site interview; Panel discussion "AI in Peace and Conflict" AI House WEF Davos 15.01.2024.

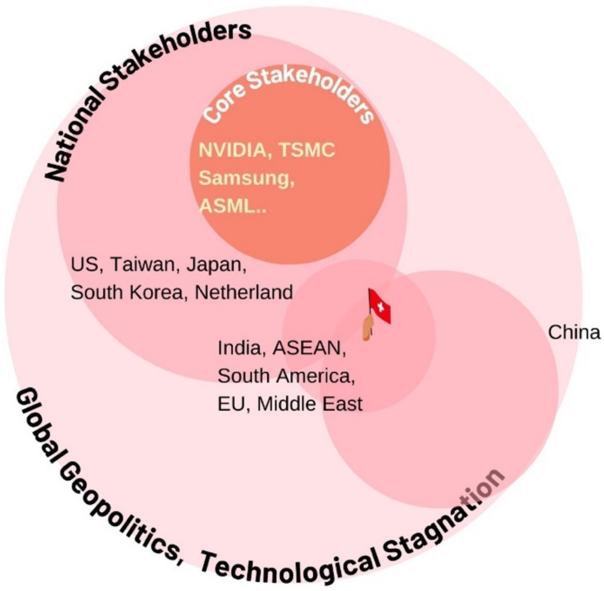

Figure 12: Description of stakeholders for Scenario 4

In a world affected by various geopolitical conflicts and natural disasters, the semiconductor industry faces a few unprecedented challenges in 2040. Disasters such as climate change,[177] and earthquakes,[178] as well as subsea cable disruptions[179] have occurred, thus impacting the SSC. However, their effects were sometimes mitigated successfully. Furthermore, raw earth materials, water and energy continue to be scarce, threatening the stability of the SSC.[180] The talent shortage in Taiwan, Japan and SK has also not been resolved,[181] causing increased concerns for the SSC.

Geopolitically, relations among the US, Taiwan and China have deteriorated but have not yet erupted into an armed conflict.[182] Moreover, several states, including from ASEAN, are increasingly vulnerable to cyber-attacks, which hinder data and critical infrastructure safety,[183] thus affecting the Indo-Pacific

[177] IR Scholar in the US, online interview.
[178] EU Official, online interview; IR Scholar in Geneva, online interview; Park, online interview; Cerutti and Nardo, online interview; Miller, *Chip War: The Fight for the World's Most Critical Technology,* p.340.
[179] Chong, online interview.
[180] Cerutti and Nardo, 'Semiconductors in the EU'; Lincoln, 'Ukraine-Russia Sector Considerations'; Capaccio, 'Pentagon Seeks Supply of Chip-Mineral Gallium After China Curbs Exports'.
[181] Mantellassi, on-site interview; Donnelly, online interview; Frank, online interview.
[182] Mantellassi, on-site interview; Frank, online interview; IR Scholar in Geneva, online interview; Mark and Niels, 'Relying on Old Enemies: The Challenge of Taiwan's Economic Ties to China'.
[183] Chong, online interview.

region, which is at the centre of the US-China rivalry. In such a disrupted environment, states attempt to de-risk and compete for dominance in AI technology.[184]

The absence of global AI regulation has led to a higher degree of fragmentation of the SSC, as AIS retain their dual-use capacity.[185] Thus, they are still highly relevant to national security and economic development and continue to be weaponised by techno-nationalist actions.[186] Additionally, scarcity of resources and risks of conflicts[187] over chip production lead to more governmental influence[188] in the SSC as states are competing to exert more control over the production by domestication.[189] The lack of cooperation and extensive fragmentation,[190] causes ineffectiveness in the SSC despite the increasing demand for chips.[191] Thus, traditional stakeholders are slowing down in growth. Even though Nvidia, TSMC, and Samsung, among others, stay central[192] and make some technological advancements, the end of Moore's Law is reached.[193] This leads to an economic depression and a reduction of technological advancements.[194] The growing and more severe US sanctions and pressure on US allies backfire and hinder US chip development.[195] Despite the cooperation between TSMC and Nvidia,[196] the US domestic production of AIS faces a slow-growing rate. The slowdown allows China to catch up and develop alternative lithography tools.[197] The US-China rivalry persists and further disrupts the SSC.[198] The subsidy race becomes more severe as states pour investments into their domestic semiconductor

