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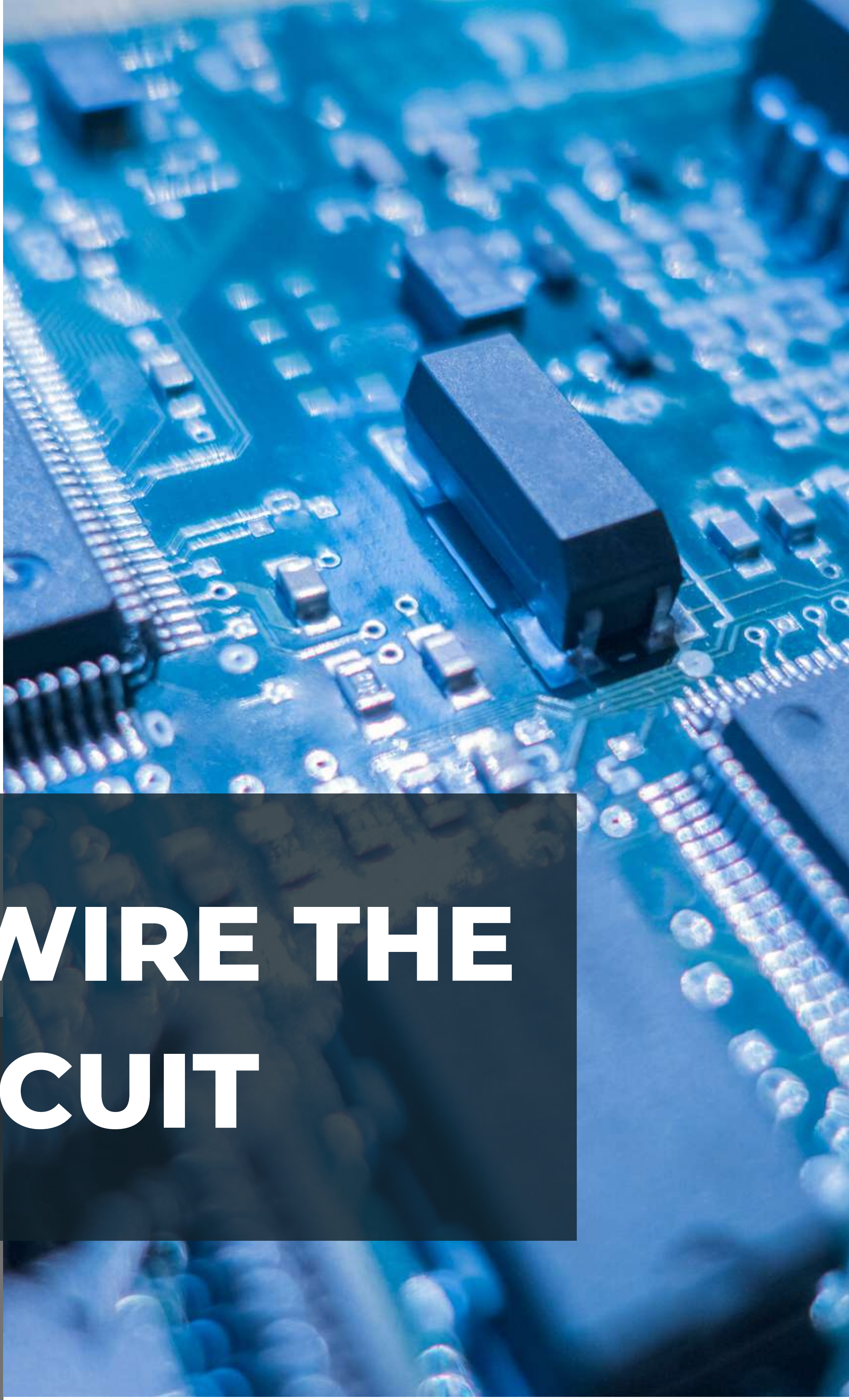

REWIRE THE CIRCUIT

An Actor and Strategy Analysis on Implementation Strategies of the European Chip Act

Engineering and Policy Analysis
EPA1144 Actor and Strategy Models

Group 15

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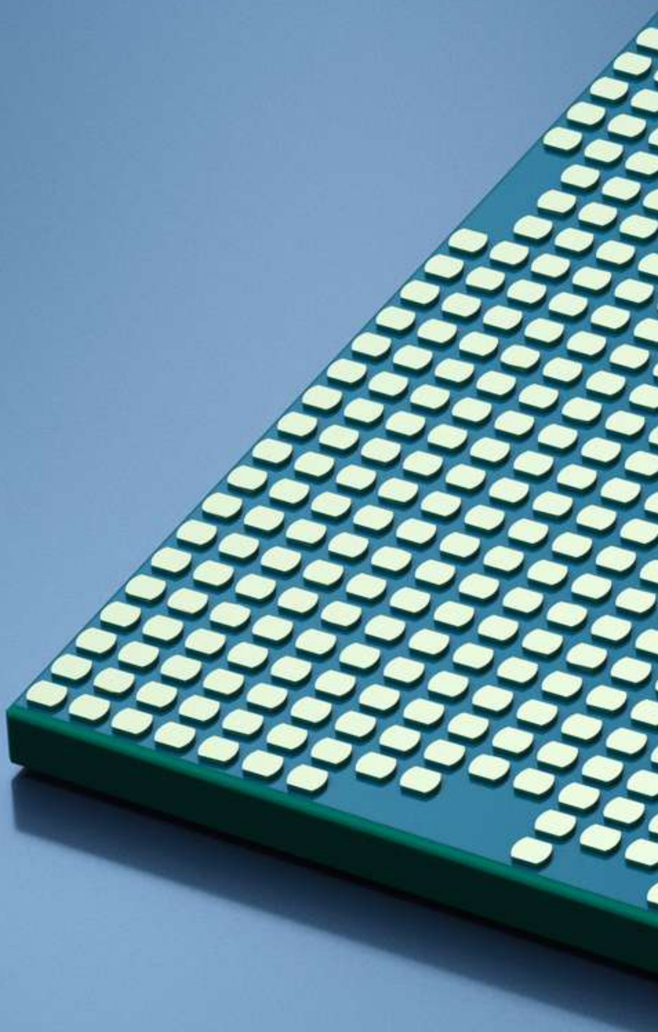

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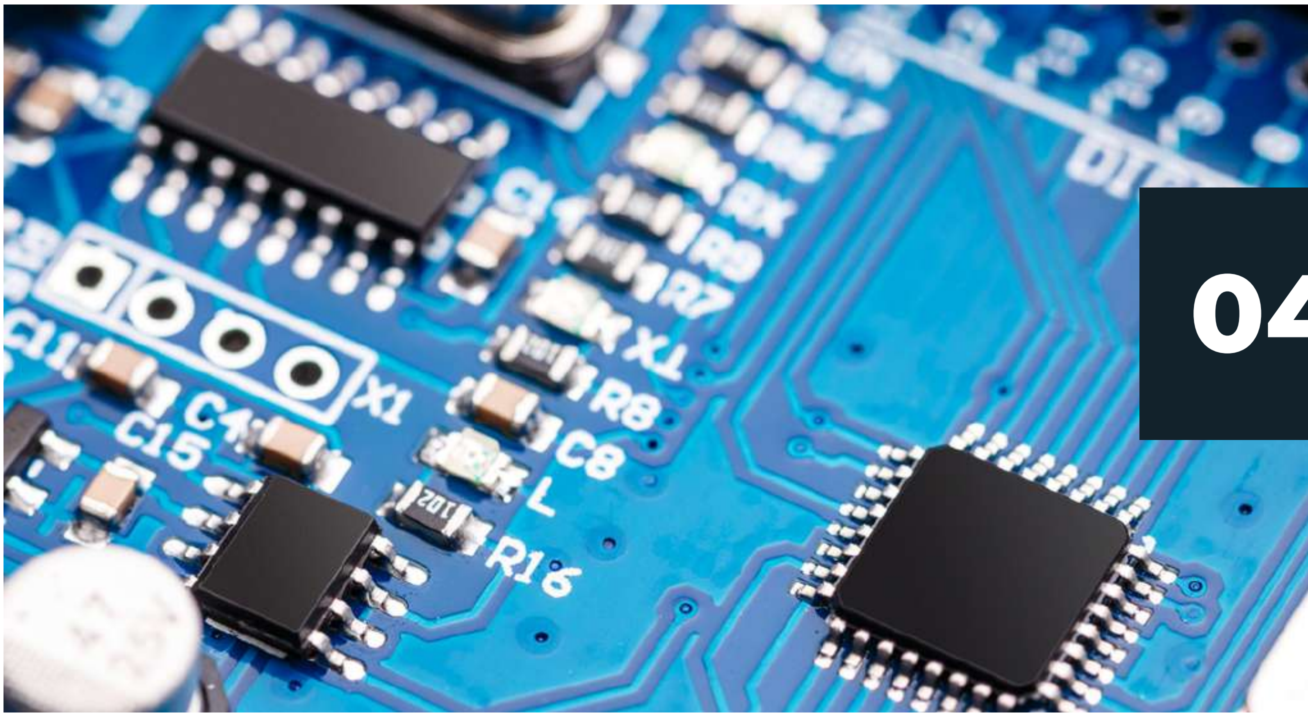


EXECUTIVE SUMMARY

The European Union (EU) has become increasingly aware of the need for self-sufficiency in the semiconductor ecosystem due to rising demand, geopolitical tensions, and a shift towards protectionist policies. In light of these concerns, the EU Commission introduced the European Chips Act in 2022.

This report aims to gain insight into implementation strategies of the European Chips Act to advice the Directorate-General Communications Networks, Content and Technology (DG CNECT) on its objective of enhancing the resilience and competitiveness of the EU's semiconductor industry. Thereby, a combined methodology of Social Network Analysis (SNA) and Game is utilized.

The SNA provides a contextual understanding of the EU's current strategic positions and vulnerabilities. It reveals that the EU lacks capacity in the areas of Fabless Design, Pureplay Foundries and Outsourced Semiconductor Assembly and Test (OSAT), which hinders the overall competitiveness and resilience in the global supply chain. Also, it identifies the opportunity to leverage ASML's current influence and shift towards a closer collaboration with the United States (US). The game theory section further builds upon the collaboration and explores possibilities and challenges for the EU and US. It shows that today the EU and the US face a prisoner's dilemma due to subsidies for the semiconductor market. However, an additional model of a iterated prisoner's dilemma introduces a potential solution to the dilemma.

THE CONTEXT

The semiconductor industry is vital in today's economy, and its growth is expected to continue steadily. The global value of the semiconductor industry is projected to reach 772.03 billion USD by the end of the decade, with an annual growth rate of 6 to 8% (Burkacky, 2022). Currently, the EU only contributes 9% to worldwide semiconductor production. This **lack of competitiveness** poses a significant risk to the EU's leading role in the automotive, computer, data storage, and wireless industries, which depend heavily on semiconductors.

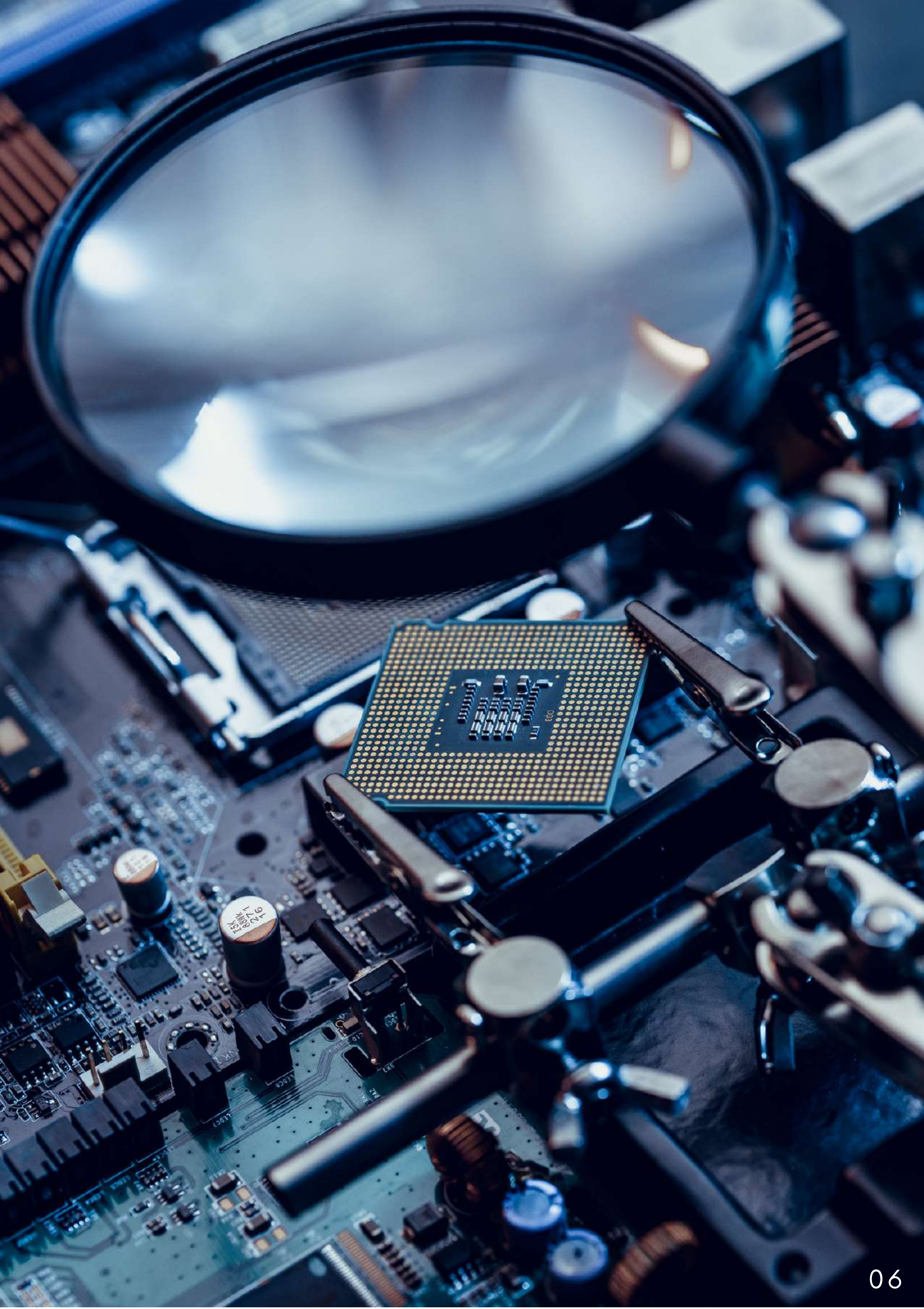
The EU's semiconductor industry is facing a major challenge with limited production capabilities and capacity. This vulnerability has serious consequences, especially in light of rising geopolitical tensions and protectionist policies. Disruptions to the supply chain caused by export restrictions or other geopolitical issues can lead to delays, cost increases, and even production shutdowns, undermining the EU's semiconductor resilience and putting it at a disadvantage compared to other regions.

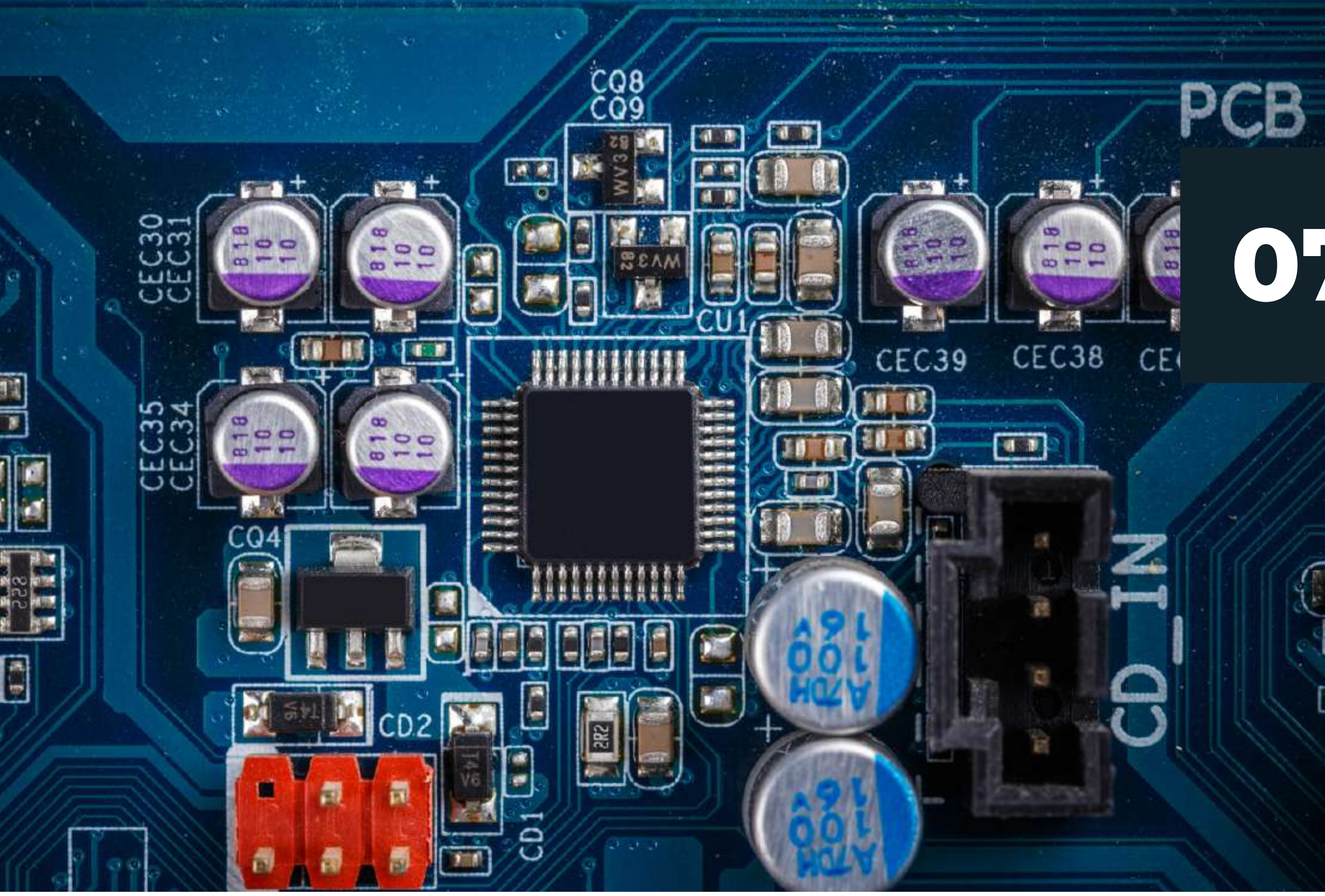
THE RECOMMENDATION

This report recommends that the DG CNECT **uses ASML as a strategic partner** at a geopolitical level to attract cooperation and investment from foreign manufacturing and testing companies to **increase** the **reshoring** of Fabless Design, Pureplay Foundries and OSAT companies. At the same time it should utilize NXP's diverse involvement in the supply chain to **strengthen EU's domestic IDM sector**.

