Tracking the Semiconductor Sector: An AI approach using Natural language and Big Data Techniques

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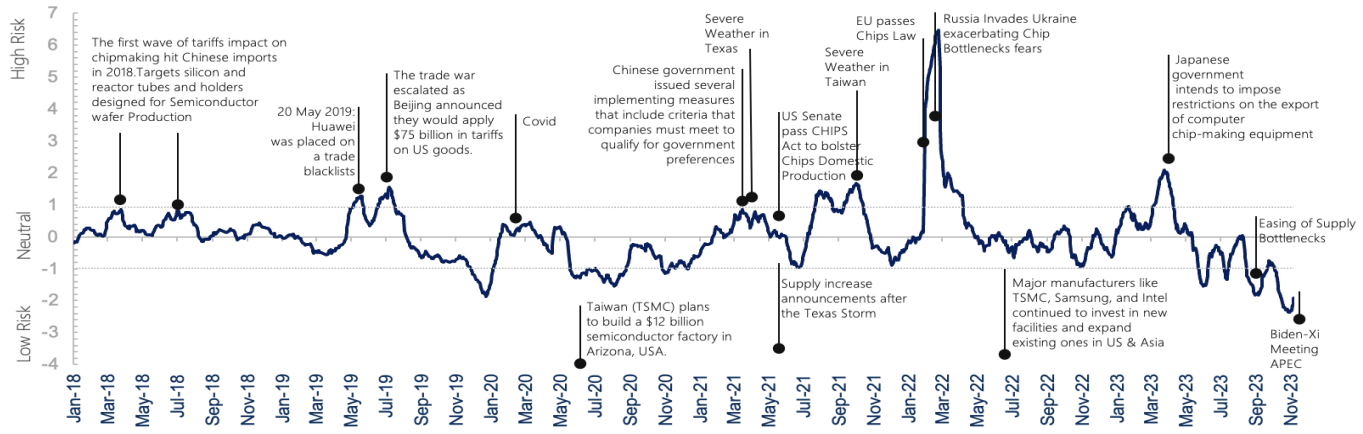
Key Messages

- We employ Big Data from Global news and AI Natural Language Processing (NLP) techniques to monitor and analyze the semiconductor crisis to offer Global, National and Corporate insights of the Semiconductor crisis in real time. This analysis can enhance the tools to monitor in real-time and analyze the Global semiconductor crisis.
- The Semiconductor Crisis has been driven by different factors including the US-China trade war, industry capacity problems after the COVID-19, bad weather during 2020-2022 and key geopolitical events. The easing of some of these factors has recently supported a significant ease of our Global Semiconductor Sentiment index.
- We built a Network of the Semiconductor Industry to show the relevance of the Taiwan Semiconductor Manufacturing Company (TSMC). The role of TSMC as a key provider of advanced chips and its position in the Semiconductor Value Chain make TSMC an important systemic risk for the semiconductor industry and advanced economies.
- The relevance of the China-Taiwan tensions has led some countries to implement policies, provide funding and enforce re-shoring or near-shoring strategies.

Figure 1. **BBVA RESEARCH GLOBAL SEMICONDUCTOR INDEX (2018-2023)** (NORMALIZED INDEX. POSITIVE VALUES STAND FOR RISK/NEGATIVE SENTIMENT, WHILE NEGATIVE VALUES FOR POSITIVE NEWS/EASING TENSIONS)



Source: BBVA Research and www.gdelt.org

Analyzing Semiconductor evolution using AI Natural Language techniques

Semiconductor chips, essential to modern technology, are at the global geopolitical crossroads due to their critical role in various sectors from consumer electronics to defense. The semiconductor production is concentrated mainly in Asia with Taiwan and South Korea leading the pack. This geographical concentration, coupled with the ongoing US-China tech war, has led to vulnerabilities in the global supply chain, especially as both nations vie for technological superiority.

The role of semiconductors in national security cannot be overstated, as they are a critical component of military equipment and infrastructure. Their importance has led to increased tensions, particularly between the US and China, with the US imposing restrictions on Chinese tech companies, citing national security concerns. These restrictions have caused China to push for more self-sufficiency in semiconductor production, a challenging prospect given the technological complexities involved.