[184] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.101.
[185] Mantellassi, on-site interview; Donnelly, online interview.
[186] Mantellassi, on-site interview; Park, online interview; Cho, on-site interview; Donnelly, online interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.91.
[187] IR Scholar in Geneva, online interview; Mark, online interview; Cerutti and Nardo, 'Semiconductors in the EU'.
[188] Donnelly, online interview.
[189] 'Semiconductor Supply Chain Update'.
[190] Mark, online interview.
[191] *Miller, Chip War: The Fight for the World's Most Critical Technology,* pp.328 - 329.
[192] Miller, p.331; Hille et al., 'US Missing Pieces of AI Chip Puzzle despite TSMC's $65bn Bet'; 'Semiconductor Market Size & Share'.
[193] Rosenbush, 'Pro Take: Going Beyond Moore's Law; Semiconductor Innovation Continues, But It Is Tougher'; Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.348 - 349; EU Official, online interview; Jaton, online interview; IR Scholar in the US, online interview; IR scholar in Geneva, online interview.
[194] Mark, online interview.
[195] Koc and Hawkins, 'Huawei Chip Breakthrough in 2023 Used Tech From Two US Suppliers - Bloomberg'; Fuller, 'U.S. Regulators Made Huawei's Chip "breakthrough" Possible'.
[196] Hille et al., 'US Missing Pieces of AI Chip Puzzle despite TSMC's $65bn Bet'.
[197] EU Official, online interview; Florian, online interview; IR Scholar in the US, online interview.
[198] IR Scholar in Geneva, online interview; Mantellassi, on-site interview; Grimes, online interview; Presentation at the University of Basel by Dr. Josie-Marie Perkuhn "Ein hundertjähriger Brennpunkt? Angespannte globale Beziehungen um die Insel Taiwans"; Cerutti and Nardo, 'Semiconductors in the EU'; Patel, Ahmad, and Xie, 'China AI & Semiconductors Rise'.

industries.[199] Overall, the supply chain experiences polarisation and fragmentation.[200] Additionally, the EU, Japan, SK, and the US are building stronger cooperation in their attempt to gain control of the situation.[201] Thus, the US and its partners are working on increasing the capacity of chip production through offshoring and friendshoring.[202]

At the same time, China's position in the SSC has grown due to huge investments in AIS innovations[203] and its control of chip facilities and key raw earth materials.[204] China established an industry that substitutes ASML and catches up with advanced US and Taiwan chip design and production,[205] leading to more sanctions and export controls as well as shifts in the US-China rivalry. Moreover, China also aligns more tightly with Brazil.[206] Other players, such as the EU,[207] India,[208] ASEAN,[209] Latin America,[210] the Middle East,[211] and Switzerland, emerge but are too late to compete with either China or the US. In this situation, non-alignment or neutrality becomes difficult[212]. Thus, as Figure 12 (p.38) indicates, they are forced into making a binary choice[213] between China and the US. The US and China race their investments, especially in resource-rich states in the ASEAN regions.[214]

Every year, states and company representatives meet in Geneva to mitigate the dual use of chips but are incapable of achieving any consensus on either chips or AI regulations. With the lack of global regulation and weaponisation of AI and AIS, governmental influence and regulation loom large.