Moreover, the authors recommend assessing the possibility of a **transatlantic cooperation agreement** in the semiconductor industry with the US. This agreement should be based on the work of the EU-US Trade and Technology Council (TTC) and promote the exchange of best practices and intellectual property to enable multilateral public and private projects. Moreover, it is suggested to establish a **joint task force** that works on **early warning mechanisms** for supply chain disruptions.

By following these recommendations, DG CNECT can adjust the course of the European Chips Act implementation and, thus, ensure reaching its initial goals.





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PROBLEM DIAGNOSIS

The semiconductor industry is currently valued in billions of USD, and is highly competitive. It is expected to experience significant growth in the coming years, with demand projected to double from $550 billion in 2021 to $1033 billion in 2031 (Tanumoy & Vineet, 2022). However, the EU's market share in the global semiconductor industry is only 6%, compared to regions such as the US, which holds a market share of 54% (Verma, 2022). Thus, the EU lacks production capacities compared to other international players.

In addition, the EU is witnessing disruptions in the supply of chips, causing shortages across multiple economic sectors. Many European sectors, including automotive, energy, communication, and health, and strategic sectors, such as defense, security, and space, are threatened by such supply disruptions *(Leslie, 2022; European Commission, 2022)*. This supply shortage exposes the EU's dependency on supply from a limited number of companies and regions *(Poitiers & Weil, 2021)*. Therefore, the EU is vulnerable to export restrictions and other disruptions in geopolitical situations *(European Commission, 2022)*, compromising its resilience.

This circumstance urged the European Commission to set a vision for a state-of-the-art European ecosystem. Hence, the EU Commission introduced the European Chips Act in 2022. The DG CNECT of the European Commission is the problem owner, as they have the mission to develop and implement policies to make Europe fit for the digital age.

Problem Diagnosis

ACTOR NETWORK SCAN

The quadruple helix framework for innovation was adapted as a baseline to account for diverse actors in all the problem areas (*Arnkil et al., 2010*). This method recognizes four major actors: science, policy, industry, and society.

Industrial actors were identified by the different steps in the supply chain (See Figure 1). Publically-released documents from already-known industry actors were used to identify the others actors. Since DG CNECT aims to focus on manufacturing capacities, this report scoped the supply value chain down to the production level (See Appendix A). Thus, the commercialization process and inputs such as raw materials or research institutions were excluded.

Public/policy actors were identified through legislative documents, like briefs of the European Chips Act and other public reports (See Appendix B). **Scientific** and **Societal** actors were less prominent in our case context but included in the actor scan (See Appendix C)

Supply Chain Domains

Fabless Design
focuses on semiconductor design and development. Rely on foundries for manufacturing.

Pureplay Foundries
specialize in manufacturing for Fabless Design.

OSATs
provide semiconductor assembly and testing services to other companies.

Machine-Equipment
provide necessary tools for foundries and OSAT.

IDM
(integrated-design- manufacturing)
design, manufacture and test semiconductors themselves and hence control the entire production process.

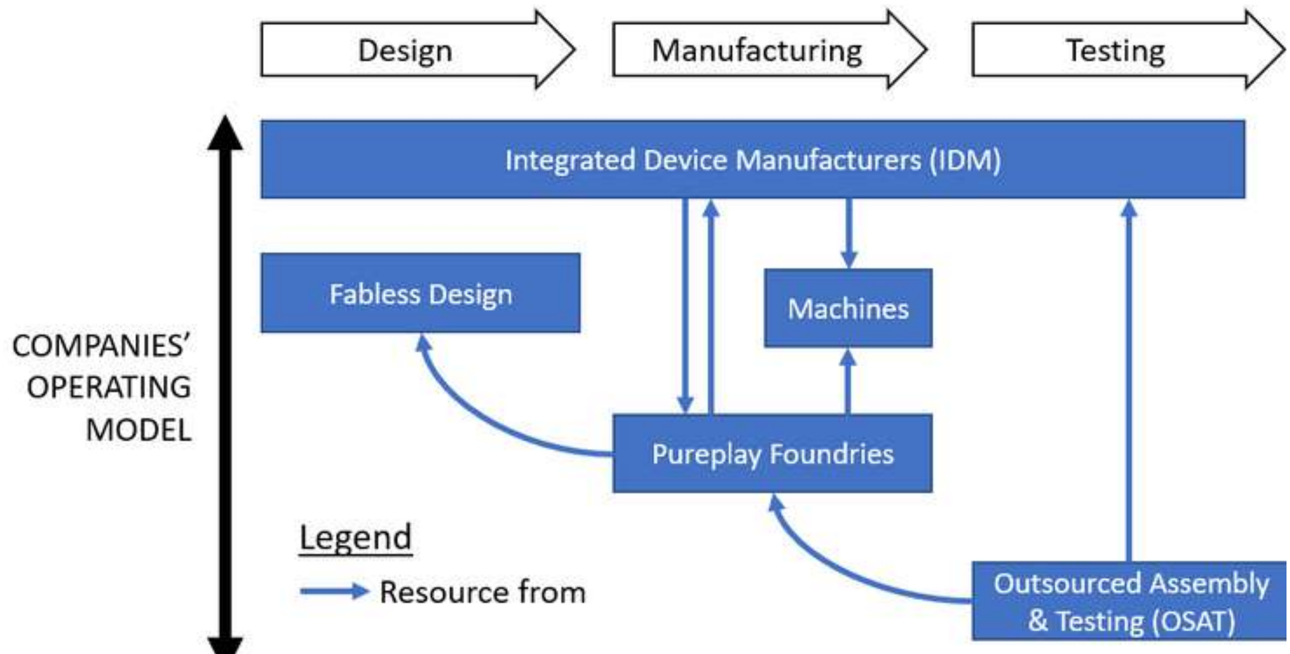


Figure 1: Conceptualized Framework of Semiconductor Supply Chain (excluding domains of raw materials and commercialization)

Problem Diagnosis

ACTOR NETWORK SCAN

When revising the list of actors, an important criterion was to have mutually exclusive actors, meaning that one actor does not have a direct stake in the positions of another actor. By doing so, we ensured an unbiased list of actors with possible objectives, perceptions, and resources (See Appendix C). Afterwards, a power interest grid was used to identify actors according to their interests and power (See Table 1).

Player

Table 1 shows that public actors from the EU and US are strategic players, having high power and interest in regard to EU's semiconductor industry. ASML, TSMC and Qualcomm are included as they are considered global leaders in their respective domains and see the EU as a potential market.

Subject

The same holds for the other less critical semiconductor companies; hence they show high interest in the growth of the industry but have lower power.

Context Setter

Due to an interconnected global supply chain, all other public actors are considered to be context setters since they have a great influence on the supply chain but show low interest in boosting the EU's semiconductor economy.

Crowd

Some semiconductor companies were perceived as having low power and interest. For instance, Canon and Nikon have comparatively minor influence in the supply chain, where their role of providing machinery just supplements players like ASML.

Table 1: Power-Interest Grid of Actors. List of actors in each square is in no particular order.

Power	Context Setter	Player
	• Chinese Ministry of Commerce (MOFCOM) • Taiwanese Ministry of Economic Affairs (MOEA) • Singapore Ministry of Trade and Industry (MTI) • Japan, Ministry of Economy, Trade and Industry (METI) • Korean Ministry of Trade, Industry and Energy (MOTIE)	• DG CNECT • DG Economic and Financial Affairs • DG Trade (TRADE) • U.S. Department of Commerce (DOC) • ASML • TSMC • Qualcomm
	Crowd	**Subject**
	• Canon • Nikon	• Infineon • NXP • stMircoelectronics • Micron • Texas Instruments • Intel • Samsung Electronics (APAC) • DG Research and Innovation (RTD) • DG Internal market industry, entrepreneurship and SMEs
	Interest	

Problem Diagnosis

MOTIVATION

The actor-network scan indicates that many actors are involved, which adds to the complexity of the problem. This report provides an actor and strategy analysis to analyze this problem further to advise the European Union on increasing competitiveness and resilience in the semiconductor market. Moreover, it provides recommendations on further advancements and initiatives to achieve the European Chips Act's goals truly. This results in the following main research question:

> *How can the DG CNECT ensure the competitiveness and resilience of EU's semiconductor industry in the global supply chain?*

This question grasps the goal of the EU, as well as its key indicators. Two different methods are used to answer the main question.

SNA is used to understand EU's strategic position within the semiconductor industry. To do so, the supply chain is modelled through resource dependencies. Once there is a thorough understanding of EU's strategic position, a Game Theory model is used to assess strategies and outcomes based on the expected responses from key actors.

In the following, the SNA and Game Theory models will be discussed consecutively. In the final chapter, the findings of both models are brought together and placed into context leading to a series of recommendations.

CLIENT - DG CNECT

The Directorate-General for Communications Networks, Content and Technology is responsible for developing policy on Digital Economy and Society, and Research and Innovation. Within the European Union, Directorates General are departments with specific zones of responsibility, the equivalent of ministries at a national level. DG CNECT represents the burden of managing funding, legislation, and policy initiatives to ensure leadership and independence of the EU in Digital Technologies (European Commission, n.d.).

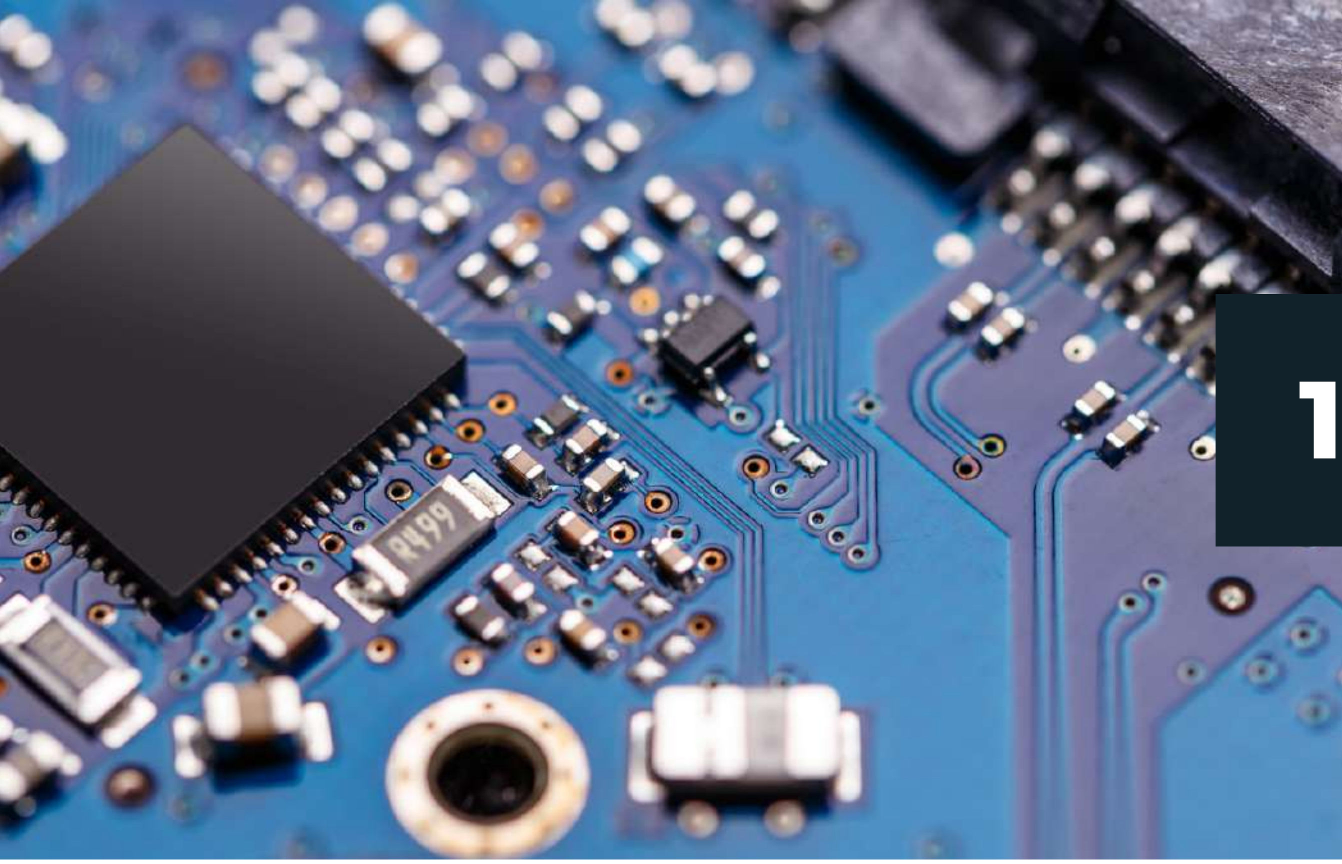
EUROPEAN CHIPS ACT

Enhance Europe's research and technology expertise in the realm of miniaturized and high-speed chip technology to solidify its leadership position in the field.

Implement measures to strengthen the ability to innovate in the areas of design, manufacturing, and packaging of advanced chips to increase the capacity for producing them.

Establish a plan to enhance production capabilities with the goal of attaining a 20% market share on a global scale by the year 2030.

Acquire comprehensive knowledge of the global semiconductor supply chains through research and analysis.



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SOCIAL NETWORK ANALYSIS

The recent surge in demand for semiconductors has resulted in greater industry specialization to capitalize on economies of scale *(Rhines, 2019; Burkacky et al., 2021)*. Therefore, the global semiconductor industry has experienced an ‘outsourcing’ phenomenon - a shift from IDM to Fabless Design and Pureplay Foundry Models, where companies hire third parties for manufacturing and testing processes *(Mohan, 2011)*. This results in greater complexity and interconnectedness within the global semiconductor industry, and hence, ought to be better understood as a network structure as opposed to a linear supply line.

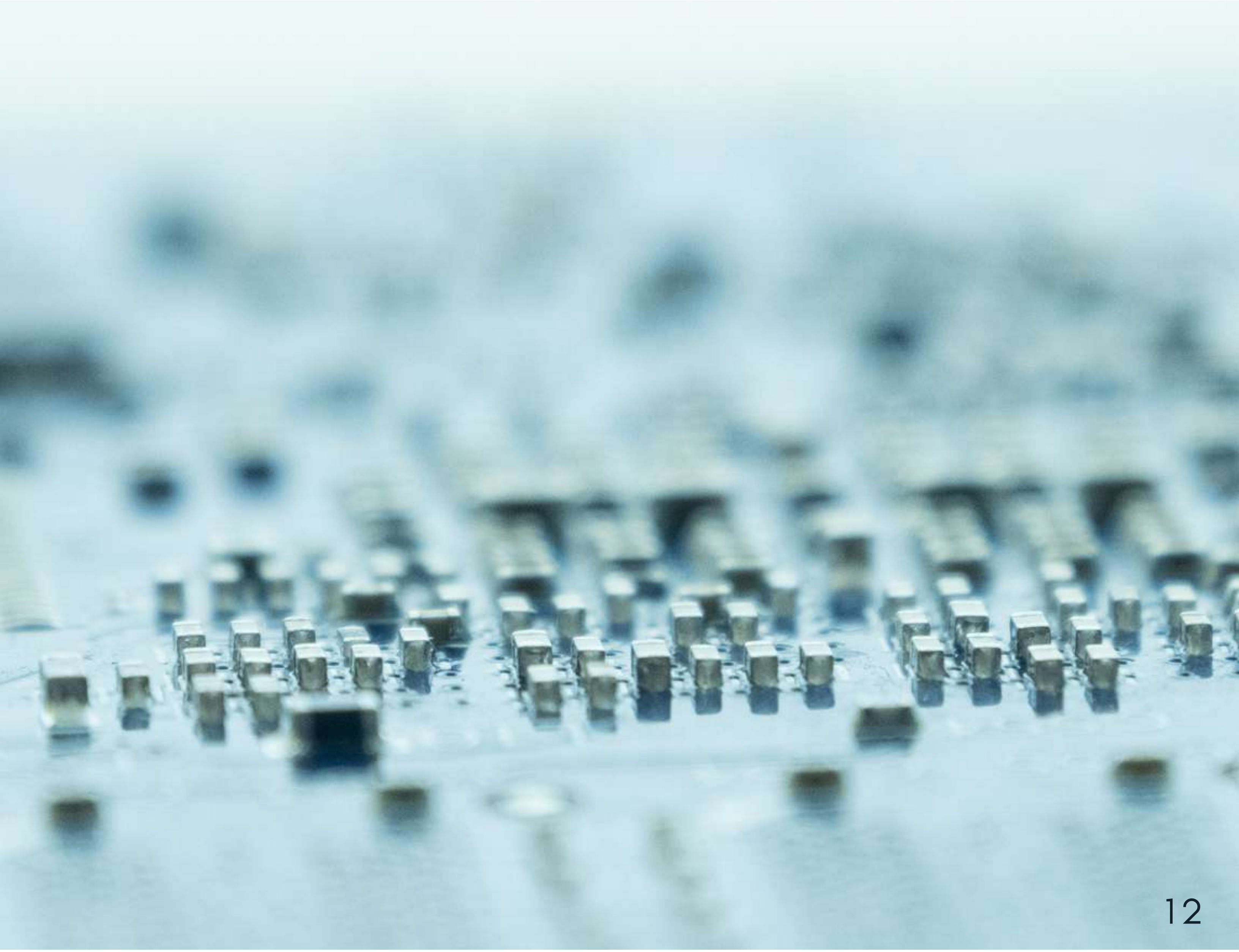
Pursuing one of the goals of the European Chips Act (*European Commission, 2022*), the motivation of this model is to understand the EU's position in the global market. By utilizing a SNA the connections (through resource dependence) within the semiconductor supply chain as well as to public actors will be analysed. SNA is particularly effective, as it can account for all relationships within the network to describe the influence of each actor (*Hermans et al., 2018*). To determine the EU's strategic position, the analysis will focus on two key factors - competitiveness and resilience.