In response to these geopolitical complexities and supply chain vulnerabilities exposed by the COVID-19 pandemic, many countries are reassessing their approach to semiconductor production. Policies and investments are being considered to boost domestic semiconductor industries and make supply chains more resilient. For instance, under the CHIPS Act, the US has proposed significant funding to bolster its domestic production and research capabilities.

In this brief, we use several AI Natural Language tools such as Sentiment analysis, Networks and Boolean searches from an International Database on News (GDELT) and Google Trends. These Tools aim to enhance the Real time and High-definition analysis of the Chips Geopolitical Crisis.

A Global Sentiment Big Data Indicator of the Semiconductor crisis

The semiconductor crisis, spanning from 2018 to the end of 2023, was a multifaceted issue influenced by several factors at different periods. In order to analyze the world sentiment towards the Semiconductor Industry, we have developed an indicator to monitor semiconductors media sentiment all over the word using an open-source database called Global Database of Events, Language and Tone (GDELT)[1], which extracts and parses digital news in broadcast, print and web media globally in over 100 languages on a daily basis, from global to local media sources.

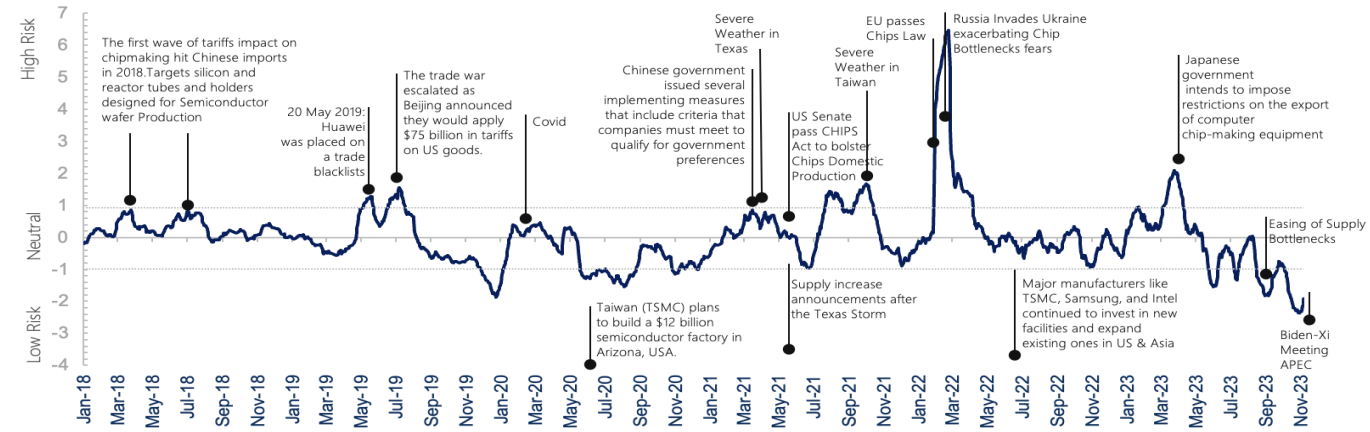
GDELT uses different dictionaries, and several thousands of taxonomies are identified in the news pieces to classify and categorize the information. The algorithms can identify organizations, locations, news sources and events across the world as well as emotions and sentiments[2]. To build the BBVA Research semiconductors sentiment index we capture both the coverage[3] and sentiment of news articles per day including any mention of

1: For detailed information about GDELT, you can consult www.gdelt.org.
2: Focusing on sentiment, once each news piece is translated into English, GDELT applies more than 40 different dictionaries that classify words associated with positive and negative tone to compute the average "tone" of all documents containing one or more mentions to the events we are looking for. The score ranges from -100 (extremely negative) to +100 (extremely positive).
3: We get the relative coverage of the topic with respect to the total number of news each day and in each country to create a sentiment intensity score, global and by country. This way, the indicator tracks the level of prevalence of the topic over time and across geographies, correcting for the exponential rise in media coverage over the last years and the different media coverage per country.

this topic. The index is normalized so it shows its relative performance to its own past and we apply a moving average of 28 days to reduce noise.

The evolution of the BBVA Research Global Semiconductor Sentiment index can be observed in Figure 1. As can be observed, the Semiconductor Crisis and later normalization has been driven by several factors such as the US-China trade war, shortages related to COVID-19 and capacity problems, bad weather, geopolitical choke points and progress in international diplomacy operating with different intensity over time.