[199] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.99.
[200] Krishnan, online interview; Cerutti and Nardo, online interview.
[201] Cerutti and Nardo, 'Semiconductors in the EU'; 'The "Chip 4 Alliance" and Taiwan–South Korea Relations', p.4.
[202] Rojas et al., 'Reshaping Supply Chains to Improve Economic Resilience'.
[203] 'TSMC's Q1 Revenue Rise Beats Market Expectations on AI Boom'; Patel, Ahmad, and Xie, 'China AI & Semiconductors Rise'.
[204] Funaiole, Hart, and Powers-Riggs, 'De-Risking Gallium Supply Chains'.
[205] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.96.
[206] Reuters, 'Brazil Paves Way for Semiconductor Cooperation with China'.
[207] Miller, *Chip War: The Fight for the World's Most Critical Technology,* pp.331 - 332; EU Official, online interview; Florian, online interview; Donnelly, online interview; Cerutti and Nardo, online interview.
[208] IR Scholar in Geneva, online interview; Cerutti and Nardo, online interview; Tripathi, 'The Global Race For AI Chips Intensifies. Where Does India Stand?'.
[209] IR Scholar in Geneva, online interview; Chong, on-site interview; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.61.
[210] Cardenas, 'Post-AMLO? The North American Semiconductor Opportunity'; 'Opportunities in South America for Semiconductor Manufacturing'.
[211] Goodrich, 'Silicon Valley Should Carefully Assess Its AI and Semiconductor Dealings in the Middle East'.
[212] 'APEC Ministers Reach Agreement to Reduce Dependence on Semiconductors from China'.
[213] Tseng, Chang, and Huang, 'TSMC Founder Discusses IC Cooperation with Japan PM at APEC Summit - Focus Taiwan'; Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.60.
[214] Bunde, Eisentraut, and Schütte, 'Munich Security Report 2024: Lose-Lose?', p.61; Chong, online interview.

5. Discussion

5.1. Implications of the Four Scenarios for the Actors in the SSC

The presented scenarios paint four significantly different possible futures. Scenario 1, "Growth in 2040", can be understood as a continuum of the current status quo in 2024. "Instability in 2040", scenario 2, shows the collapse of the SSC as the outcome of severe disruptions. Scenario 3, "Transformation in 2024", underlines the transformative power of change in the SSC and "Discipline in 2040", scenario 4, can be characterised by stagnation in the SSC and thus a more dangerous future. These possibilities help us navigate today's world and the geopolitics of the AI-relevant SSC.

5.1.1. Technological Advancements

The critical factor that overarches all the scenarios is the technological advancement of the AIS sector. As can be seen, technological progress can significantly impact the dynamics of the SSC. This progress can take different forms, including making smaller and more effective chips, utilising new resources for chips, such as gallium-nitride chips, or alternative tools for ultraviolet lithography. This technological progress can be effective differently due to various factors, as reflected in the four scenarios. In scenario 1, the industry dealt with the growing demand for AIS through technological advances. The endurance of Moore's law also plays a crucial role in this question. Scenario 2 shows what happens when, through geopolitical conflict or other sources of disruption, technological progress comes to a halt and, with it, Moore's law. Losing this techno-scientific promise would lead to a severe global economic depression as chip demands cannot be met, and states are conflicted over this scarce resource.

Meanwhile, scenario 3 shows the exact opposite power of technological development. New frontiers and breakthroughs in the industry enable Moore's law's positive transformation and new stakeholders' emergence. By diversifying and further spreading the SSC, stability is enhanced. An industry that can meet the demand of AIS can also bring stability to the geopolitical realm as the forceful competition and sanctions are no longer needed or at least reduced. However, scenario 4 shows that the stagnation of technological advancements and the end of Moore's law impact the competition as states try to secure the SSC and keep their technological advancement over their adversaries, making semiconductor technology an even bigger weapon than it is today. Those perspectives underline one of the critical findings of this research, which is that geopolitics and the stability of the AIS supply chain are inevitably connected to the ideas of Moore's law and the promise of technological advancements.

Furthermore, the US-China rivalry, as reflected in scenarios 3 and 4, can develop in a dangerous direction in case of stagnation of technological progress. This factor is connected to the fact that AIS have a dual-use capacity and are used in nearly all modern and future weapons systems, making them necessary for national security. Weaponisation, mainly through sanctions and export controls in the SSC, fragmentation, techno-nationalism, and government control over the SSC are possible outcomes. Contrarily, scenarios 1 and 3 show that the international community can precisely address this issue as AI regulation can effectively reduce the tensions connected with the AIS supply chain. This is the case because the AIS are the only physical components that can be regulated in the case of AI. However, the nature of the international system and its traditionally weak influence in domains of national security make effective global regulation or governance of the SSC complicated. Despite this, some attempts have already been made in this direction. Furthermore, AI regulation through specialised semiconductors and possible mitigation of the threats arising from the dual-use capacity of chips are further understood as potentially stabilising as it could reduce tensions in the SSC and overall, in the world.