To assess the EU's competitiveness, the distribution and control of resources and assets among players are investigated. Furthermore, by examining the general structure of the global supply chain, competitive companies, vital to the European semiconductor industry, are examined. Moreover, characteristics inherent to each actor, such as region of origin, sector, and expertise, are reviewed to gain a more contextual understanding of the EU's resilience within the global semiconductor supply chain. This will provide a clear insight into the EU's role and position in the global semiconductor economy.

In the context of ensuring the EU's competitiveness and resilience in the global semiconductor supply chain, it is crucial to identify competitive actors and areas where the EU currently lacks resilience. Thus, the analysis aims to answer:

> *What are competitive actors within the global semiconductor supply chain that the DG CNECT should be aware of?*

> *In what key areas of the global semiconductor supply chain does the EU lack resilience?*



MODEL CONSTRUCTION

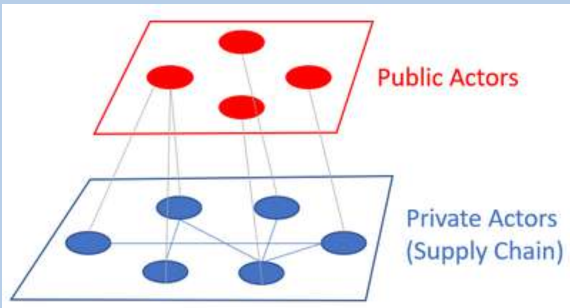
The previous actor network scan was extended via extensive desk research and content analysis to model the semiconductor supply chain. The research is based on the conceptualized framework for resource dependence within the semiconductor supply chain (See Figure 1 – where arrows highlight the main interaction points in different domains); hence, the research team systematically searched through primary sources, such as company documents, company websites, governmental websites, and news articles, for the critical collaborative ties between key players in the global supply chain. For instance, the team would reference Fabless Design companies in their actor scan and search for the respective Pureplay Foundries to which they outsource their manufacturing. The results translate into a Node and Edge List, which are necessary inputs for constructing the network.

Node List - records the actors used in the network model and their corresponding key attributes. The key attributes are the operating model (or role) and geographic location (or ownership)(See Appendix D).

Edge List - records the connections between two actors (also called 'edge list') based on literature as described. The list was structured in Microsoft Excel (See Appendix E). Directed edges account for power asymmetries of the supply chain where resource dependencies are often one-sided *(Hermans et al., 2018)*. Moreover, the analysis focuses on structural embeddedness (less on the quality of ties) - hence, unweighted edges are used for simplicity.

For the network implementation, Gephi *(Bastian et al., 2009)*, a software that performs SNA, was used for the visualization of the network and to compute quantitative measures in the form of network-level metrics, i.e., density, average clustering coefficient, average degree, and node-level metrics, i.e., eigenvector and betweenness centrality (See definition in Appendix F). A general color scheme was applied to visualize the resulting network properly, and the nodes were displayed in an intuitive layout that positioned 'central' nodes in the center of the network (the 'ForceAtlas 2' layout).

NETWORK DEFINITION



Network models resource dependence within and between private and public actors.

Private actor layer represents the semiconductor supply chain to gain insight into the importance of actors and to analyze the competitiveness of companies. The layer comprises private actors from the network scan up to their respective direct collaborators. This is organized according to the supply chain framework, see Figure 1.

Public actor layer adds geopolitical aspects of the global semiconductor industry to analyze the resilience of different geographical regions. It represents public actors that have more than two links to private actors. Conceptually it is an extension of the supply chain layer as it accounts for links of governmental power in the location of a company or its factories.

MODEL ANALYSIS

General Network Structure

The overall network structure is visualized below in Figure 2. The analysis identified 30 private actors and 77 ties in the supply chain layer. With the addition of the public layer, the network becomes denser with 7 public actors and 53 ties.

Moreover, the average clustering coefficient of the network doubled (from 0.064 to 0.138) after adding the private actors to the supply chain.

The clustering coefficient represents the tendency for actors to cluster; hence it shows the role of public actors as brokers to connect companies in a supply chain that might otherwise not collaborate.

Furthermore, it has been found that the average degree of the supply chain is 2.3, which translates into an average company collaboration of two corporations. This number is considerably high, especially when a quarter of the companies are IDM, which mostly have self-contained processes. It hints that in the current state of the semiconductor market, companies could be outsourcing much of their processes to each other to keep up with the booming demands of semiconductors.

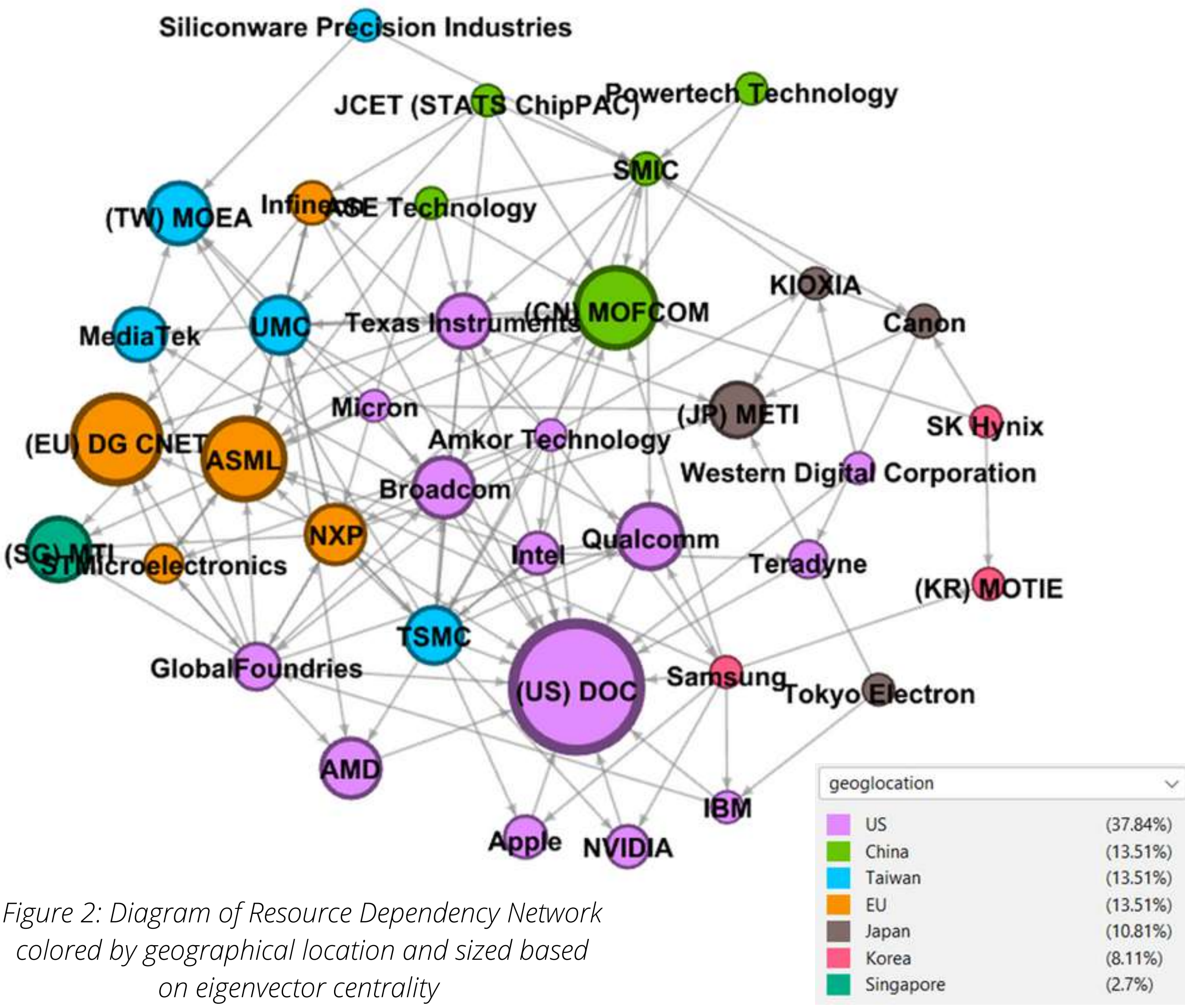


Figure 2: Diagram of Resource Dependency Network colored by geographical location and sized based on eigenvector centrality

Social Network Analysis

MODEL ANALYSIS

Supply Chain Structure

At first glance, Figure 3 depicts the supply chain network as having a core-periphery structure.

The "core" is dominated by close and dense interactions between pureplay foundries (orange) and IDM (pink) companies, e.g., GlobalFoundries, TSMC, Texas Instruments, and SMIC.

The 'periphery' comprises the fabless design and assembly/testing/packaging (A/T/P) companies that are more involved in the start and end processes of the supply chain.

This reflects the reality of the supply chain network, where manufacturing is the middle step of the supply chain. It will always be important because of its central involvement in the supply chain. It also means a greater probability for manufacturing to bottleneck, which explains the presence of the “core” where key manufacturers need to collaborate closely to meet the world's increasing demand for semiconductors. Manufacturing-related companies (IDM, Foundries, Machines) make up half of all companies in the supply chain. For clarity, a visualization of the standalone supply chain layer is documented in Appendix G.

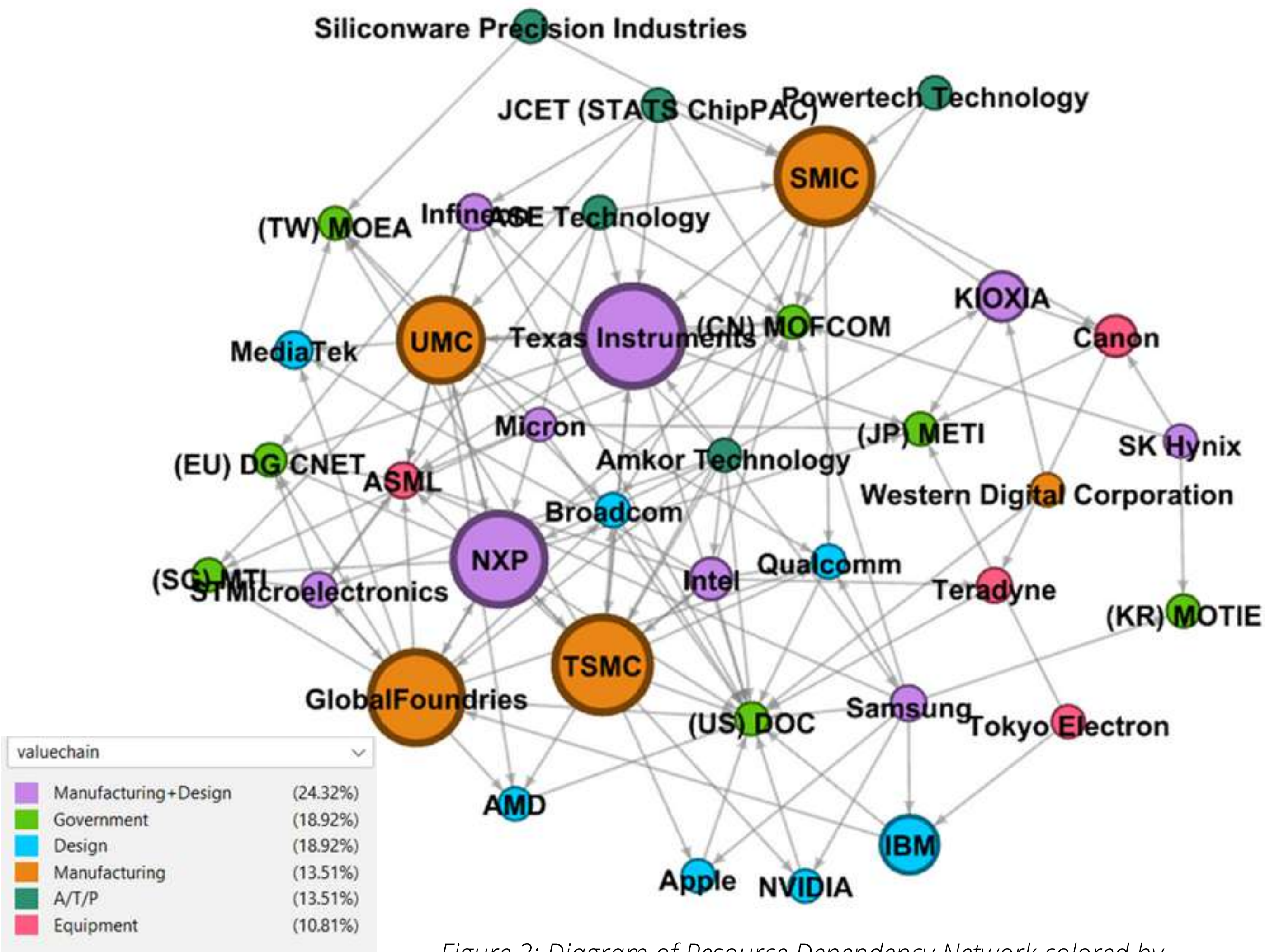


Figure 3: Diagram of Resource Dependency Network colored by role in the supply chain and sized based on betweenness centrality

MODEL ANALYSIS

Analysis of Competitiveness

Private Actors
The competitiveness analysis shows that ASML, followed by Qualcomm and Broadcom, are the most competitive players (See Table 2). These companies are the most competitive because they are heavily relied on by the supply chain, where they provide key resources that companies depend on.

- ASML supplies manufacturing equipment that all advanced semiconductor chip producers require.
- Qualcomm and Broadcom is a leading semiconductor designer for mobile systems - 4G LTE and 5G technologies.
- Broadcom is a leading designer of communicational semiconductors in broadband, server storage, wireless, and industry.

COMPETITIVENESS

Competitiveness of a company refers to its ability to deliver value through key resources. Within the SNA, this can be understood by the extent to which other companies (as customers) depend on an actor in the supply chain. Eigenvector centrality is used to assess competitiveness (*Takes & Heemskerk, 2016*) – it considers which companies depend on it and the importance of these companies. A company will be as competitive as other companies depend on it.

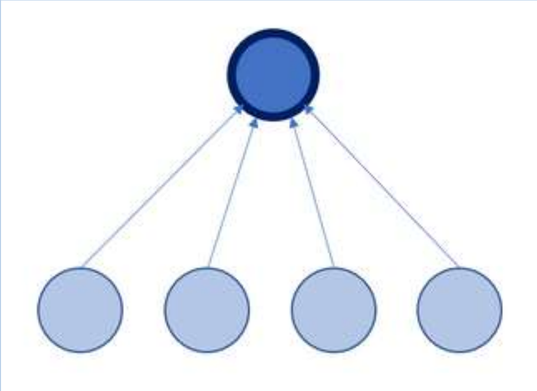


Table 2: Table ordering top 8 actors in descending order of eigenvector centrality

Actor	Region	Supply Chain	Eigenvector Centrality
ASML	EU	Machines	0.514
Qualcomm	US	Design	0.344
Broadcom	US	Design	0.297
NXP	EU	Manu + Design	0.287
AMD	US	Design	0.286
UMC	Taiwan	Manufacturing	0.267
TSMC	Taiwan	Manufacturing	0.262
Texas Instruments	US	Manu + Design	0.232

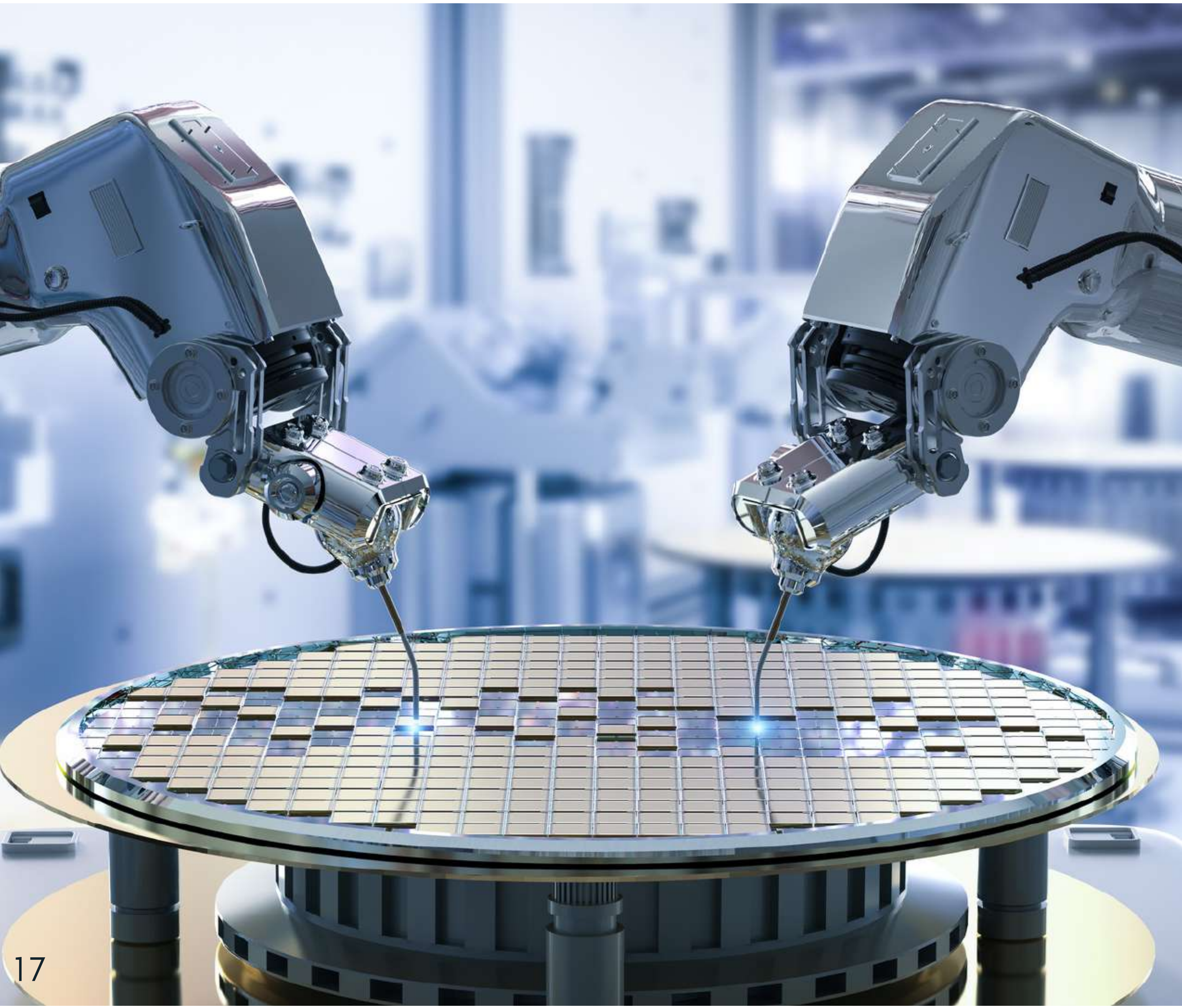
Social Network Analysis

MODEL ANALYSIS

Public Actors

Taking a geographical perspective, the most competitive companies are from the EU, the US and Taiwan.