Figure 1. **BBVA RESEARCH GLOBAL SEMICONDUCTOR INDEX (2018-2023)** (NORMALIZED INDEX. POSITIVE VALUES STAND FOR RISK/NEGATIVE SENTIMENT, WHILE NEGATIVE VALUES FOR POSITIVE NEWS/EASING TENSIONS)



Source: BBVA Research and www.gdelt.org

- **The Initial Phase: US and China Trade war (2018-2019):** This period was characterized by the trade war between the US and China, initiated under the Trump administration. Taiwan, a global leader in semiconductor manufacturing, notably through Taiwan Semiconductor Manufacturing Company, became a focal point in the trade war. The US sought to secure semiconductor supplies from Taiwan, heightening tensions with China, which claims sovereignty over Taiwan. The first of tariffs impact on chipmaking hit Chinese company imports, particularly of silicon and reactor tubes and wafer production. The situation remained in a neutral range until mid 2019 when the key Chinese Big Tech company, Huawei, was placed on a trade blacklist. The Chinese retaliation came up soon and Chinese authorities decided to apply 75 US Bn tariffs on US Goods. This phase of the trade war triggered the first increase of our indicator on the risk area.
- **Shortages on Covid and Weather Events (2020-22).** The outbreak of COVID-19 in early 2020 led to unprecedented disruptions in global supply chains. Semiconductor production was significantly affected due to factory shutdowns, particularly in Asia. The pandemic also caused a surge in demand for electronics due to remote work and education, exacerbating the shortage which were more evident during the second half of 2020 and 2021 where there were some bad weather events, and Governments and companies initiated efforts to ramp up production and diversify supply chains, but the industry struggled to meet the soaring demand.
- **Geopolitical events: The Russian-Ukraine war in 2022:** The Russian-Ukraine war led to a scarcity of neon and palladium, essential for chip manufacturing, as Ukraine was a major supplier of these resources. The war acted as an amplifier of the problems in global supply chains, leading to a reevaluation of strategies, with companies seeking to reduce dependence on regions with geopolitical risks.

- **Market Normalization 2022-2023:** As the initial surge in demand for electronics due to the pandemic normalized, the market adapted, leading to a more balanced demand-supply scenario. On the supply side, companies across various sectors improved their inventory management and strategic stockpiling of chips, reducing the panic and urgency that characterized the early stages of the crisis.
- **Easing tensions between China and USA (2023):** While continuing to address the technological rivalry with China, the Biden administration showed a rapprochement with Chinese authorities. Enhanced diplomatic efforts previous to the Biden-Xi Jinping meeting in the APEC summit led to some easing of the tensions last November 2023. Despite these efforts, the fundamental challenges and strategic competition in the semiconductor sector remained a critical aspect of the US-China relations.

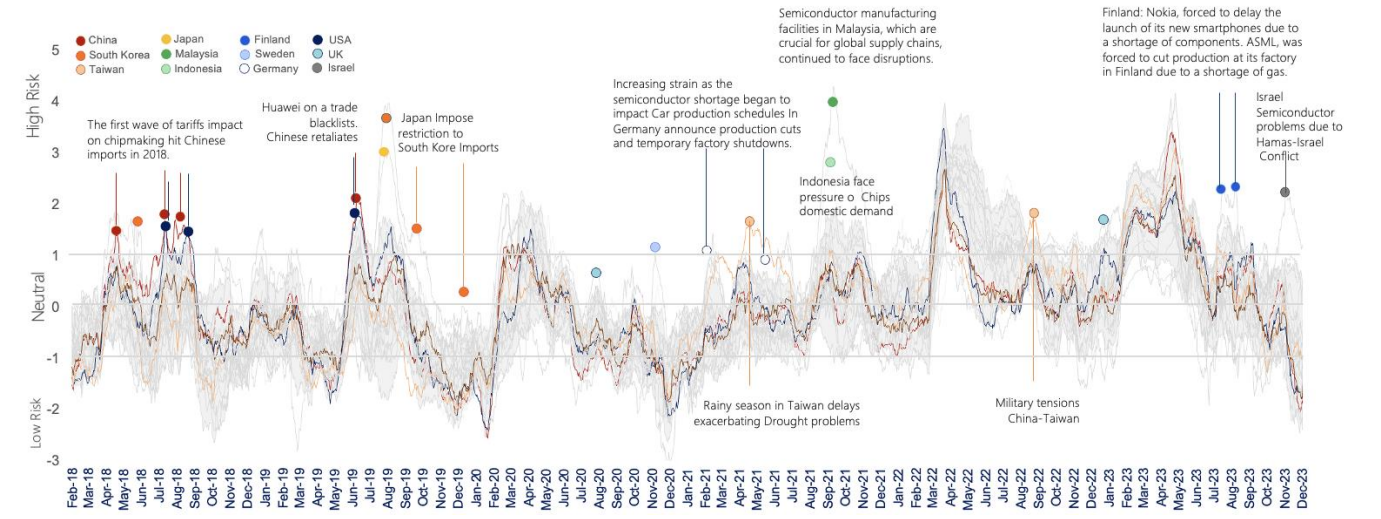
In sum, the semiconductor crisis, spanning from 2018 to the end of 2023, was a multifaceted issue influenced by geopolitical tensions, global health crises, environmental factors, and international diplomacy.