5.1.2. Politics and Disruption

Another pressing issue that can be found in all scenarios is the US-China rivalry and its influence on the SSC. Should this rivalry grow into a new cold war, as in some part reflected in scenario 4, it would put severe pressure on the SSC and other non-aligned or neutral countries in the SSC and consumers of chips, as non-alignment might be more and more difficult. Thus, weaponisation might occur in the industry and the host countries of crucial facilities. Fragmentation, techno-nationalism and instability would be the outcome.

A more diversified SSC with many countries and companies involved would have a different effect. Diversification can be found in some parts of scenario one and very firmly in scenario 3. Reducing bottlenecks, enabling new players to emerge, and the overall cooperative nature (especially in scenario 3) can successfully influence geopolitics and provide more stability.

Political decisions lead this push for diversification. Thus, as seen in scenario 3, a change in politics, mainly in China and the US, would impact how business is done in the industry. When losing the reasons for the aggressive approach, there is the possibility of halting hurtful sanctions or export controls (that sometimes backfire – scenario 4). However, politics does not always follow specific rules. Arbitrary decisions from powerful politicians or autocrats could change the face of the SSC overnight from a highly effective to a disrupted one. This could lead to powerplays and blockades with devastating impacts on the SSC. Scenario 2 paints such a future where geopolitical conflicts escalate, mainly the conflict in the Taiwan Strait that leads to an SSC in smithereens and more techno-nationalism.

Thus, the grade of diversification is critical. If the AIS supply chain is more diversified, the loss of one part of the chain might impact it shortly, but governments and companies might be more able to address crises effectively (scenarios 1, 3, and 4) in the long run. Other disruptions might come from another geopolitical conflict, war, earthquake, or natural disaster. With the dangers of climate change and connected natural disasters, war might not be needed to severely disrupt the SSC and plunge the globe into an economic depression. This puts sustainable solutions for the whole SSC and, overall, the effective address of the climate crisis necessary for providing stability and growth in the SSC.

5.2. Challenges and Opportunities for Actors in the AIS Supply Chain

These potential disruptions of the SSC from the effects of climate change, the danger of a conflict, for example, over Taiwan, or any other disruptions are critical challenges for the geopolitics of the AIS supply chain. Another challenge is the future of Moore's law. In the case of an end to Moore's Law, stakeholders must address how to cope with this situation.

A positive transformation and endurance of the law is a clear opportunity. This opportunity might come in the form of new players emerging in other areas of the world, such as Europe, India, China, South America, the Middle East, or even Russia (scenario 3). However, it could also bolster the successes of traditional stakeholders, such as the US, China, Taiwan, SK, or Japan, and their part of the SSC. This might lead to an even stronger position for private companies, such as TSMC, ASML, Nvidia, Intel, Samsung, or others (scenario 1). Additionally, there is a significant opportunity that arises from a more sustainable approach in the whole industry for greener chip production.

Some scenarios would also significantly impact the IOs in Geneva and Switzerland. In scenario 3, Switzerland and its AIS industry might profit from the strong diversification and specialisation, potentially boosting its currently small semiconductor industry.[215] In scenarios 2 and 4, Switzerland's traditional neutral stance might be more and more challenging to hold as pressure from the US and China will rise.[216] Therefore, diversification is key to ensure a neutral stand in the SSC - either as part of it or as a consumer. Utilising a diversification strategy will help to mitigate geopolitical challenges in the future. However, being able to anticipate changes in the politics of critical states is vital as one could quickly be weaponised by one dominant actor (scenarios 2 and 4). Thus, it might be necessary to make a choice in the future. Having a clear understanding of the geopolitics of the SSC will help make

[215] 'SwissChips-Initiative: Ein Schub für die Schweizer Chipindustrie'; 'Halbleiterindustrie in der Schweiz – bedeutend, aber wenig sichtbar'.
[216] Ibrahim, 'Fearing China, Switzerland Sacrifices Scientific Ties with Taiwan'.

choices at the right moment and ensure a steady flow of AIS. Pushing for regulation also helps reduce weaponisation and pressure in the SSC.