- The most competitive EU companies are ASML and NXP, which focus on machines and manufacturing & design, respectively. ASML's eigenvector centrality is much higher than the other companies, showing the uncontested influence ASML's machines have in the supply chain.
- US companies are overall the most competitive, owning 4 out of 8 of the top companies. They generally dominate the design stages of the supply chain.
- The most competitive Taiwanese companies are Pureplay Foundries models - UMC and TSMC, both powerhouses in the manufacturing stages of the supply chain.



MODEL ANALYSIS

Analysis of Resilience

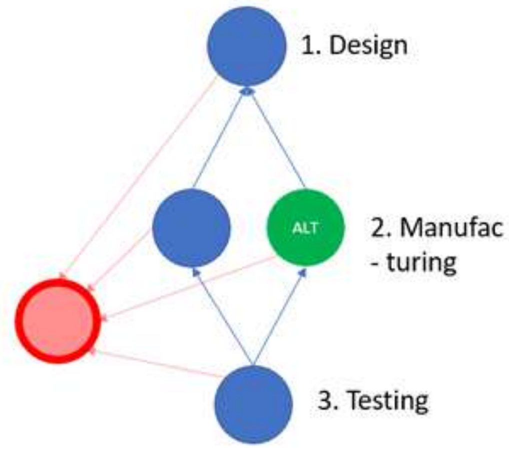
Supply Chain

The resilience analysis shows that the EU, with 6, the US, with 17, and China, with 12, have the most significant number of collaborative ties within the supply chain. Furthermore, regions have a niche in certain stages of the supply chain. The heatmap in Table 3 shows the unequal distribution of collaborative ties, e.g., the EU, China, and Korea are involved with IDM (Manufacturing & Design) companies, while the US is heavily involved with Design.

- Focusing on a niche is a clear strategy to build competitiveness through economies of scale. However, it might not be ideal for building resilience as there might not be enough control over parts of the supply chain.

Table 4 summarizes the regions' degree of collaboration with other foreign regions, showing different approaches ranging from only domestic (Korea) to only foreign companies (Singapore). As depicted by the blue cells in Table 4, most regions tend to focus on their local companies, except for China and Singapore, where most of the companies operating in these regions are foreign.

RESILIENCE



Region should have more "alternatives" for different parts of the supply chain

The resilience of a region refers to its ability to maintain the supply chain process under challenging scenarios, I.e., companies being compromised. In the SNA, an ego-centric network analysis zooming into the structural connections from the perspective of a public actor illustrates this aspect. This analysis identifies the range of companies a public actor has access to (as first-order neighbors) and qualitatively assesses if an actor has enough suppliers to ensure the robust continuity of the supply chain.

Table 3: Heatmap distribution of first-order neighbours (companies) by role in supply chain public actor.

	Design	Manuf	Manuf & Design	Machine	A/T/P	Total
EU	0	1	4	1	0	6
US	6	3	6	1	1	17
China	0	3	6	0	3	12
Taiwan	1	2	1	0	1	5
Korea	0	0	2	0	0	2
Singapore	0	2	3	0	0	5

Colour scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5, 15.0

MODEL ANALYSIS

Governmental Resilience

The resilience of the EU, US, and China are focused on as they are the largest end consumers of semiconductor chips (PwC, 2015); hence resilience has much greater relevance for these public actors. The visualized connections between these public actors and the supply chain can be found in Figure 8 in Appendix I.

EU (DG CNET)

The EU is involved mainly in IDM processes through NXP, Infineon, Texas Instruments, and STMicroelectronics. However, the EU's contribution to the supply chain is disproportional to the magnitude of semiconductors it demands. Table 3 shows that it works with just 6 companies, while US and China have 17 and 12, respectively. Also, although they only have 4 local companies, they have few collaborations (only 2) with foreign companies. This shows a degree of vulnerability in which the EU will be at the mercy of other public actors if they exert pressure on the supply chain.

US (DOC)

Comparatively, the US fairs well in resilience as they are the most spread out across all parts of the supply chain, where they collaborate with at least one company at each stage of the supply chain. This could result from the sheer number of relevant local companies. There are 13 US companies; the second highest is 4 local companies in the EU, China, and Taiwan. They also work with 4 relevant foreign companies showing a certain extent of international influence.

China (MOFCOM)

China has companies at every stage of the supply chain, except for machines and design. Existing China's key local companies are primarily involved in A/T/P or OSAT, which does not take a primary role in the supply chain. However, they make up for it by working extensively with major foreign companies like TSMC, UMC, and Samsung at different parts of the supply chain by supplying talent and spaces in China for operations. The dependency on foreign companies ensures resilience in the short term but not in the long term, where foreign companies can choose to retract operations from China.

Table 4: Depicting the distribution of collaborative ties between public actors and companies based on region. Percentage shows the proportion of semiconductor companies operating in a region that is local. Coloured cells shows the local companies of each region.

	Region of Origins of Companies					
	EU	US	China	Taiwan	Korea	Singapore
EU	4 (67%)	2	-	-	-	-
US	2	13 (76%)	-	1	1	-
China	1	3	4 (33%)	2	2	-
Taiwan	-	1	-	4 (80%)	-	-
Korea	-	-	-	-	2 (100%)	-
Singapore	2	2	-	1	-	- (0%)

Social Network Analysis

CONCLUSION

Insights on Competitiveness and Resilience

The competitiveness analysis shows that the EU presently has competitive companies – ASML holds a prominent position in the machinery domain, and NXP has relevance in the IDM domain. However, one can argue that the dependency on ASML and NXP is insufficient to claim the EU's technological leadership. Hence, the EU should capitalize on its current competitive advantages to build more holistic competitiveness in the semiconductor supply chain.

"The European Chips Act will strengthen Europe's competitiveness and resilience and help achieve the digital transition"

The resilience analysis highlights that the EU is vulnerable compared to other regions of comparable sizes, i.e., the US and China. With only six company corporations, it lacks adequate involvement in the design, manufacturing, and testing domain to provide security in its semiconductor supply lines.

Especially as the EU is a heavy-end consumer of semiconductors, DG CNECT must increase the resilience of the EU semiconductor industry to secure a steady supply for Europe's semiconductor-demanding economy. Hence, the EU should focus more on investing in Fabless Design, Pureplay Foundries, and OSAT areas.

Most Competitive Actors

The most notable companies in the supply chain are **ASML, Qualcomm, Broadcom,** NXP, AMD, UMC, TSMC and Texas Instruments.

The **EU, US, Taiwan, and China** are the strongest regions

- EU's position is highly **dependent on ASML** and **NXP**
- The **US, Taiwan** and **China** dominate the Design, Manufacturing and testing domains respectively.

Supply Chain Resilience

The EU has only six cooperations - four are local and two are foreign.

To build technological leadership, the EU needs to **increase** their **growths in design, manufacturing and testing** domains within the supply chain.

Social Network Analysis

CONCLUSION

Recommendations

The findings fully support the European Chips Act's strategy to enhance the competitiveness of the EU through the attraction of foreign investment and the support of established domestic companies. DG CNECT should use ASML as a strategic partner to effectively demonstrate the attractiveness of Europe as a location for foreign companies. Furthermore, it should continue to support the domestic semiconductor industry. NXP has shown the potential for Europe's Design and Manufacturing domain through its competitive and diverse involvement in the supply chain; hence this sub-sector should be a primary focus point.

Taking the expertise and resources of ASML as leverage would demonstrate the EU's leadership of the machinery equipment domain. It is advised to highlight the advantages of having ASML in close geographical proximity. Companies dependent on ASML equipment would benefit from the closeness as it enhances flexibility and adaptability through working-level collaboration. Furthermore, it enables more networking opportunities for companies such as foundries or OSATs to promote knowledge exchange. These opportunities could convince many foreign companies to enter and invest in Europe's semiconductor industry and spread the EU's influence in the global supply chain. In addition, DG CNECT could also target specific companies, such as TSMC and UMC, that rely on ASML equipment to promote re-shoring (moving foundries to the EU).

However, using ASML as leverage to attract relevant companies only works for manufacturing and testing companies; Fabless design companies are independent of ASML. Therefore, DG CNECT should seek strategic collaboration with the US to attract Fabless Design companies. Based on the SNA competitiveness analysis, the US, with its influence on relevant design companies like Qualcomm, Broadcom, and AMD, has the most potential for a strategic partnership. Thus, it is recommended that the DG CNECT actively pursue a partnership with the United States Department of Commerce to enhance further the resilience of the European semiconductor industry in the field of semiconductor design.

KEY RECOMMENDATIONS

Holistic development to a wider range of domains is essential to build technological leadership

Competitiveness

- use ASML as a strategic partner to demonstrate the attractiveness of the EU semiconductor industry
- concentrate domestic support on NXP to increase production capacity and market share

Resilience

- increase re-shoring of pureplay foundries and OSAT companies using ASML as leverage
- deepen strategic collaboration with the US to increase corporation in the Fabless Design domain

LIMITATIONS

Uncertainties

Most uncertainties within the network derive from the inaccuracies and imperfect information from the sources referenced to construct the network:

- There is varied accessibility and transparency of data for each company. For instance, collaboration ties extracted for some companies were straightforward through their reports, and some would require referencing primary sources to find out. The erroneous presence or absence of ties will affect how measures are computed within the network model.

- Additionally, smaller but strategically important companies could be missing the model. Most companies are biased towards reporting collaborators with a higher market share. Hence, as these reports are referenced to build the model, it is acknowledged that the network boundaries could be biased towards a market-oriented perspective even though a supply-chain-oriented understanding was desired.

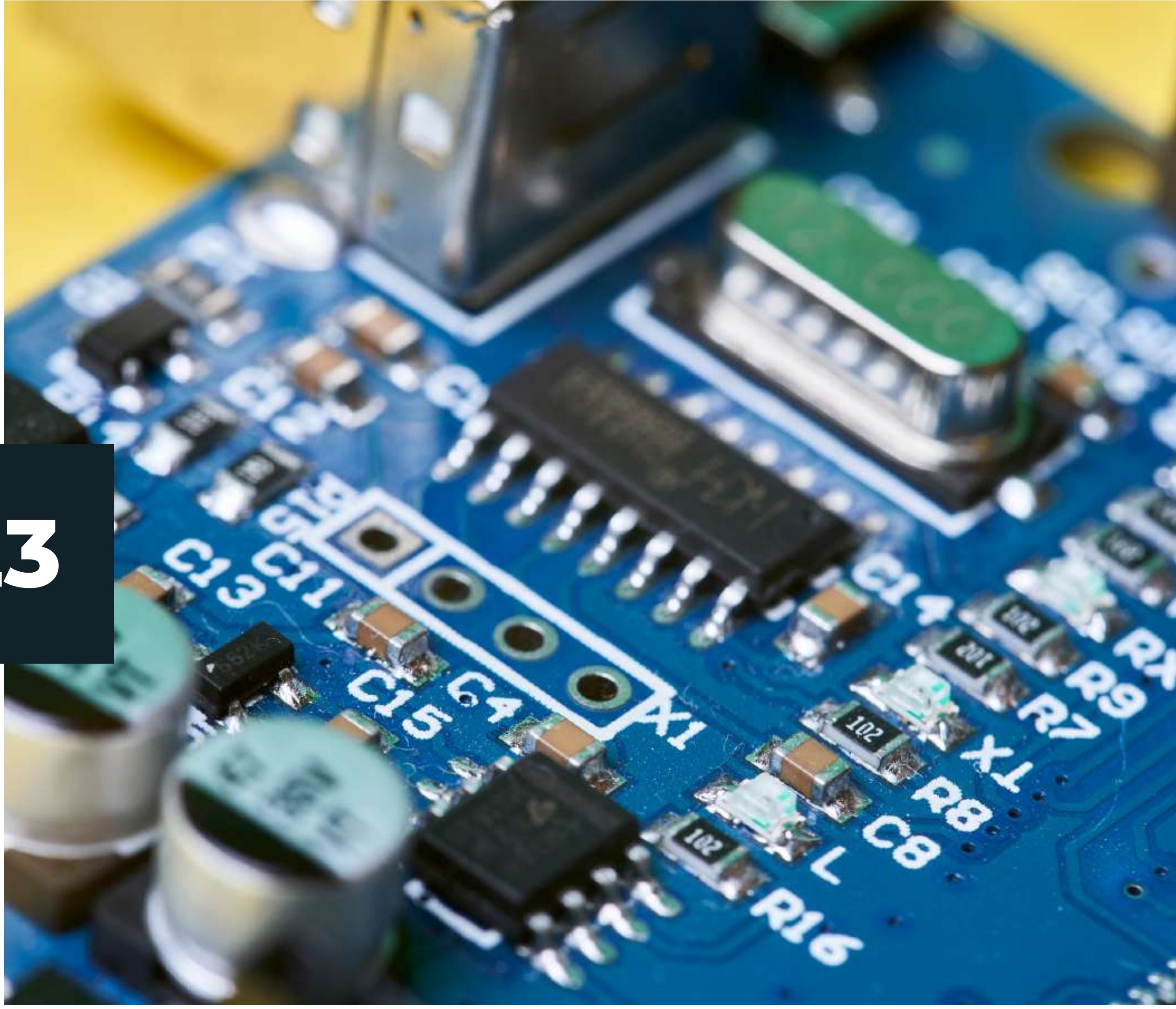
Sensitivity

Sensitivity testing was mainly conducted on centrality measures as they serve as the primary means to quantify ideas of competitiveness and resilience in the model. As such, experimentation and observations were made to identify key characteristics that could influence the computation of centrality measures:

- The choice of constructing a directed or undirected network has a significant influence on the ways centrality measures are computed. The results showed vast differences in centrality measures. These differences arise because the ties' property changes the network's foundational meaning. An undirected network would represent equal bidirectional relationships, while a directional network would represent an asymmetrical one. Hence, it affirms the choice of a directed network as it better describes the power relations of private and public actors.

- It was observed that centrality measures tend to discount companies with substantial market shares but self-contained processes, e.g., Samsung. However, this is still valid because a more considerable emphasis on the importance of actors was placed concerning the global supply chain as opposed to the end consumer market.

- Furthermore, parameters for the eigenvector centrality algorithm were tested. The iterations parameter was varied from 25, 50, 100, 200, and 400 to determine its influence on the computation of the centrality measure. There seems to be some variation in results in iteration numbers lower than 200; iteration 400 was used as a conservative parameter for all computations (See Figure 7 in Appendix H).



GAME THEORY

The SNA shows that DG CNECT should increase the competitiveness and resilience of the European semiconductor industry to secure a steady semiconductor supply in the future. Diversification strategies across the value chain would help the EU to become more resilient. A prominent recommendation is, therefore, to seek strategic partnerships with the US within the Fabless Design domain. Especially a collaboration with the US Department of Commerce, which is responsible for the internal supply chain market, would be promising and possibly highly beneficial.

At first thought, this recommendation seems simple to implement, as the EU and the US have a long history of economic cooperation and agreement on business standards and trade *(EU Delegation to the US, 2021)*. However, the current political climate is tense. Governments of both sides accuse each other of protecting their respective semiconductor industries with subsidies *(Kreps & Timmers, 2022)*. These rising tensions could make it harder to bring both parties together in a solid partnership.

The biggest semiconductor consumer markets are the US, China, and the EU *(PwC, 2015)*. A possible partnership with China is not feasible for the following reasons. Since May 2021, the European Commission has been pursuing an active policy to reduce dependency on China (*Economist Intelligence, 2021*). China also pursues a protectionist policy on the semiconductor industry towards the EU (*Chan, 2018*). Moreover, the Chinese government has refused to condemn the Russian invasion of Ukraine, making bilateral relations increasingly chilly (*Oxford Analytica, 2022*). Lastly, the results of the SNA show that a partnership with the US will be much more valuable, as the US's semiconductor industry is by far the largest, the most resilient, and the most competitive.

Hence, game theory aims to take a deep dive into EU-US relations and answers the following questions:

> *What is the potential for a transatlantic semiconductor coalition between DG CNECT and the US Department of Commerce?*

> *How can DG CNECT and the US Department of Commerce establish a long-term cooperative relationship?*

Game Theory
MODEL CONSTRUCTION

With SNA as a tool to understand resource dependencies, the game theory model focuses on assessing strategies and outcomes based on the expected actions or responses from one another. As described in the previous paragraph, geopolitical interactions can be suitably analyzed using a game theory model, as one can quickly assess potential strategies and their corresponding outcomes. Moreover, the game theory points out social dilemmas in the implementing strategy. Furthermore, it enables the analysis of long-term strategies, as games can be played for multiple rounds. This analysis could provide new insights into the learning responses of actors.

NON - COOPERATIVE GAME

Players:
Two Players (N=2)

Set of Moves:
S_i={focus on protectionism, intensify EU−US partnership} with $i \in$ {EU, US}

Both players are utility maximizers. The payoffs or utilities ui's denote ordinal utilities. Utilities are ranked from most preferred (highest utility) to least preferred (lowest utility)

MODEL CONSTRUCTION

If one player plays "focus on protectionism" and the other "intensify EU-US partnership", they earn utilities of 4 and 1, respectively. This scenario is the most preferred for the player with payoff 4 and the least preferred for the player with payoff 1. The following preferred move is that both the EU and the US play "intensify EU-US partnership". They each earn a utility of 3. Finally, if both players play "focus on protectionism", they each earn a utility of 2 (See Table 5).

The game is represented in normal form using a bimatrix as shown in Table 5. The moves of the EU are on the left-hand side, while the moves of the US are on the top of the matrix.