The National Semiconductors Index: Global and Idiosyncratic divergences

Beyond the development of a Global Semiconductor Sentiment index, we have built nearly thirty indexes by country applying similar techniques. The results show that while there is a strong common component coinciding with the pattern of the Global sentiment index (given the high integration of the Global Value Chain of the Industry), there are also idiosyncratic factors with important divergences at some moments.

The Figure 2 shows the different indexes in gray for which we have computed the median and a confidence band of one and a half standard deviations. We have marked in blue (US), light orange (Taiwan) and red (China) some of the indexes to see how these relevant countries' indexes move relative to the median and the uncertainty band.

Figure 2. **BBVA RESEARCH SEMICONDUCTOR INDEX BY COUNTRY AND OUTLIERS (2018-2023)** (NORMALIZED INDEX. POSITIVE VALUES STAND FOR RISK/NEGATIVE SENTIMENT, WHILE NEGATIVE VALUES FOR POSITIVE NEWS/EASING TENSIONS)



Source: BBVA Research and www.gdelt.org

While we can observe the common component in the band around the median, we can also appreciate some of the outliers standing for some significantly different behaviors. While a robust index should reflect a common factor; it can also display the idiosyncratic national peculiarities. To account for this, we have marked with colored circles these national differences with different colors by country.

The first group of idiosyncratic factors corresponds to April to September of 2018 for the case of the US and the Asian countries. Those correspond to the tariff war between the US and China, followed by successive retaliation measures by the Chinese. The next significant idiosyncratic event corresponds to the inclusion of Huawei in a blacklist followed by retaliation by the Chinese authorities. This was followed by some special events such as the trade restrictions imposed by Japan to Korean semiconductors and the response of the Koreans.

While the COVID-19 and Post COVID-19 period were broadly common and driven by a significant ease of the climate boosted by the increasing demand of semiconductors due to the spur of demand thanks to the lockdowns, some special events start to appear due to the first signs negative sentiment due to the bottlenecks in the industry reinforced by bad climate in some countries in 2021-22. There was a particular negative sentiment in Germany due to the Bottlenecks as well as some bad weather effects affecting Malaysia, and indirectly to Indonesia (a key client of Malaysian chips).

During 2023 most of the bottleneck's problems started to be solved and the Sentiment index started to recede. Only the geopolitical events affecting Taiwan were somehow special (see next section). Beyond this, we have observed some problems in Finland and more recently some idiosyncratic differences in Israel due to the recent Israeli-Hamas war.