Especially for the UN and its bodies, regulation of AI and its chips is not just an opportunity but also a necessity to support its member states in responsible AI governance and reduce tensions – overall and in the SSC.

Generally, the four scenarios underline the danger of disruption of the SSC as AIS are intertwined with geopolitical challenges, resource scarcity, and the effects of climate change. Nonetheless, the potential for technological advancements is essential for the long-term stability of the SSC. Technological progress, emerging players, diversification, specialisation, regulation, and resilience will reduce tensions in the SSC and enhance its stability. By taking such steps, the global community ensures that the worst scenario, number 2, will not happen but a more positive one, with a focus on growth and transformation (scenarios 1 and 3).

5.3. Likelihood and Plausibility

All scenarios are plausible as they are supported by our pool of factors. Scenario 2, with its extensive conflicts – potentially between the US and China over Taiwan – is not very likely as a conflict or war between two nuclear powers could have devastating consequences with huge losses on both sides. The many interconnections between the two countries further restrain any potential war. However, accidents or short-sighted decisions of power-seeking politicians happen, making this scenario still possible and a dark future. Additionally, powerplays or blockades could still disrupt the SSC without ending in a major war. Contrarily, scenario 4 is very plausible, though not preferred, as stagnation in technological advancement would have far-reaching consequences. Governments try to deal with this situation by engaging in alliance-building, leading to a more fragmented SSC. Also, the aspect of not successfully addressing climate change and its outcomes seems to be at the current stage, unfortunately, very likely.

On the other hand, scenario 1, with the continued status quo from 2024, seems to be the most likely. Especially given the vast dominance of the traditional players in the SSC, such as TSMC, Nvidia, ASML, and others. However, this scenario does not consider the potentially transformative impact of new technologies. Scenario 3 underlines this, making it the pure opposite of scenario 1. However, given the high expenses and investments needed for emerging players, this scenario might happen differently despite the bright picture it paints.

Ultimately, the most likely outcome is a mix of different aspects of all the scenarios.

6. Recommendation for 2024

Based on the discussion of the four scenarios, the following policies are recommended for all actors to utilise the opportunities and address the challenges arising in the scenarios that have been presented above:

ACTORS/STAKEHOLDERS

DIMENSIONS	ALL ACTORS	INTERNATIONAL ORGANISATIONS
POLITICAL	• **Regulation:** Safe and fair chip access, as well as a reduced dual-use capacity to prevent the weaponisation of either AIS or the SSC, is needed. Actors, especially governments, should work towards global, multilateral and cooperative AI and AIS regulations, considering different actors' perspectives. A multilateral organisation, for example, the International Telecommunications Union, could safeguard these regulations. Such a regulation would aim to ensure that the risks and dual-use capacities of chips are mitigated while not hindering technological advancements. • **Peaceful Resolution of Conflicts:** In a geopolitical conflict, potentially over Taiwan, actors should refrain from using violent means of conflict engagement but rather must partake in dialogue and other means of resolution, preventing the escalation of differences into a war. Other stakeholders should be prepared for such a conflict by enhancing the resilience of the SSC.	• **Initiate Dialogue:** Given the geopolitical conflicts surrounding the SSC, there is an urgent need to initiate dialogues between states on supply chain resilience. • **Active Participation:** While working towards regulations, IOs must promote active participation of all stakeholders, including private companies, thus ensuring that regulations are transparent and govern the latest innovations, among others. • **Advocacy:** IOs must advocate for safe and fair chip use, as they are neutral parties who can communicate and negotiate with states, even when states may not be willing to cooperate amongst themselves.
ECONOMIC	• **Cooperation:** All actors in the SSC should enhance cooperation and keep it intact, as only a cooperative and interconnected SSC would secure its stability and resilience. • **Diversification:** All actors should work on diversification and enhancing resilience. By reducing bottlenecks, the danger of weaponisation is further reduced. However, actors in the SSC should not trade diversification for efficiency, as only an efficient SSC will be able to meet the growing demands of the future. Additionally, diversification is especially necessary for self-perceived neutral actors and consumers in the SSC as it helps reduce the danger of being weaponised or losing AIS supply.	• **Best Practices:** IOs can create a mechanism for monitoring best practices when it comes to producing AIS, thus ensuring that companies and states can benefit from each other and collectively move towards supply chain resilience.