It can be observed that both players have a dominant strategy when maximizing their utility (see Table 5). Choosing "focus on protectionism" always yields a better payoff than "intensify EU-US partnership" regardless of the other players' strategy:

$$u_{EU}(PROT, PROT) = u_{US}(PROT, PROT)$$
$$= 2 > 1$$
$$= u_{EU}(PART, PROT) = u_{US}(PROT, PART)$$

Equation 1. Payoffs for EU and US

Following both players' dominant strategies, a Nash equilibrium is reached:

$$u_{EU}(PROT, PART) = u_{US}(PART, PROT)$$
$$= 4 > 3$$
$$= u_{EU}(PART, PART) = u_{US}(PART, PART)$$

Equation 2. Payoffs for EU and US (dominant strategy)

A Nash equilibrium exists if no player can unilaterally change its strategy to improve its outcome (*Nash, 1950*). The illustrated game is known as a prisoner's dilemma. This game entails a paradox in which two players do not produce the optimal outcome when acting in their self-interest. If both players cooperate, a higher outcome than the Nash equilibrium can be achieved.

The Nash equilibrium is not a Hicks optimum as it has a combined payoff of 4 (=2+2), which is lower than the highest possible combined payoff of 6 (=3+3). Also, the Nash equilibrium is not a Pareto optimum as both players can change their strategies without making the other player worse off by moving to the optimal outcome of (3;3). Hence, there is a social dilemma as the Nash equilibrium is not a social optimum.

Table 5: 2x2 Payoff-Matrix of the prisoner's dilemma between EU and US

		US	
		Focus on protectionism	Intensify EU-US partnership
EU	Focus on protectionism	$(2;2)$	$(4;1)$
	Intensify EU-US partnership	$(1;4)$	$(3;3)$

MODEL DISCUSSION

This prisoner's dilemma shows that a partnership between the EU and the US would be mutually beneficial but is not easy to reach.

Hence, it is fair to ask: "What hinders cooperation?" Trust is the basis of a well-functioning partnership. Decisions made in the semiconductor industry are often made for multiple years. To establish a fruitful cooperation between two parties, it is, therefore, necessary to have an adequate level of trust in each other to go for the long-term partnership above choosing protectionist policies. By playing the previous game multiple times, each round can be seen as a reassessment of the status quo. It could provide new strategic insights as all players know previous decisions and will use this information for their next move.

If a finite number of rounds is assumed, it can be shown through backward induction that both players would still play "focus on protectionism". If the last round is observed in isolation, the Nash equilibrium is for each player to play "focus on protectionism". Therefore, a player will not expect that cooperation in earlier rounds leads to cooperation in later rounds.

By not setting a fixed number of rounds, each player expects that the game will continue. The infinite game brings in a new dynamic as players discount future payouts. This follows the assumption that future payouts are of less value than receiving the same payoff today.

This can be modelled using a discount factor $\delta \in [0,1)$. For this game, it is assumed that the US goes for a tit-for-tat strategy, meaning they will first go for a partnership initially and then respond to the EU's previous move for subsequent rounds.

Based on this, it is up to the EU to find an optimal response. The EU has two strategies: be a reliable partner by always playing partnership or being more selfish by always going for protectionist policies. The resulting present value of these two strategies are as follows (following the rules of geometric series):

$$3 + 3\delta + 3\delta^2 + ... = \frac{3}{(1-\delta)}$$

Equation 3. Payoff for cooperation strategy

$$4 + 2\delta + 2\delta^2 + ... = 4 + \frac{2\delta}{(1-\delta)}$$

Equation 4. Payoff for protectionist strategy

Given these payout formulas, the discount factor that would lead to a higher payout for the always partnership strategy can be obtained by solving the inequality:

$$\frac{3}{1-\delta} > 4 + \frac{2\delta}{(1-\delta)}$$

$$\delta > \frac{1}{2}$$

Equation 5. Calculating δ for which cooperation payoff is higher than protectionist

Hence, it is possible to establish cooperation in any given round if the discount factor is higher than 1/2. This shows potential for a transatlantic coalition between the EU and the US.

Game Theory

MODEL ANALYSIS

A likely consequence of the predicted outcome of the non-iterated game (that is, both players focusing on protectionism) in Table 5 is that the EU and US end up in a subsidy race competing against one another.

According to chipmakers, direct government subsidies, loan guarantees, and tax credits are the single most important factor in deciding where to stand up a new production capacity (*Kannan & Feldgoise, 2022*). Although it is in the interests of the semiconductor industry to play up supply chain fears to drive up subsidies, a race to the bottom in protectionist subsidies is undesirable for allies. Individual policies may attract new domestic and foreign investment in the short term. Still, in the long term, the EU and the US will collectively inflate the value of subsidies and, as a result, make the chips more expensive. These costs will be passed on to taxpayers. Hence, protectionist policies may ultimately lead to counterproductive results without guaranteeing the desired increase in supply chain resilience.

To mitigate the severity of this possible subsidy race, policymakers of the EU and the US are looking for ways to enhance cooperation. The iterative game shows that a partnership is possible when there is trust between both players. A good example of an established partnership is the EU-US Trade and Technology Council (TTC) which has the goal to achieve "sustainable, inclusive economic growth and development" through, for example, more coordinated export restriction and collaborative research projects (*The White House, 2022*).

The TTC has announced a joint effort to prevent governments from competing rather than addressing the real problems by developing new mechanisms to ensure a coordinated supply of semiconductors. Hence, a close trade partnership between the US and EU can help to retain the economic benefits of specialization across the supply chain and to maintain a competitive position in the global semiconductor industry.

To conclude, a cooperation strategy in a non-iterative game is not beneficial as it leads to suboptimal outcomes, demonstrating the difficulty of establishing trust and long-term cooperation. In an iterated game, the strategy with the highest individual payout would be if both players intensify their partnership. It is possible to construct an optimum cooperation for an unknown number of rounds. In practice, this implies that DG CNECT must strive for long-term cooperation with the US Department of Commerce under the condition that there is mutual trust.

KEY INSIGHTS

- The EU and the US face a prisoner's dilemma due to subsidies for semiconductor market
- Given an iterated game, it is possible to explain a optimum in mutual cooperation

Game Theory

CONCLUSION

The game theory model provides answers to the question posed. The model shows potential for a transatlantic semiconductor coalition between DG CNECT and the US Department of Commerce. The biggest hurdle is the necessity of mutual trust, which may be hard in times of high geopolitical tensions. However, there are multiple ways in which both actors can establish a long-term cooperative relationship.

First, it is recommended to accelerate existing projects of the TTC through transparent processes and regular exchange. The TTC can be the foundation of long-term cooperation between the EU and the US in the semiconductor sector.

Moreover, it is important to establish a network between European and American private actors to promote information and best practice sharing. In this regard, it is advised to enable joint public-private research projects and to work on a common workforce development plan that facilitates the mobility of skilled workers between the regions. The expertise of the EU and US semiconductor sectors relates strongly to intellectual property (IP). Facilitating the licensing of IP can accelerate common research agendas and results, hence, maintaining the global lead.

In addition, establishing a common task force to assess the risk of global supply chain disruptions is recommendable, providing an early warning mechanism for disruptions and eventually coordinating a joint response.

"The EU needs an international approach to realistically accomplish the goals of the European Chips Act"

This task force can be established based on already existing cooperation in the working groups of the TTC. It should also promote equal market access for all US and EU stakeholders.

With these actions in mind, the cooperation should actively work against a subsidies race to limit the risk of a subsidies race. Furthermore, it will be the foundation to agree on common standards and norms that help to agree on a common combined target that the EU-US should have for the global semiconductor market by 2030. Based on a common understanding of transparency and cooperation, both actors can ensure an innovative, resilient, and competitive long-term approach for the semiconductor supply chain.

KEY RECOMMENDATIONS

- DG CNECT should work on establishing a long-term partnership with the US in the semiconductor market
- An agreement should be based on trust and mutual exchange
- Establish a joint task force to become actionable on aspects such as supply chain disruptions
- Agree on common standards and norms to facilitate market access and common understanding

LIMITATIONS

Uncertainties

Most observed uncertainties are from the decision arena, action and payoffs. The implications of the uncertainties are listed below as well as our means to manage them.

- There is uncertainty in the decision arena - in the form of information and players' actions. This is largely attributed to the core game theory assumption that all agents act rationally and have all available information. Especially in a complex geopolitical situation, it is hard to pinpoint hidden action, hidden information, and incomplete information. This was compensated with extensive desk research on the context of the EU and the US, and a simplification of the model to capture the true essence of the game.

- Another uncertainty would be the variability and biases within the payoffs. In this analysis, payoffs reflect ordinal utilities; hence, it might be a cause of concern that payoffs are not grounded in real-life quantities and representations. Even so, if this uncertainty is numerically sensitive, it can be overlooked because the model focuses on the dynamics of the decision process rather than using it to assess the status quo quantitatively. However, if this is behaviorally sensitive, it will be important to understand the implications of the choice of payoffs. Hence, this leads us to our sensitivity analysis in the next paragraph.

Sensitivities

In addition to the uncertainties, a qualitative sensitivity test was conducted to understand the structural characteristics and input data of the game that could be influential to its execution. The following two scenarios should be known:

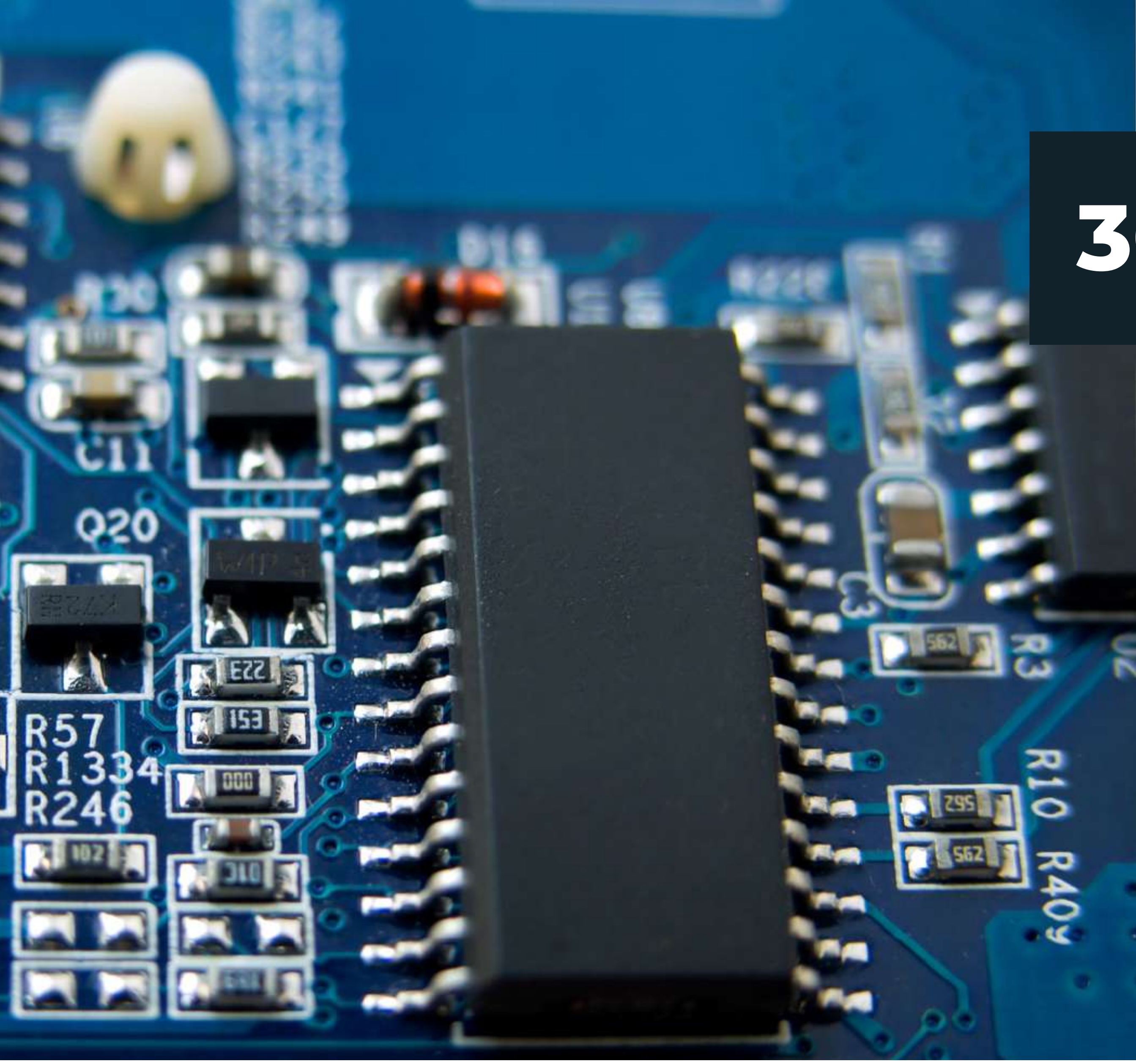
Scenario 1:

- The payoffs were varied while maintaining the prisoner's dilemma structure. It was noticed that the discount factor changes based on the relative difference between payoffs, hence, influencing the present value of a strategy. However, this does not change the actions of the respective player and the made conclusions. This scenario shows no behavioural sensitivity.

Scenario 2:

- The payoffs were varied and the variation removed the prisoner's dilemma structure. This scenario would lead to potentially different Nash equilibriums and thus, also different conclusions and recommendations. This scenario shows behavioural sensitivity.

Given the fact that the prisoner's dilemma is used to explain the dynamics between the EU and the US, the analysis focuses on scenario 1 and thus, is not affected by behavioural sensitivity. Hence, the findings are likely to be within reasonable margins of errors and uncertainties.



CONCLUSION AND RECOMMENDATION

The global semiconductor economy plays a crucial role in today's economy, and its growth is projected to continue in the coming years. However, the complex and interconnected nature of the semiconductor supply chain highlights the need for a more competitive and resilient European semiconductor industry. To address this need, the EU Commission introduced the European Chips Act in 2022. To evaluate the potential effectiveness of the strategies proposed in the act, this report utilizes a joint approach of Social Network Analysis and Game Theory to provide a strategic actor analysis of the implementation of the European Chips Act and its potential impact on the European semiconductor industry. Specifically, this report aims to answer the question:

> *How can the DG CNECT ensure the competitiveness and resilience of the EU's semiconductor industry concerning the global supply chain?*

Conclusion and Recommendation

SUMMARY

Social Network Analysis

The SNA investigated resource dependencies within the semiconductor supply chain by addressing the following questions:

- *What are important global semiconductor supply chain actors that DG CNECT should be aware of?*
- *In what key areas of the global semiconductor supply chain does the EU lack resilience?*

Results

- The EU lacks competitiveness in the fields of design, foundry, and testing of semiconductors
- ASML provides high competitiveness in the field of machinery
- NXP can become valuable for design and manufacturing
- The EU has the highest level of vulnerability compared to the US and China
- The EU lacks connections to the design, manufacturing, and testing sector

Implication

The results show that the EU is not self-sufficient and needs a more global approach with trustworthy partners.

Game Theory

Based on the results of the SNA, a game theory approach was conducted. It focused on the following points:

- *What is the potential for a transatlantic coalition between the EU and the USA in the semiconductor sector?*
- *How can DG CNECT and the US Department of Commerce establish a long-term cooperative relationship?*

Results

- Collaboration between the EU and the US could provide a higher total outcome
- Cooperation could leverage each strength but requires a high level of trust for a long-term partnership
- Cooperation can be achieved by establishing joint forums of knowledge exchange, reduction of subsidies, and agreement on common goals and standards

Implication

Hence, a cooperation agreement with the US should be one of the core targets of DG CNECT in the upcoming years.

RECOMMENDATION

The analysis showed the current dependencies of the EU and the potential for close cooperation with the US. It is recommended to use ASML as a strategic partner on a geopolitical level to attract cooperation and investment from foreign manufacturing and testing companies.

Furthermore, this can increase the re-shoring of Pureplay Foundries and OSAT companies. In addition, we have shown the potential for a strategic collaboration with the US focusing on the Fabless Design sector.

Therefore, it is further advised to assess the possibility of a transatlantic cooperation agreement in the semiconductor sector. This agreement should be based on the work of the TTC and especially their working group on resilient supply chains.

The main aspect of such an agreement should be:

- Accelerate projects of TTC through transparent processes and regular exchange
- Promote information and best practice sharing between European and American private actors
- Desire a common workforce development plan that facilitates the mobility of skilled workers in the sector
- Facilitate licensing of intellectual property to promote common research agenda and accelerated results
- Enable joint public-private research projects in chip design, packaging, and manufacturing
- Ensure equal market access for EU and US stakeholders
- Establish a common task force with the US to assess the risk of global supply chain disruption and to coordinate a respective joint response, evaluate strengths and weaknesses in the semiconductor supply chain and publish regular reports to stakeholders, and provide early warning mechanisms for disruptions
- Actively work against a subsidies race to limit the risk of a subsidies race with like-minded countries like Taiwan, South Korea, and Japan and evaluate these like-minded countries to join the task force
- Agree on a common combined target that the US-EU should have for the global semiconductor market by 2030
- Agree on common standards and norms to facilitate cooperation

Following these recommendations, DG CNECT can accomplish the goals laid out in the European Chips Act.

Conclusion and Recommendation

REFLECTION

Social Network Analysis

In our SNA model, the assumptions about the network boundaries that constrain the model's explanatory power are acknowledged. However, it is also argued how they do not influence the validity of our model in addressing the research question:

Actors such as companies focused on the commercialization role of semiconductors are omitted even as the network is framed as a resource-dependence model. Since our research focuses on structures within the supply chain, this would be apt.
Even so, comparatively less important stages within the supply chain, e.g., raw materials, were omitted. The rationale is that these companies function less as key players in the semiconductor industry and including them would add unnecessary complexity.

The model does not distinguish the different kinds of chip production. Even if two actors work at the same "stages", they might contribute to different supply chains depending on the range of semiconductor types they work on. Hence, this lack of resolution makes it difficult to provide specific policy interventions but is sufficient in analyzing and providing macro strategies.