The geopolitical dimension of the Crisis: The China-Taiwan-US Strategic Relations

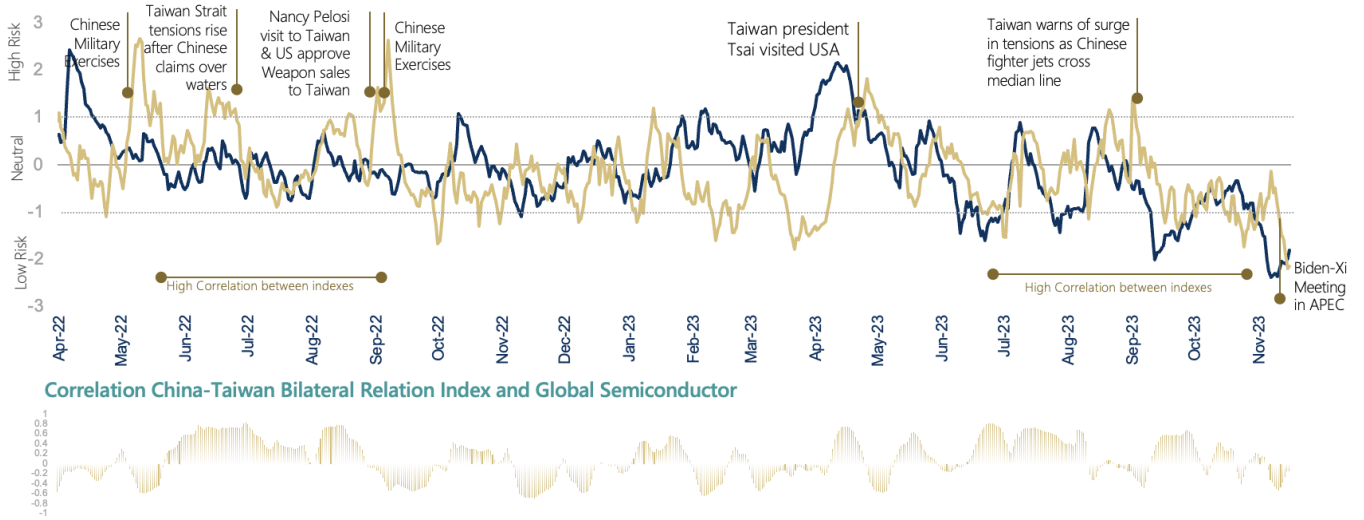
To understand the impact of these geopolitical factors on the global semiconductor industry, we examine the interactions between China, Taiwan, and the US, focusing on the period between 2022 and 2023 (Figure 3). This timeframe helps us to separate the influence of these relations from other issues like COVID-19 related capacity problems and weather disruptions experienced during 2020-2021.

The years 2022 and 2023 were characterized by growing tensions and complex interactions between China, Taiwan, and the United States, driven by deep-rooted political conflicts and strategic interests.

The relationship among China, Taiwan, and the US experienced considerable strain in 2022. Notably, in April 2022, China intensified its military presence near Taiwan. By June, tensions escalated further when Taiwan's Foreign Ministry criticized Beijing for claiming the Taiwan Strait as part of its exclusive economic zone. The situation worsened with the US supporting Taiwan through weapons sales and House Speaker Nancy Pelosi's visit in August, leading to China conducting military exercises in response. During this period, our bilateral relations index between China and Taiwan shifted from neutral to a risker zone, correlating with fluctuations in the global semiconductor index.

The year 2023 witnessed varying levels of tension. Early in the year, spikes in tensions were observed, particularly around President Tsai's visit to the United States. Military tensions resurfaced in September. However, there was a notable improvement in relations later in the year, as diplomatic efforts between China and the US ramped up in preparation for the Xi Jinping-Biden meeting at the APEC summit in November.

Figure 3. **BBVA RESEARCH GLOBAL SEMICONDUCTOR INDEX AND CHINA-TAIWAN BILATERAL INDEX (2022-2023)** (NORMALIZED INDEX. POSITIVE VALUES STAND FOR RISK/NEGATIVE SENTIMENT, WHILE NEGATIVE VALUES FOR POSITIVE NEWS/EASING TENSIONS)



Source: BBVA Research and www.gdelt.org

These developments indicate a strong correlation between the China-Taiwan-US relations and the global semiconductor industry's stability. Understanding this relationship is crucial for policymakers and industry stakeholders to navigate the complex geopolitical landscape impacting this vital sector.

The Corporate Dimension: Who is exposed to Taiwan Semiconductors (TSMC)

Geopolitical Sciences and Economic Analysts have focused on the potential economic implications of a hypothetical conflict between China and Taiwan. A centric issue on the analysis has been the relevance of Taiwan on the world Semiconductor Industry through the Taiwan Semiconductor Manufacturing Company (TSMC) this is particularly relevant to produce chips for most sophisticated devices.