Figure 13: Political and Economic Recommendations

ACTORS/STAKEHOLDERS

DIMENSIONS	ALL ACTORS	INTERNATIONAL ORGANISATIONS
CLIMATE	• **Climate Action:** Given the danger of rapid and uncontrolled climate change for the SSC, governments and private actors should push for rapid decarbonisation to ensure that the disruptive effects of climate change will not affect the SSC further. This could also ensure that actors utilise alternative resources for chip production and produce sustainably.	• **Support climate action:** IOs must support climate action by promoting alternative materials for semiconductors, as well as the use of alternative resources for producing AIS.
CAPACITY AND INVESTMENTS	• **Capacity Building:** Actors in the SSC should engage in capacity building to enhance their understanding of the complexity and the interconnectedness of the supply chain. Thus, governments and companies should educate their officials on social science and technological perspectives on the AIS supply chain. This would help actors to have a holistic approach when addressing geopolitical and technological challenges. This is particularly important for self-perceived neutral actors to anticipate arising geopolitical challenges. • **R&D Investments:** To ensure technological advancements, investments in research and development are needed. Actors should enhance their R&D capacities. This could also lead to the emergence of new players, address the talent shortage, and ensure the endurance of Moore's law etc.	• **Monitoring:** IOs can monitor the industry and look for aspects that may help them understand how the dynamics would evolve in the political as well as the economic spheres, for example, sanctions or technological advancements.

Figure 14: Climate and Capacity and Investment Recommendations

7. Conclusion

This research started with the question: "*What are future scenarios for AI-relevant semiconductor supply chain geopolitics?*" To answer this question accurately, this research included conducting a literature review to understand the AIS supply chain and the surrounding geopolitics. Following that, this research enlisted a foresight analysis to develop future scenarios based on factors gathered from the interviews and desk research conducted.

The foresight exercise offers valuable insights into four possible trajectories, each significantly different regarding technological advancements and politics. It is evident that the dynamics surrounding the SSC are complex and continuously evolving. Techno-nationalism, national security and the overall geopolitical dynamics of the SSC have an impact not only on the SSC but also on the future of technological development.

The scenarios also provide scope for several opportunities for stakeholders, but at the same time, they also come with a set of challenges. It is imperative for stakeholders to exercise caution and take measures to secure their supply of AIS and enhance their understanding of this vital supply chain. The recommendations presented mitigate the threats of some of the aspects of these scenarios and help maintain a resilient supply chain.

Given the broad scope of this research, there are opportunities for future studies in specialised areas. These include, among others, exploring alternative resources for chip production, analysing the specific details of stakeholders' supply chains, such as those of TSMC or ASML, investigating sustainable methods of chip production, and examining the potential impact of newer technologies.

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Annexe

Disclaimers

1. The views expressed by EU officials, especially Cerutti, Isabella, and Nardo, Michela, are purely those of the speakers and may not in any circumstances be regarded as stating an official position of the European Commission.
2. The views and opinions expressed in this research are those of the authors and do not necessarily reflect the official policy or position of Swisscom, the Swisscom Digital Lab, or the Geneva Graduate Institute. This research was conducted as part of the Applied Research Project (ARP), which is a component of the authors' Master's program at the Geneva Graduate Institute.

Detailed Distribution of the Factors in the Scenarios

Excel Sheet Online Available:
https://www.dropbox.com/scl/fi/knger7s5t5nqqbsyojomi/Annexe_Distribution_Factors.xlsx?rlkey=7oe4yk2ywhzkexmmro1h2puwl&st=m7l46ug8&dl=0

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