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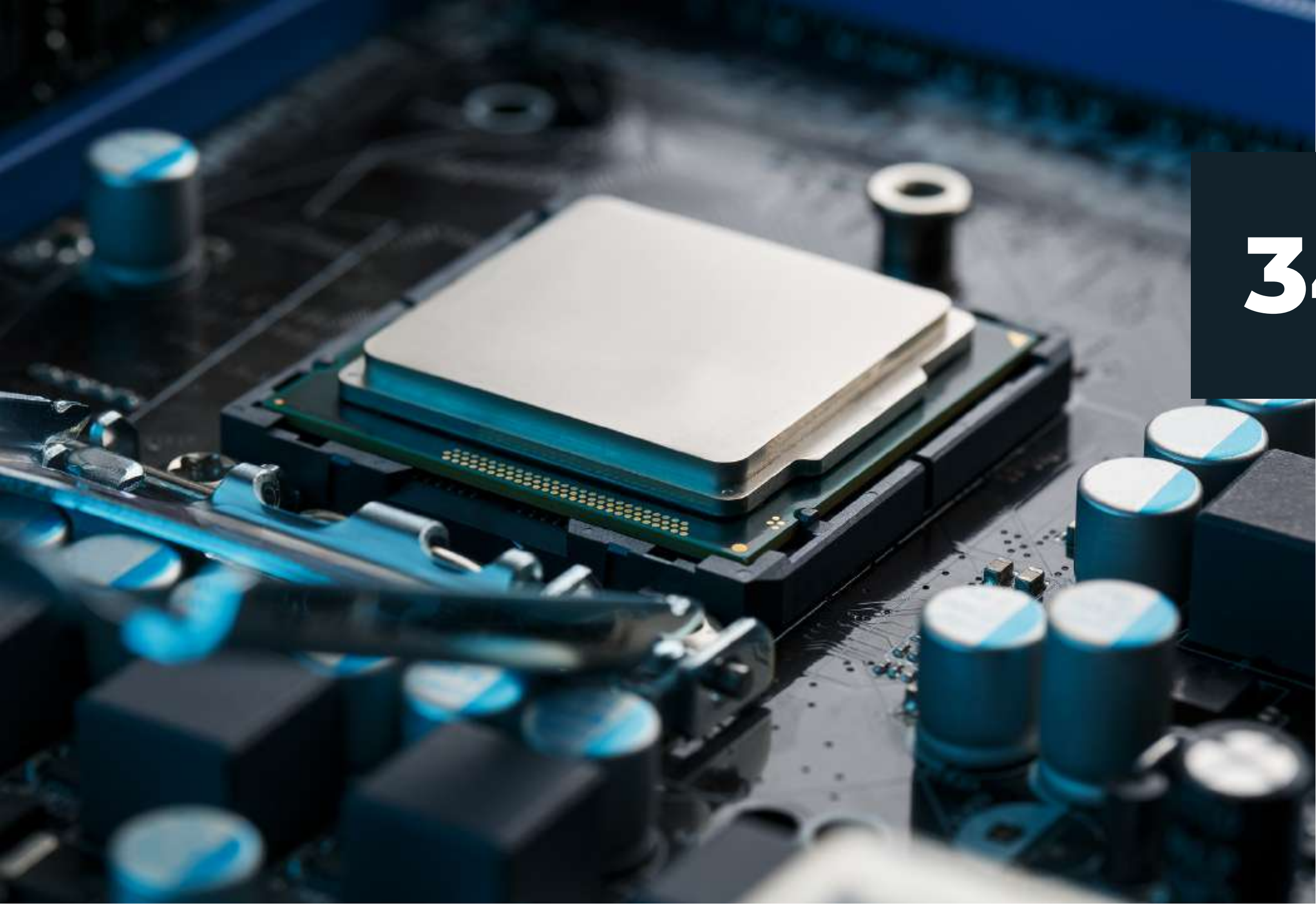
Hence, this lack of resolution makes it difficult to provide specific policy interventions but is sufficient in analyzing and providing macro strategies.

Game Theory

Game Theory is an approximate model of reality and it should be used with caution when applied to real-world problems. In the section on uncertainties and limitations, the model' s core assumptions are described

Moreover, Game Theory assumes fully rational actors, yet research has shown that this is often not the case (Hermans et al., 2018). We analyzed geopolitical actors represented by governmental institutions. These actors depend on external factors such as the economic situation for financing and upcoming elections. Those dependencies can incentivize irrational behaviour, which lowers the suitability of our game theory approach. Moreover, the used model assumes that all players know the game and the payoffs. Such complete information sets are hard to achieve.

We are aware of the purely qualitative approach of our Game Theory model and also account for simplifications in the interaction between the EU and the US. In a further analysis, one could try to find a approach to find realistic payoffs representations for the players. Furthermore, it might be interested to extend the analysis by including additional players and investigate their influence on the dynamics.



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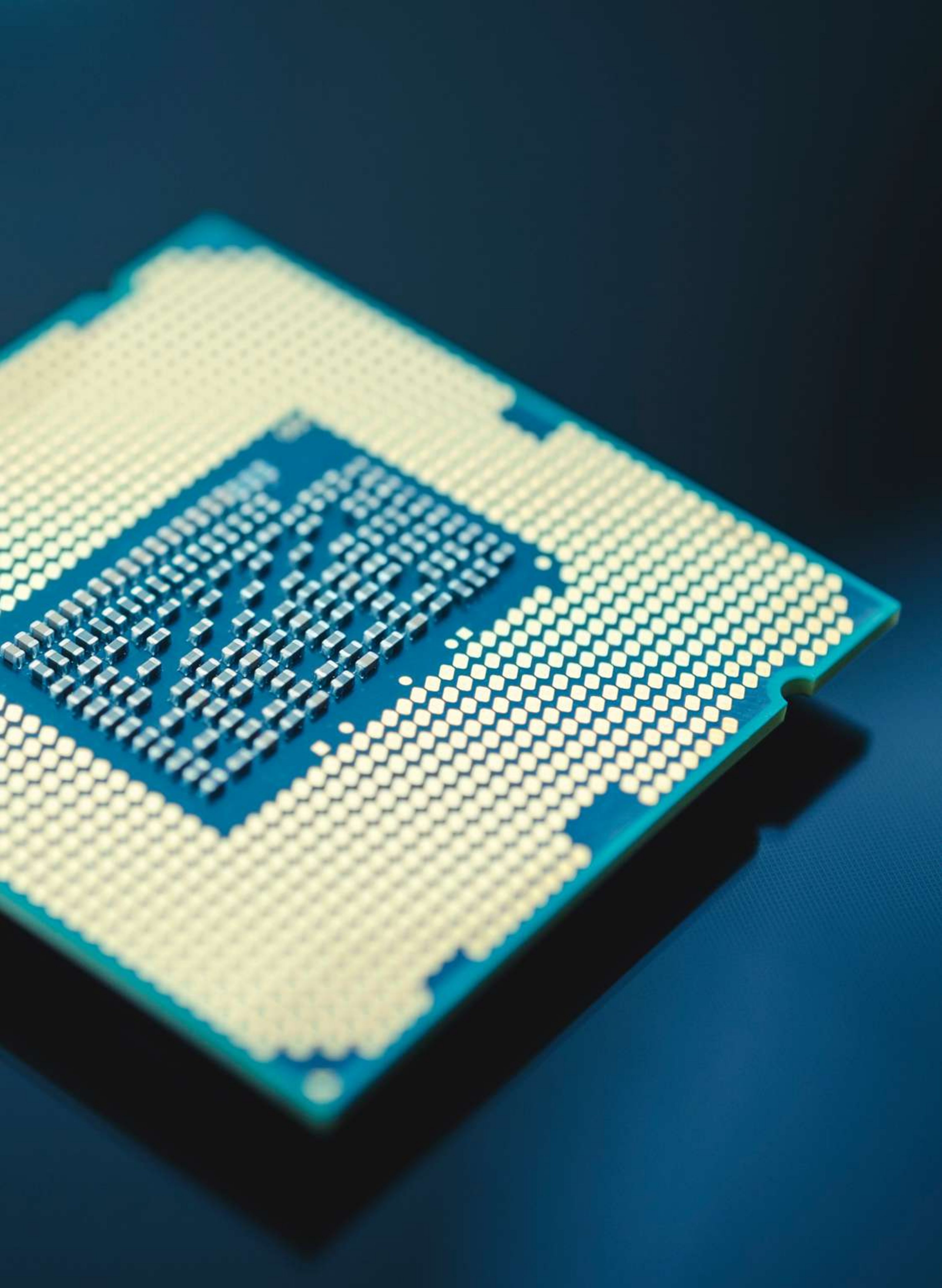

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Figure 1: Conceptualized Framework of Semiconductor Supply Chain (excluding domains of raw materials and commercialization)

Figure 2: Diagram of Resource Dependency Network colored by geographical location and sized based on eigenvector centrality

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APPENDIX A: (INTRO) SUPPLY CHAIN

In general, the semiconductor supply chain can be summarized as a series of steps. It starts with the design of semiconductors, followed by the manufacturing of these devices, and ends with the assembly, testing and shipping of the finished products - see Figure 1.

THE IDM APPROACH
IDM, or Integrated Device Manufacturer, are companies that design, manufacture and sell semiconductor devices and integrated circuits all by themselves. They own fabrication facilities, allowing them to control the entire production process and are, therefore, more independent. On the downside, they also have higher costs and risks than fabless companies, to run their fabs. In the past, IDM companies have had trouble keeping up with the fast development of new semiconductors. Relevant IDM actors are Intel, Samsung Electronics, Texas Instruments or SkHynix.

THE FABLESS FOUNDRY MODEL
Within the Fabless-Pureplay approach, every step is done by different actors which interact and collaborate to create and deliver advanced semiconductor products.
Fabless Design companies are companies that design semiconductors but outsource the manufacturing process to a foundry. They focus on design and development, and rely on third-party foundries for manufacturing, allowing them to reduce costs and minimize the risks associated with operating a fab. Important actors among others are Qualcomm - largest and most successful Fabless Design company (Josh Norem, 2022), Broadcom MediaTek and NVIDIA.

Pureplay Foundries are companies that specialize in manufacturing semiconductors for Fabless Design companies. They provide wafer fabrication and allow fabless companies to bring new products to the market quickly and efficiently, while also providing a cost-effective alternative to internal manufacturing.
TSMC and Samsung Foundries are the two leading manufacturer providing cutting edge production channels no other companies have. Other relevant actors are UMC, SMIC and GlobalFoundries.

OSAT stands for "outsourced semiconductor assembly and test" companies. These companies are firms that provide semiconductor assembly and testing services to other companies, such as wafer probing, die preparation, packaging and testing. They enable fabless companies to outsource these specialized manufacturing processes and bring new products to market quickly and efficiently. Critical actors are for example ASE Technology and Amkor Technology.

Machine-providing companies within the semiconductor supply chain design and manufacture equipment used in the production of semiconductors, such as wafer fabrication and assembly and packaging. They play a critical role in the supply chain by providing necessary tools and equipment for manufacturers to produce high-quality semiconductors. Examples include ASML, Lam Research, Applied Materials, Tokyo Electron, and KLA Corporation.

APPENDIX B: (INTRO) PUBLIC ACTORS

The most important public actors are described in the following. To assess the importance, we analyzed all governments that are home or provide factory space to the most important semiconductor companies.

Japan, Ministry of Economy, Trade and Industry (METI)
The ministry is competent in promoting and developing domestic and foreign trade in the global semiconductor market. Furthermore, it develops and implements policies, promotes and fosters innovation, and manages international economic relations and trade negotiations. By supervising and regulating companies such as - KIOXIA or CANON, it has a relevant influence on the global semiconductor market and thus on the EU's chips act.

Korea, Ministry of Trade, Industry and Energy (MOTIE)
The ministry aims to provide a foundation for economic growth by combining areas of commerce, investment, industry and energy. Since Samsung - one of the global leading semiconductor companies, is from Korea, the ministry is understood to be crucial for the whole semiconductor market as it provides innovative cutting-edge manufacturing technology.

Singapore, Ministry of Trade & Industry (MTI)
The ministry plays a crucial role in driving the country's economic development and growth through policies and programs that support trade, industry development, investment, enterprise development, and international economic relations. Regarding the global semiconductor market Singapore is important because a great margin of the manufactured semiconductors is tested and assembled in Singapore.

Chinese Ministry of Commerce (MOFCOM)
The ministry manages foreign economic relations and formulates trade policies, affecting the semiconductor industry's access to technology and markets. It also regulates and promotes foreign trade and investment in industry. China is very much involved in the chip market, as the political decisions made by this actor influence the global economy (Harrison & Farrer, 2022).

US Department of Commerce ((US)DOC)
This department of the US government is responsible for creating the conditions for economic growth and opportunities for all communities (About Commerce, n.d.). Besides the Chinese government, the US government is also heavily involved in the politics of the semiconductor market (Harrison & Farrer, 2022). To fully understand the dynamics of the problem, both actors are analyzed.

Taiwan, Ministry of Economic Affairs (MOEA)
The ministry oversees promoting and supporting the growth of strategic industries in Taiwan, including the semiconductor industry. It provides financial incentives and other support to companies in the semiconductor supply chain to help them to expand and compete globally. Since Taiwan is home to the biggest semiconductor manufacturer TSMC, it plays a pivotal role in the politics of the semiconductor market.

APPENDIX C: (INTRO) ACTOR LIST

Table 6: Public Actor List

Public actors			
Actor	Objectives	Perceptions	Resources
EU Commision:		All commissions have the following resources: - Proposing new law - Managing and allocating EU funds - Enforcing EU law - Representing EU internationally https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/institutions-and-bodies-profiles/european-commission_en	
Communication networks and content technologies (CNECT)	'Connect develops and implements policies to make Europe fit for the digital age'	funding, legislation and policy initiatives ensures leadership and independence in digital technologies	Communication https://ec.europa.eu/info/departments/communications-networks-content-and-technology/what-we-do-communications-networks-content-and-technology_en
Economic and Financial Affairs	'contribute to the creation of economic conditions in which all Europeans can thrive, now and in the future, and to develop the means for Europe to be a leading force for stability and prosperity in the world.'	'contribute to development of policies that underpin economic growth based on competitive sustainability, while preserving macroeconomic and financial stability and contributing to transforming our economies towards climate neutrality.'	Communication, economic surveillance, financing, https://ec.europa.eu/info/departments/economic-and-financial-affairs/mission-statement-economic-and-financial-affairs_en

Internal market industry entrepreneurship and SMEs	‘ensure a greener, digital and more resilient single market economy for the benefit of all EU citizens.’	‘supports an open, seamless and resilient Single Market, with open borders and free flow of goods and services.’	Communication https://www.parlementairemonitor.nl/9353000/1/j9tvgajcor7dxyk_j9vvij5epmj1ey0/vjqymk3f93m4
Research and Innovation (RTD)	‘improving the competitiveness of European businesses’	‘develop and carry out the Commission's policies on research and innovation’	Develop policy, coordinate research activities, manages research programs, promote understanding of role of science in society https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vg9ibeitf3yw
Trade (TRADE)	‘An open, sustainable and assertive EU trade strategy’	‘manages its trade and investment relations with non-EU countries through its trade and investment policy’	Negotiation, projecting eu rules and values in trade agreements, informing https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/making-trade-policy_en

Table 7: National Governments Actor List

National government:			
Taiwanese Ministry of Economy	'seize new opportunities amid global economic restructuring, to tkae a more reliable role in the global supply chain'	'implement measures to help enterprises accelerate industrial innovation'	Make policy, proposing law, publishing papers https://www.moea.gov.tw/MNS/english/multimedia/Multimedia.aspx?menu_id=230
Chinese Ministry of Foreign Affairs	'implement the state's diplomatic principles and policies and related laws and regulations'	'China will continue to pursue the win-win strategy of opening up and grow friendship and cooperation in all fields with other countries on the basis of the Five Principles of Peaceful Co-existence'	Draft laws, handle global security, deal with international arms control, handle international judicial cooperation, make policy, release information, handle foreign affairs, perform other tasks https://www.fmprc.gov.cn/mfa_eng/wjb_663304/zyzz_663306/
U.S. Department of Commerce	'create the conditions for economic growth and opportunity for all communities'	'work to drive U.S. economic competitiveness, strengthen domestic industry, and spur the growth of quality jobs in all communities across the country'	Investing in economy, addressing domestic and global challenges, collaborating, modernizing and securing data for analysis https://www.commerce.gov/about
Korean Ministry of Trade, Industry and Energy (MOTIE)	'help to transform South Korea into a dynamic and economic powerhouse'	'provide a foundation for economic growth by combining its efforts to fulfill its wide range of responsibilities in the areas of commerce, investment, industry, and energy'	Implementing measures, inform https://english.motie.go.kr/en/am/introduction/introduction.jsp

Table 8: Private Actor List

Private actors			
Actor	Objectives	Perceptions	Resources
International Semiconductor Production Companies			
TMSC	Be a technology, manufacturing and service leader.	be the most advanced and largest technology and foundry services provider to fabless companies and IDMs, and in partnership with them, to forge a powerful competitive force in the semiconductor industry	https://www.tsmc.com/english/aboutTSMC/mission
Samsung Electronics (APAC)	'devote its talent and technology to creating superior products and services that contribute to a better global society'	'comply with local laws and regulations as well as applying a strict global code of conduct to all employees'	https://www.samsung.com/sg/about-us/company-info/
Qualcomm	'enable a world where everyone and everything can be intelligently connected'	'With our one technology roadmap, we're building on our leadership in connectivity, high-performance and low-power computing, and on-device AI to power the connected intelligent edge'	https://www.qualcomm.com/news/media-center
Infineon, nxp, stMircoelectronics	'combine entrepreneurial success with responsible action to make life easier, safer, and greener	'Barely visible, our semiconductors have become an indispensable part of everyday life.'	https://www.infineon.com/cms/en/about-infineon/company/

Intel	‘driving business and society forward by creating radical innovation that revolutionizes the way we live’	‘we are applying our reach, scale, and resources to enable our customers to capitalize more fully on the power of digital technology’	https://www.intel.com/content/www/us/en/company-overview/company-overview.html
Texas Instruments	‘design, manufacture, test and sell analog and embedded semiconductors in markets that include industrial, automotive, personal electronics, communications equipment and enterprise systems.’	‘create a better world by making electronics more affordable through semiconductors.’	https://www.ti.com/about-ti/company/what-we-do.html
Micron	‘Transforming how the world uses information to enrich life for all’	‘inspiring the world to learn, communicate and advance faster than ever’	https://www.micron.com/about
ASML	‘provide leading patterning solutions that drive the advancement of microchips’	‘Unlocking the potential of people and society by pushing technology to new limits.’	https://www.asml.com/en/company/about-asml/vision-and-mission
Nikon	‘Unleashing the limitless possibilities of light. Striving to brighten the human experience. Focused, with purpose, on a better future for all.’	‘Trustworthiness and Creativity’ are the two words that represent the perception of Nikon	https://www.nikon.com/about/corporate/philosophy/