Rather than the evolution of news in isolation to analyze the systemic role of TSMC for the Semiconductor Industry, we build a network of global news. This strategy allows us to describe the potential relationships in the Taiwan Semiconductor Crisis news with the rest of the industry[4]. In essence we analyze who is specially linked to TSMC in the Semiconductor Industry. To do this, we use the GDELT database to analyze the co-occurrence of news articles of Semiconductor Companies, jointly with TSMC.

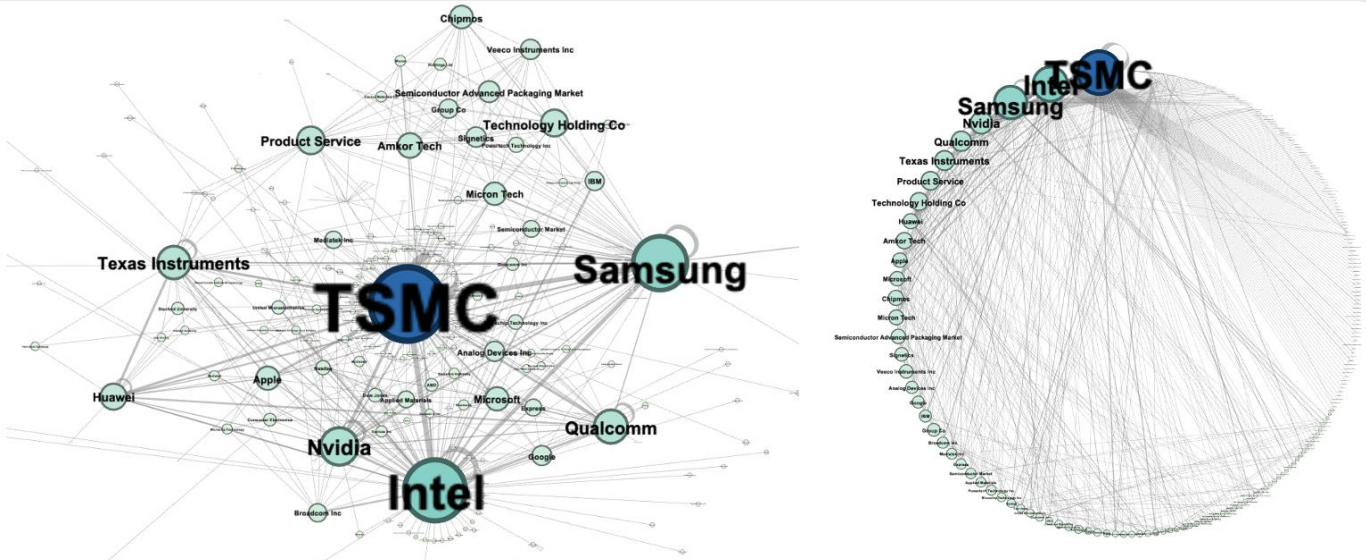
To understand the relation between Semiconductor corporations it is important to describe briefly how the Semiconductor industry is structured according to the business model and which phase of the semiconductor value chain operates. According to this, we can distinguish between:

4: For a comprehensive description of the use of Networks in Social Science see Imai, Kosuke. Quantitative Social Science: An Introduction (p. 205). Princeton University Press.

- **Semiconductor Foundry (Foundry) companies** which only manufacture devices for other companies (TSMC, GlobalFoundries & SMIC).
- **Semiconductor Fabless (Fabless) companies** which only design semi processors (Qualcomm, Broadcom, Nvidia, MediaTek, AMD...).
- **Semiconductor Integrated Device Manufacturers (IDMs) companies which** design and manufacture semi processors (Intel, Samsung, Power chip, Texas Instruments…).
- **Semiconductor Packaging and Testing (OSAT**) companies specialized in the crucial packaging and testing stages in the production process and following the manufacturing of semiconductor wafers (ASE, Amkor, JCET,).
- **Semiconductor Top Clients (Clients)** or private corporate clients, including large companies in the technology, consumer electronics, automotive, telecommunications and computing industries (Apple, Google, Sony, Dell, Amazon, Car Industry, LG, Huawei, medical equipment,).

A Network graph is a simple way to represent network data where nodes (vertices) represent units (i.e., companies) and an edge between two nodes indicates that a relationship exists between them. There are various centrality measures, including degrees, closeness and betweenness. These measures evaluate the extent to which each node plays a central role in a graph. As in this case we are interested in analyzing the systemic role of TSMC. We implement an algorithm to describe the size of each node, not only on the number of edges but also to consider the relevance of these connections of edges. The measure we use is the Eigenvector Centrality which accounts for the transitive influence of nodes. A high eigenvector score means that a node is connected to many nodes who themselves have high scores thus better reflecting the systemic nature.

Figure 4. **TSMC AND SEMICONDUCTOR CORPORATES NETWORK (2022)** (MULTI-GRAVITY FORCE ATLAS –LEFT- AND CIRCULAR LAYOUT –RIGHT- ALGORITHMS. NODE'S SIZE BY EIGENVECTOR CENTRALITY)



* Eigenvector Centrality is an algorithm that measures the transitive influence of nodes. Relationships originating from high-scoring nodes contribute more to the score of a node than connections from low-scoring nodes. A high eigenvector score means that a node is connected to many nodes who themselves have high scores.

Source: BBVA Research and www.gdelt.org

The results for news occurring during 2022 can be observed in Figure 4. Both networks reflect the relevance of the corporations in their relationship with TSMC and the semiconductor industry. As we imposed the algorithm to examine the links with TSMC, the networks reflect the higher centrality of the TSMC, but also show its relationship with the rest of the industry. The results for the rest of the companies display the following relevant links:

- **The Big IDMs (Intel, Samsung, Texas Instruments & Micron Tech) lead the network in terms of systemic relevance.** While IDMs typically have their own manufacturing capabilities, many of them also outsource part of their production to TSMC, especially for advanced process technologies that they might not have in-house. TSMC is an important supplier of certain advanced technology nodes.

- **Nvidia and Qualcomm (Fabless):** Perhaps the most significant clients of TSMC followed by other relevant fabless clients as Broadcom and AMD. Fabless companies focus on designing and selling hardware devices and semiconductor chips while outsourcing the fabrication (or 'fab') of these chips to foundries like TSMC.

- **Apple, Huawei, and Microsoft (Clients):** Large technology companies, especially those with a focus on consumer electronics, rely on TSMC for the fabrication of their custom-designed chips. Apple for example relies on TSMC for its A-series and M-series chips used in iPhones, iPads, and Macs) while Microsoft relies on both directly from some TSMC products and indirectly from Intel and AMD. Huawei has been a major client of TSMC, but it has been affected by the US restrictions, TSMC reportedly stopped taking new orders from Huawei in May 2020 and had to comply with the US regulations, which meant ceasing shipments to Huawei after a specified grace period.

- **Amkor Tech and Chipmos (OSAT):** Outsourced Semiconductor Assembly and Test (OSAT) companies generally do not directly contract with TSMC for chip fabrication but provide packaging and testing services for the semiconductor wafers produced by TSMC. Recently (November 30), Apple announced that Amkor will package the new Chips manufactured in Arizona.

The US Response to the Crisis: Funding and Re-Shoring?

As a response to the Semiconductor Crisis, the US Administration approved the Semiconductors and Science Act of 2022 (CHIPS Act), signed into law on August 9, 2022. The Act is designed to boost US competitiveness, innovation, and national security. Among other goals, the law aims to catalyze investments in domestic semiconductor manufacturing capacity.

The Act boosted the interest for the “Reshoring” (i.e. the process of bringing offshore business operations back to the company's home country). However, reshoring also poses challenges, including potentially higher costs of labor and materials, as well as the need to build or update the infrastructure necessary for these industries.

The NLP techniques can help us to track the sentiment and interest from a regional and local point of view. Rather than focusing on sentiments, we use here the interest on Boolean Google searches on Semiconductors by Google Trends as a proxy of the interest of different US states on semiconductors. According to Figure 5, the searches for Semiconductors by States, the ones with a higher intensity on Semiconductor searches were:

- **California and Washington State:** These traditional tech strongholds show a sustained high interest in semiconductor news. As major tech hubs, both states are poised to play crucial roles in semiconductor reshoring efforts.