APPENDIX D: (SNA) NODE LIST

Table 9: Node List

Id	Label	model	valuechain	subvaluech	geoglocati	betweenes	clustering	eigencentrality
AMD	AMD	Fabless	Design	IP	US	0.166667	0.166667	0.285578
Amkor Tec	Amkor Tec	OSAT	A/T/P	/	US	0	0.172727	0
Apple	Apple	Fabless	Design	/	US	0	0.333333	0.109743
ASE Techn	ASE Techn	OSAT	A/T/P	/	China	0	0.133333	0
ASML	ASML	/	Equipment	Equipment	EU	3.583333	0.155556	0.51394
Broadcom	Broadcom	Fabless	Design	IP	US	1.416667	0.1	0.297368
Canon	Canon	/	Equipment	Equipment	Japan	11.75	0.1	0.016273
China	(CN) MOFC	Governme	Governme	Governme	China	0	0.136364	0.498297
EU	(EU) DG CN	Governme	Governme	Governme	EU	0	0.266667	0.58008
GlobalFour	GlobalFour	Pureplay F	Manufactu	/	US	86.72857	0.106061	0.155276
IBM	IBM	Fabless	Design	IP	US	36	0.166667	0.003061
Infineon	Infineon	IDM	Manufactu	/	EU	4.219048	0.095238	0.113051
Intel	Intel	IDM	Manufactu	/	US	13.00952	0.142857	0.108322
Japan	(JP) METI	Governme	Governme	Governme	Japan	0	0.033333	0.239524
JCET (STAT	JCET (STAT	OSAT	A/T/P	/	China	0	0.4	0
KIOXIA	KIOXIA	IDM	Manufactu	/	Japan	23.83333	0.15	0.00164
Korea	(KR) MOTII	Governme	Governme	Governme	Korea	0	0	0.003061
MediaTek	MediaTek	Fabless	Design	IP	Taiwan	5.5	0.083333	0.222173
Micron	Micron	IDM	Manufactu	/	US	0	0	0
NVIDIA	NVIDIA	Fabless	Design	IP	US	0	0.333333	0.109743
NXP	NXP	IDM	Manufactu	/	EU	86.76191	0.122222	0.287218
Powertech	Powertech	OSAT	A/T/P	/	China	0	0.5	0
Qualcomm	Qualcomm	Fabless	Design	IP	US	1.416667	0.142857	0.343706
Samsung	Samsung	IDM	Manufactu	/	Korea	3.509524	0.069444	0.00082
Siliconwar	Siliconwar	OSAT	A/T/P	/	Taiwan	0	0	0
Singapore	(SG) MTI	Governme	Governme	Governme	Singapore	0	0.3	0.328468
SK Hynix	SK Hynix	IDM	Manufactu	/	Korea	0	0	0
SMIC	SMIC	Pureplay F	Manufactu	/	China	90.95	0.081818	0.007763
STMicroele	STMicroele	IDM	Manufactu	/	EU	2.602381	0.166667	0.069126
Taiwan	(TW) MOEA	Governme	Governme	Governme	Taiwan	0	0.05	0.31018
Teradyne	Teradyne	/	Equipment	Equipment	US	2.25	0.166667	0.060342
Texas Instr	Texas Instr	IDM	Manufactu	/	US	98.64524	0.136364	0.232342
Tokyo Elec	Tokyo Elec	/	Equipment	Equipment	Japan	0	0	0
TSMC	TSMC	Pureplay F	Manufactu	/	Taiwan	91.86191	0.115385	0.262893
UMC	UMC	Pureplay F	Manufactu	/	Taiwan	73.79524	0.068182	0.267336
US	(US) DOC	Governme	Governme	Governme	US	0	0.110294	1
Western D	Western D	Pureplay F	Manufactu	/	US	0	0	0

APPENDIX E: (SNA) EDGE LIST

Table 10: Edge List

Type of Connection	Target	Source	Reference
1 Fabless -> Pureplay	AMD	TSMC	https://www.anandtech.com/show/17200/amd-were-using-an-optimized-tsmc-5nm-process
1 Fabless -> Pureplay	AMD	UMC	
1 Fabless -> Pureplay	AMD	GlobalFoundries	https://en.wikipedia.org/wiki/GlobalFoundries
1 Fabless -> Pureplay	Apple	TSMC	
1 Fabless -> Pureplay	Apple	Samsung	
1 Fabless -> Pureplay	Broadcom	SMIC	https://csimarket.com/stocks/suppliers_glance.php?code=AVGO
1 Fabless -> Pureplay	Broadcom	UMC	
1 Fabless -> Pureplay	Broadcom	TSMC	
1 Fabless -> Pureplay	Broadcom	GlobalFoundries	
1 Fabless -> Pureplay	IBM	Samsung	https://www.digitimes.com/news/a20220919VL212/ic-manufacturing-intel-samsung-tsmc.html
1 Fabless -> Pureplay	IBM	Tokyo Electron	
1 Fabless -> Pureplay	MediaTek	GlobalFoundries	
1 Fabless -> Pureplay	MediaTek	UMC	
1 Fabless -> Pureplay	MediaTek	Intel	https://www.intel.com/content/www/us/en/newsroom/news/intel-july-2022-announce.html#gs.lklmky
1 Fabless -> Pureplay	NVIDIA	TSMC	https://asia.nikkei.com/Business/Technology/Nvidia-taps-TSMC-to-manufacture-new-gaming-chips-with-AI-features
1 Fabless -> Pureplay	NVIDIA	Samsung	https://www.bloomberg.com/news/articles/2022-03-23/nvidia-ceo-to-look-at-intel-for-foundry-says-shift-will-be-hard
1 Fabless -> Pureplay	Qualcomm	Samsung	https://www.digitimes.com/news/a20220919VL212/ic-manufacturing-intel-samsung-tsmc.html
1 Fabless -> Pureplay	Qualcomm	SMIC	
1 Fabless -> Pureplay	Qualcomm	GlobalFoundries	
1 Fabless -> Pureplay	Qualcomm	UMC	
1 Fabless -> Pureplay	Qualcomm	Intel	https://www.eetimes.com/intel-signs-mediatek-as-third-major-foundry-customer/
1 Fabless -> Pureplay	Qualcomm	TSMC	
2 Machines -> Pureplay	ASML	Intel	https://finance.yahoo.com/news/semiconductor-equipment-maker-asml-profit-053209228.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJM8C2EN_2dfkSr4a0PAuC3k74wRcJVvDt_SStIjEiNHmf3FGXclyFushURlaq1im7IYk_jecZH5-9KiRAnz-s1uMqRyuk9Uyhi_5GNGrTLm-RL8Q5x0VTSTSAQYlBEXtLGYDCpoTk0qBblfPZ_e2Xd1J5KkaInBvUI-U60JmaJR
2 Machines -> Pureplay	ASML	TSMC	https://finance.yahoo.com/news/semiconductor-equipment-maker-asml-profit-053209228.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJM8C2EN_2dfkSr4a0PAuC3k74wRcJVvDt_SStIjEiNHmf3FGXclyFushURlaq1im7IYk_jecZH5-9KiRAnz-s1uMqRyuk9Uyhi_5GNGrTLm-RL8Q5x0VTSTSAQYlBEXtLGYDCpoTk0qBblfPZ_e2Xd1J5KkaInBvUI-U60JmaJR
2 Machines -> Pureplay	ASML	Samsung	https://finance.yahoo.com/news/semiconductor-equipment-maker-asml-profit-053209228.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJM8C2EN_2dfkSr4a0PAuC3k74wRcJVvDt_SStIjEiNHmf3FGXclyFushURlaq1im7IYk_jecZH5-9KiRAnz-s1uMqRyuk9Uyhi_5GNGrTLm-RL8Q5x0VTSTSAQYlBEXtLGYDCpoTk0qBblfPZ_e2Xd1J5KkaInBvUI-U60JmaJR
2 Machines -> Pureplay	ASML	UMC	https://www.trouw.nl/nieuws/umc-koopt-voor-eur-27-4-miljoen-asml-apparatuur~b86ee1e0/?referrer=https%3A%2F%2Fwww.google.com%2F
2 Machines -> Pureplay	ASML	GlobalFoundries	https://www.asml.com/en/news/press-releases/2013/globalfoundries-partners-with-asml-for-leading-edge-chip-tapeouts
2 Machines -> Pureplay	Canon	SMIC	https://technode.com/2022/11/16/canon-exec-shares-progress-in-lithography-and-views-on-the-chinese-chip-market/
3 IDM -> Pureplay	Infineon	UMC	
3 IDM -> Pureplay	Intel	TSMC	https://www.gizmochina.com/2021/09/22/intel-explains-why-it-is-outsourcing-chip-manufacturing-to-tsmc/
3 IDM -> Pureplay	KIOXIA	Western Digital Corporation	https://www.kioxia.com/en-jp/about/news/2022/20220726-1.html
3 IDM -> Pureplay	NXP	GlobalFoundries	https://www.nxp.com/files-static/training/doc/ftf/2014/FTF-AUT-F0354.pdf
3 IDM -> Pureplay	NXP	TSMC	https://www.nxp.com/files-static/training/doc/ftf/2014/FTF-AUT-F0354.pdf
3 IDM -> Pureplay	NXP	UMC	https://www.nxp.com/files-static/training/doc/ftf/2014/FTF-AUT-F0354.pdf
3 IDM -> Pureplay	STMicroelectronics	GlobalFoundries	https://gf.com/de/gf-press-release/stmicroelectronics-and-globalfoundries-to-advance-fd-soi-ecosystem-with-new-300mm-manufacturing-facility-in-france/

Type of Connection	Target	Source	Reference
3 IDM -> Pureplay	Texas Instruments	SMIC	
3 IDM -> Pureplay	Texas Instruments	UMC	https://seekingalpha.com/article/4444048-texas-instruments-better-ownership-of-supply-chain-is-a-big-advantage
3 IDM -> Pureplay	Texas Instruments	TSMC	https://seekingalpha.com/article/4444048-texas-instruments-better-ownership-of-supply-chain-is-a-big-advantage
4 Pureplay -> IDM	GlobalFoundries	STMicroelectronics	
4 Pureplay -> IDM	GlobalFoundries	NXP	
4 Pureplay -> IDM	Intel	Intel	
4 Pureplay -> IDM	Samsung	Samsung	
4 Pureplay -> IDM	SMIC	KIOXIA	
4 Pureplay -> IDM	TSMC	Intel	
4 Pureplay -> IDM	TSMC	NXP	
4 Pureplay -> IDM	TSMC	Texas Instruments	
4 Pureplay -> IDM	UMC	Infineon	
4 Pureplay -> IDM	UMC	Texas Instruments	
4 Pureplay -> IDM	UMC	NXP	
5 Machines -> IDM	ASML	Samsung	https://finance.yahoo.com/news/semiconductor-equipment-maker-asml-profit-053209228.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJM8C2EN_2dfkSr4a0PAuC3k74wRcJVvDt_SStljEiNHmf3FGXcIyFushURlaq1im7IYk_jecZH5-9KiRAnz-s1uMqRyuk9Uyhi_5GNGrTLm-RL8Q5x0VTSTSAQYlBEXtLGYDCpoTk0qBblfPZ_e2Xd1J5KkaInBvUI-U60JmaJR
5 Machines -> IDM	ASML	Intel	https://finance.yahoo.com/news/semiconductor-equipment-maker-asml-profit-053209228.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJM8C2EN_2dfkSr4a0PAuC3k74wRcJVvDt_SStljEiNHmf3FGXcIyFushURlaq1im7IYk_jecZH5-9KiRAnz-s1uMqRyuk9Uyhi_5GNGrTLm-RL8Q5x0VTSTSAQYlBEXtLGYDCpoTk0qBblfPZ_e2Xd1J5KkaInBvUI-U60JmaJR
5 Machines -> IDM	ASML	Texas Instruments	https://www.fool.com/investing/2022/07/25/whats-good-news-for-asmls-may-be-bad-news-for-texa/
5 Machines -> IDM	ASML	Infineon	https://www.asml.com/en/news/press-releases/2001/asml-wins-300mm-business-at-infineon-technologies-with-multiple-order-for-twinscan-platform
5 Machines -> IDM	ASML	STMicroelectronics	https://www.asml.com/en/news/press-releases/2009/asml-and-brion-technologies-extend-partnership
5 Machines -> IDM	ASML	Micron	https://www.asml.com/en/news/press-releases/2004/media-advisory-micron-technology-inc-and-asml-masktools
5 Machines -> IDM	Canon	KIOXIA	https://info.fusionww.com/blog/asml-dominance-spurs-innovation-and-creates-new-competition
5 Machines -> IDM	Canon	SK Hynix	https://info.fusionww.com/blog/asml-dominance-spurs-innovation-and-creates-new-competition
5 Machines -> IDM	Teradyne	Intel	https://csimarket.com/stocks/markets_glance.php?code=TER
5 Machines -> IDM	Teradyne	Canon	https://csimarket.com/stocks/markets_glance.php?code=TER
6 Pureplay -> OSAT	GlobalFoundries	Amkor Technology	https://gf.com/gf-partner-community/globalsolutions-ecosystem/
6 Pureplay -> OSAT	GlobalFoundries	IBM	https://gf.com/gf-partner-community/globalsolutions-ecosystem/
6 Pureplay -> OSAT	Intel	Amkor Technology	https://ir.amkor.com/news-releases/news-release-details/amkor-technology-receives-intels-preferred-quality-supplier-1
6 Pureplay -> OSAT	Samsung	Samsung	https://semiconductor.samsung.com/us/foundry/advanced-package/
6 Pureplay -> OSAT	Samsung	Amkor Technology	https://semiconductor.samsung.com/us/foundry/advanced-package/
6 Pureplay -> OSAT	SMIC	Amkor Technology	https://www.smics.com/en/site/one_stop_service
6 Pureplay -> OSAT	SMIC	JCET (STATS ChipPAC)	https://www.smics.com/en/site/one_stop_service
6 Pureplay -> OSAT	SMIC	ASE Technology	https://www.smics.com/en/site/one_stop_service
6 Pureplay -> OSAT	SMIC	Siliconware Precision Industries	https://www.smics.com/en/site/one_stop_service
6 Pureplay -> OSAT	SMIC	Powertech Technology	https://www.smics.com/en/site/one_stop_service
6 Pureplay -> OSAT	TSMC	Amkor Technology	https://amkor.com/blog/amkor-joins-tsmcs-oip-3dfabric-alliance/
6 Pureplay -> OSAT	UMC	JCET (STATS ChipPAC)	https://www.umc.com/en/News/press_release/Content/technology_related/20130129
7 IDM -> OSAT	Infineon	Amkor Technology	https://www.eenewseurope.com/en/amkor-looks-to-eu-chips-act-for-semiconductor-packaging-in-portugal/
7 IDM -> OSAT	Infineon	JCET (STATS ChipPAC)	https://www.infineon.com/dgdl/Infineon-QTP_110901_44L_64L_TQFP_NIPDAU_MSL3_260C_REFLOW_JCET-_CHINA_(JT)-ProductQualificationReport-v03_00-EN.pdf?fileId=8ac78c8c7d710014017d714b5184105f
7 IDM -> OSAT	Infineon	ASE Technology	https://ase.aseglobal.com/en/press_room/content/149
7 IDM -> OSAT	KIOXIA	Amkor Technology	https://ir.amkor.com/static-files/d81c430d-6d7f-4f05-932e-19222fd76cf1
7 IDM -> OSAT	NXP	Amkor Technology	https://www.nxp.com/files-static/training/doc/ftf/2014/FTF-AUT-F0354.pdf
7 IDM -> OSAT	NXP	ASE Technology	https://www.nxp.com/files-static/training/doc/ftf/2014/FTF-AUT-F0354.pdf
7 IDM -> OSAT	SK Hynix	SK Hynix	https://www.cnbc.com/2022/08/12/sk-hynix-to-break-ground-on-new-us-chip-packaging-plant-next-year.html

Type of Connection	Target	Source	Reference
7 IDM -> OSAT	STMicroelectronics	Amkor Technology	https://www.marketresearchreports.com/blog/2019/04/24/top-10-osat-companies-world
7 IDM -> OSAT	STMicroelectronics	ASE Technology	https://cmd.st.com/static-files/a028e35e-1f63-45d1-a0eb-c3929fe4374b
7 IDM -> OSAT	Texas Instruments	Amkor Technology	https://www.marketresearchreports.com/blog/2019/04/24/top-10-osat-companies-world
7 IDM -> OSAT	Texas Instruments	JCET (STATS ChipPAC)	https://www.prnewswire.com/news-releases/jcet-group-subsidiary-recognized-for-excellence-by-texas-instruments-301527742.html
7 IDM -> OSAT	Texas Instruments	ASE Technology	https://ase.aseglobal.com/en/press_room/content/ti-award-2019-en
8 government -> company headquarters	China	ASE Technology	
8 government -> company headquarters	China	JCET (STATS ChipPAC)	
8 government -> company headquarters	China	Powertech Technology	
8 government -> company headquarters	China	SMIC	
8 government -> company headquarters	EU	Infineon	
8 government -> company headquarters	EU	NXP	
8 government -> company headquarters	EU	STMicroelectronics	
8 government -> company headquarters	EU	ASML	
8 government -> company headquarters	EU	Infineon	
8 government -> company headquarters	EU	NXP	
8 government -> company headquarters	EU	STMicroelectronics	
8 government -> company headquarters	Japan	Tokyo Electron	
8 government -> company headquarters	Japan	KIOXIA	
8 government -> company headquarters	Japan	Canon	
8 government -> company headquarters	Korea	Samsung	
8 government -> company headquarters	Korea	SK Hynix	
8 government -> company headquarters	Taiwan	TSMC	
8 government -> company headquarters	Taiwan	UMC	
8 government -> company headquarters	Taiwan	TSMC	
8 government -> company headquarters	Taiwan	UMC	
8 government -> company headquarters	Taiwan	MediaTek	
8 government -> company headquarters	Taiwan	Siliconware Precision Industries	
8 government -> company headquarters	US	Intel	
8 government -> company headquarters	US	Micron	
8 government -> company headquarters	US	Texas Instruments	
8 government -> company headquarters	US	Intel	
8 government -> company headquarters	US	Micron	
8 government -> company headquarters	US	GlobalFoundries	
8 government -> company headquarters	US	Texas Instruments	
8 government -> company headquarters	US	NVIDIA	
8 government -> company headquarters	US	Qualcomm	
8 government -> company headquarters	US	Teradyne	
8 government -> company headquarters	US	Western Digital Corporation	
8 government -> company headquarters	US	AMD	
8 government -> company headquarters	US	IBM	
8 government -> company headquarters	US	Amkor Technology	
8 government -> company headquarters	US	Apple	
8 government -> company headquarters	US	Broadcom	
9 government -> company foundries	China	Samsung	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	NXP	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	Intel	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	Micron	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	Texas Instruments	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	SK Hynix	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	TSMC	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	UMC	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	China	SMIC	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	EU	Infineon	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants

Type of Connection	Target	Source	Source
9 government -> company foundries	EU	NXP	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	EU	Texas Instruments	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	EU	GlobalFoundries	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Japan	NXP	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Japan	Micron	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Japan	Texas Instruments	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Japan	KIOXIA	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Korea	Samsung	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Korea	SK Hynix	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Singapore	NXP	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Singapore	STMicroelectronics	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Singapore	Micron	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Singapore	UMC	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Singapore	GlobalFoundries	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Taiwan	Micron	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Taiwan	TSMC	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	Taiwan	UMC	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	Samsung	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	Infineon	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	NXP	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	Intel	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	Micron	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	Texas Instruments	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	TSMC	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants
9 government -> company foundries	US	GlobalFoundries	https://en.wikipedia.org/wiki/List_of_semiconductor_fabrication_plants

APPENDIX F: (SNA) DEFINITION OF METRICS

Network Level Measures

The average Clustering Coefficient measures the extent of local clustering – explains how likely triads (3 nodes) will form. This can be used to understand the nature of collaborations within the network.