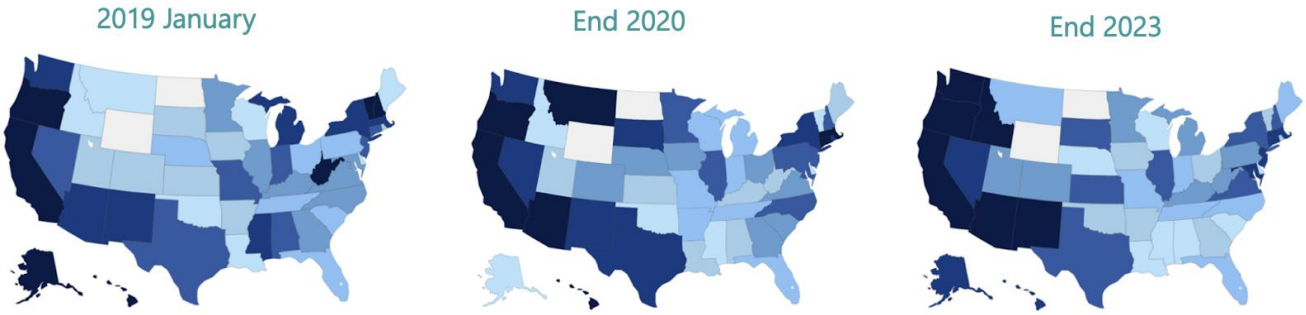
- **Oregon:** Particularly in the Portland area, Oregon's interest is driven by its status as a key location for Intel and a growing cluster of tech companies reliant on semiconductor supplies.

- **Northeast Corridor:** Massachusetts, at the heart of the Northeast Corridor and home to prestigious institutions like MIT and Harvard, shows a booming interest, reflecting its robust tech sector and significant semiconductor R&D activities. Neighboring states, including New York, also exhibit increased search activity, aligning with their growing roles in semiconductor manufacturing.

- **Texas:** Texas maintains a strong semiconductor manufacturing presence, with major companies like Texas Instruments and Samsung's large semiconductor plant. The state's interest is further fueled by Austin's burgeoning tech scene and Dallas's telecom sector.

- **Arizona:** Arizona's tech industry, bolstered by Intel's presence and TSMC's significant investment, including a $40 billion commitment for two new factories, shows a keen interest in semiconductor developments. TSMC's plans align with the CHIPS Act's objectives, highlighting Arizona's growing importance in the semiconductor landscape.

Figure 5. **INTEREST ON SEMICONDUCTORS IN US BY STATE (2022)** (GOOGLE TRENDS SEARCHES OF SEMICONDUCTORS IN THE US BY STATE. DARKER COLOR STANDS FOR HIGHER RELATIVE SEARCHES)



Source: BBVA Research and www.gdelt.org

Conclusions

The Global Semiconductor Crisis has been a multifaceted crisis driven by different factors. These include the US-China trade war, capacity challenges in the industry following COVID-19, adverse weather conditions from 2020 to 2022, and significant geopolitical events such as the tensions between China and Taiwan, and the Russia-Ukraine conflict.

From mid-2023, there has been a noticeable easing of some of these factors, such as the resolution of trade bottlenecks, increases in supply and recent diplomatic efforts between the US and China. The combination of all of them have positively impacted the Global Semiconductor Sentiment Index.

Geopolitical dynamics, particularly the relationship between China and Taiwan and the United States' response, plays a crucial role in the global semiconductor industry. This significance is further amplified by the pivotal position of Taiwan Semiconductor Manufacturing Company (TSMC), especially in the production of advanced chips, and the specialized value chain structure of the semiconductor Industry.

The exposure to China-Taiwan potential conflict and TSMC systemic risk has led some Governments to provide funding and to design restrictive policies and corporations to enhance re-shoring or near-shoring strategies.

While the situation has calmed down during the last six months, it should be closely monitored given the strategic nature of some of its drivers. The elections in Taiwan will take place early next year and recent problems in the main trade routes could expand.

In this context, leveraging Big Data and Natural Language Processing (NLP) techniques to analyze millions of semiconductor related news articles in real time becomes invaluable. These tools offer a comprehensive way to stay informed and understand the impact and propagation of shocks affecting the semiconductor industry.

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