The average Degree measures the average number of connections each node/actor have. This shows the extent of reliance actors have on one another in the network.

(These measures will be calculated for the supply chain layer as well as the full network as it will be informative to briefly compare and evaluate the impact of public actors on the supply chain.)

Node Level Measures (centrality)

Betweenness Centrality measures the extent to which the node lies within the shortest paths. This is useful to analyze companies in the supply chain, where a company's importance is represented by how involved it is in the complete process.

Eigenvector Centrality measures the node's importance by how much it connects to other nodes with high importance. In a supply chain, a company's importance is determined by the other companies that are reliant on it for key resources. For public actors, a country will be important because companies are reliant on it for talent and space for operations.

APPENDIX G: (SNA) SUPPLY CHAIN LAYER

Betweenness Centrality -

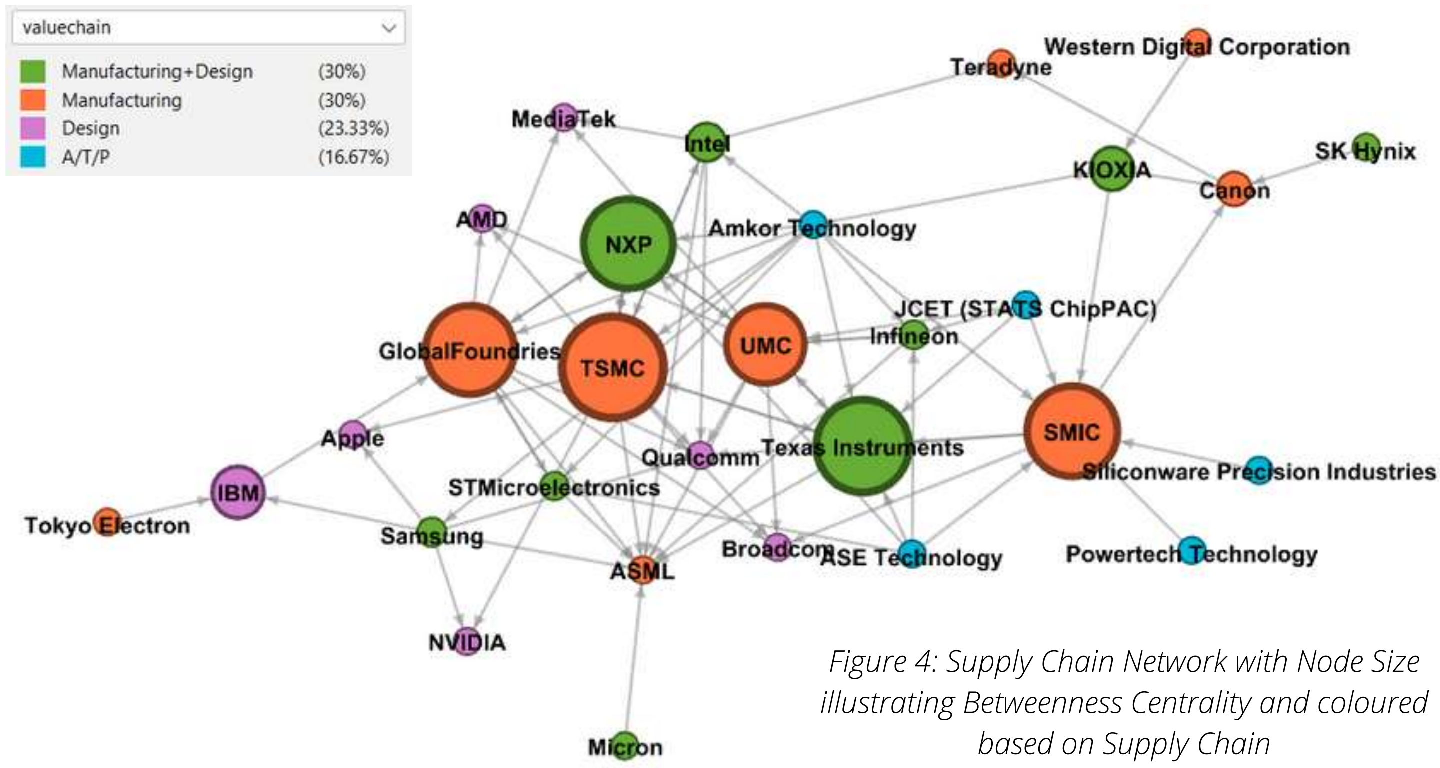

Figure 4: Supply Chain Network with Node Size illustrating Betweenness Centrality and coloured based on Supply Chain

Eigenvector Centrality -

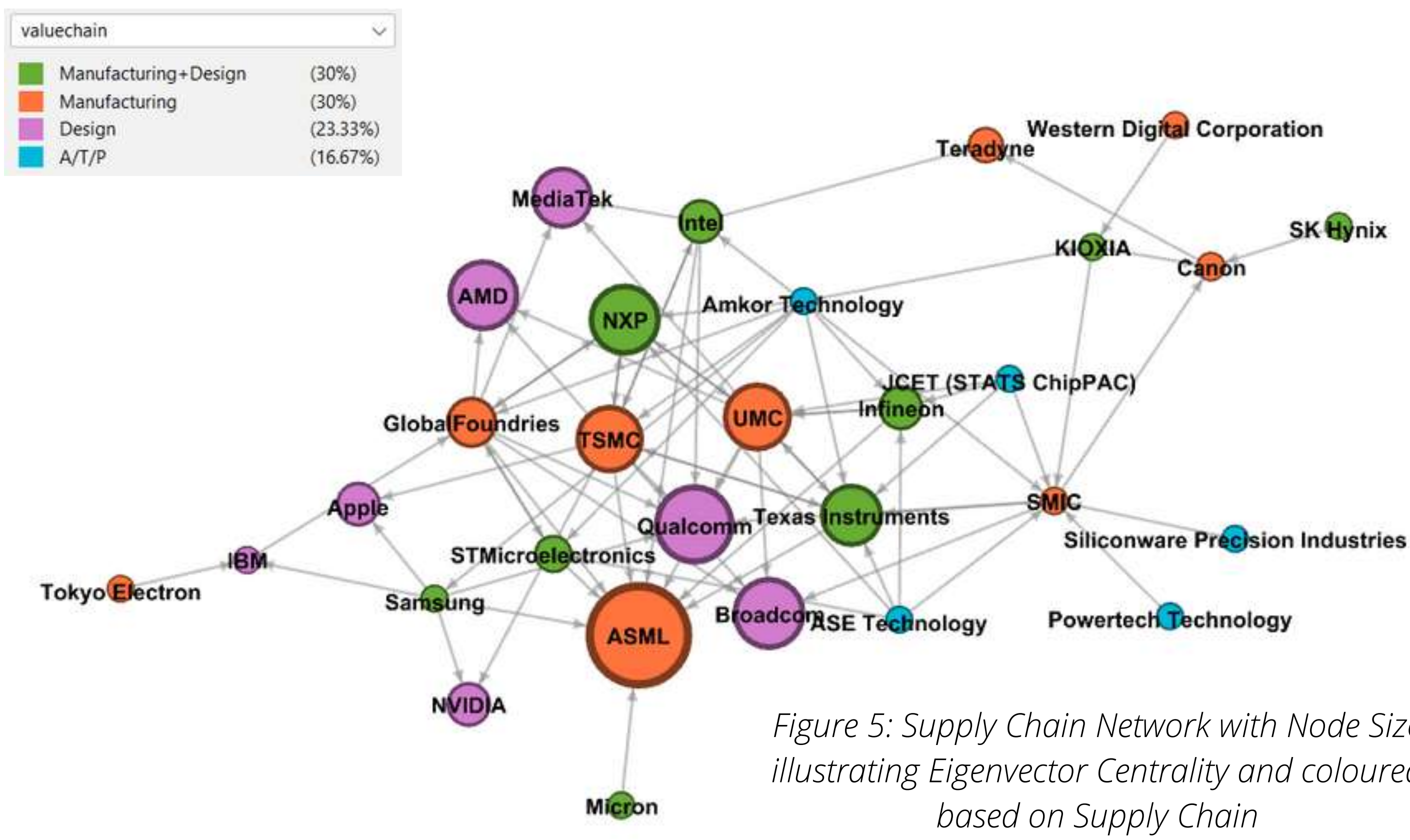

Figure 5: Supply Chain Network with Node Size illustrating Eigenvector Centrality and coloured based on Supply Chain

APPENDIX H: (SNA) EIGENVECTOR SENSITIVITY

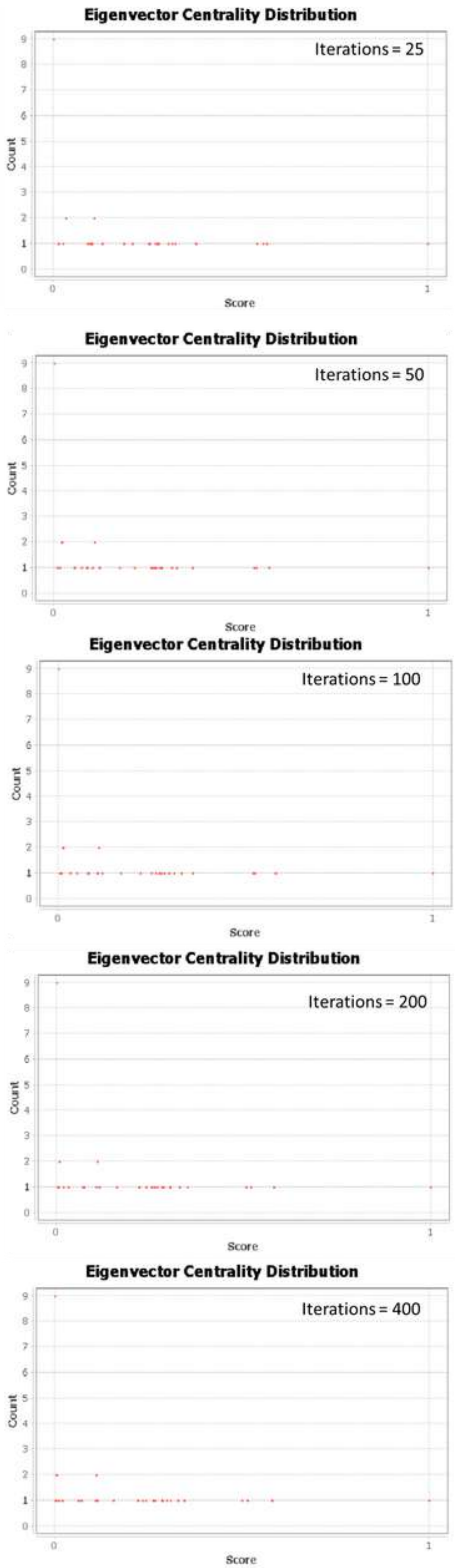

Figure 6: eigenvector sensitivity

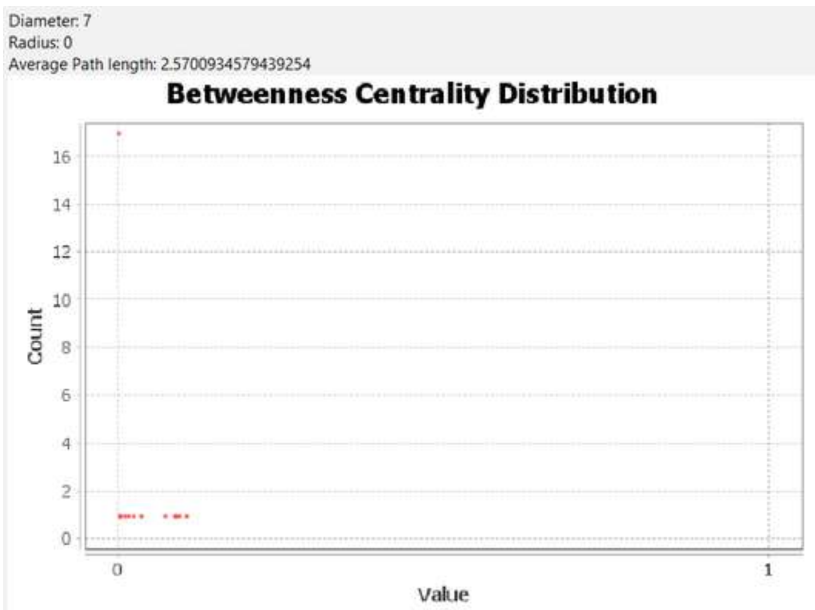

Figure 7: Sensitivity of Eigenvector and Betweenness Centrality

APPENDIX I: (SNA) RESILIENCE ANALYSIS

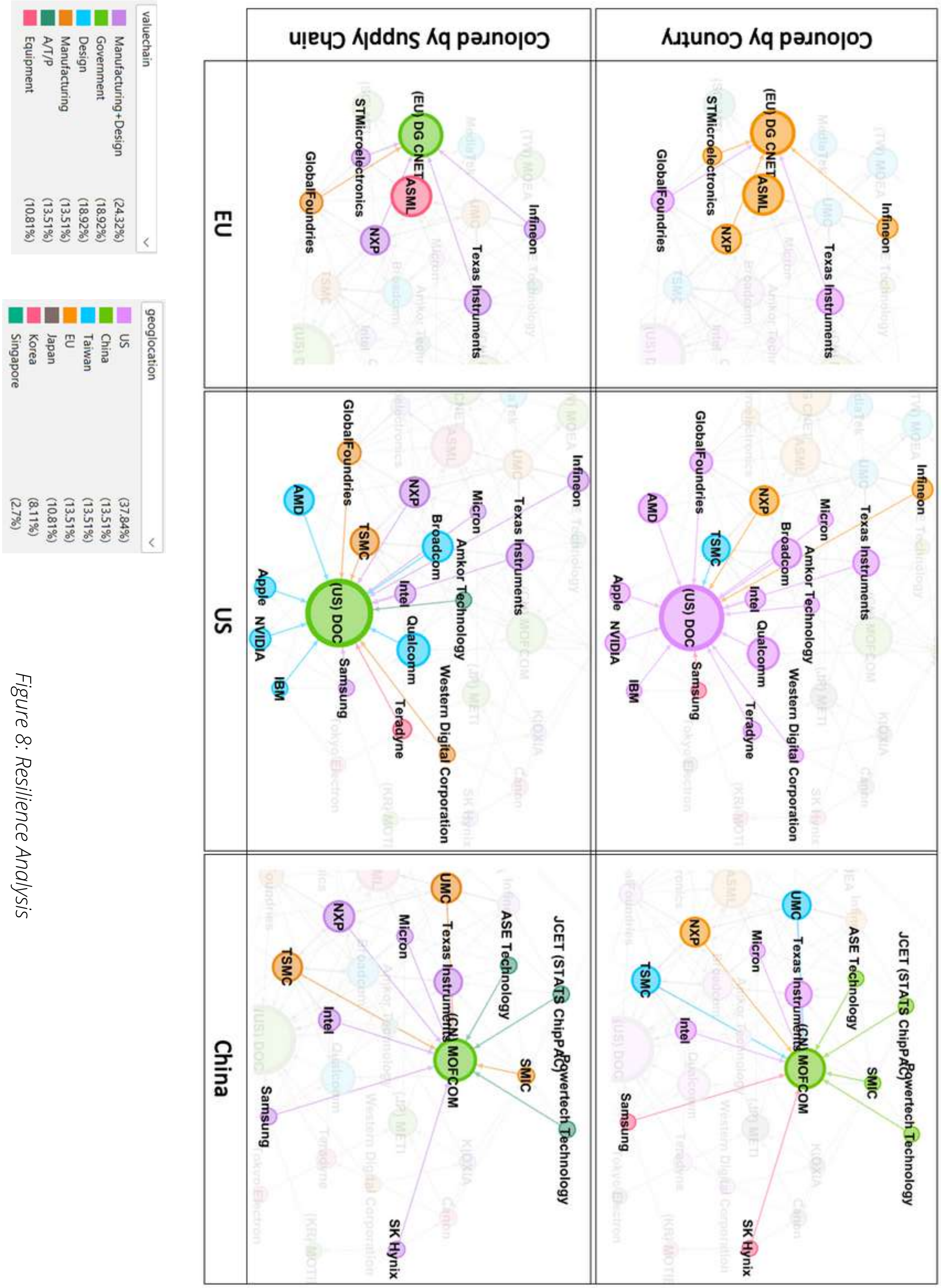

Figure 8: Resilience Analysis