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Semiconductor Supply: an Strategic Must for Technology Sovereignty in a Country like Spain

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Abstract—This paper summarizes the current worldwide crisis of chip supply chain: the context, how the situation has come about, the perspectives and the possibilities that a European country as Spain can have in the described international situation.

Index Terms—semiconductor, chip, supply chain resilience, strategic goods, manufacturing.

I. INTRODUCTION: GEOPOLITICS AND SEMICONDUCTOR INDUSTRY

The incapacity of setting a peaceful US-Russia relation in these days has stressed the idea that a new cold war has returned. Some world experts [1] think that a new era has started, in which the ideal of globalization has surrendered to big blocks pulling to their own interests: US and the Western block, on the one hand, and China-Russia on the other, either of which do not hide their intention to compete for a worldwide hegemony that involves politics and economy. As described in [2], it is evident that China has a displacement strategy against US, what was not so clear in the past. Thus, US has gathered its resources to restrain Chinese growth by setting alliances mainly with Eastern countries (e.g., QUAD agreement which involves Australia, Japan and India and AUKUS agreement which involves Australia and UK). This fact leaves the strategic connection with continental Europe as a secondary priority. In this context of “indirect confrontation” between blocks, the struggle for strategic resources plays a key role for hegemony. Today, apart from assuring the main energy resources, semiconductor industry has turned to be one of the most prominent strategic goods for national security, and consequently a political weapon above particular economic interests. This is the framework for the current crisis of chips supply chain, which is described in the present article with particular focus on Europe and Spain.

II. SEMICONDUCTOR MARKET SHARE: PRESENT AND FUTURE

Supply chain vulnerabilities has been identified in four key products, among them, semiconductor devices [3]. The global semiconductor market size reached $528 billion in 2021. It is projected to grow to $1,381 billion by 2029 according to Fortune Business Insights [4] and to $726 billion in 2027 according to the more specialized American Semiconductor Industry Association (SIA) [3]. The main chunk of the market consists of logic semiconductors processors (CPU, GPU, FPGA…) consisting of about 42% in 2020. American companies lead this part of the market. Memory chips (DRAM, NAND…) take up about 26%. Here Asian companies like Samsung take a significant share. Analog chip sector takes about 14%, with the remainder of the market comprised of non-integrated-circuit semiconductors: discrete, optoelectronic, and sensor devices [3]. From all these sectors, the only significant European presence lies in analog and non-integrated markets.

There is currently an imbalance between region-wise semiconductor industry market shares and the corresponding consumption. Thus, US firms take 47% of the global market share in 2020, whereas the region absorbs “only” the 22% of the consumption [5]. At the other end, Asia-Pacific (excluding Japan) has 32% vs. 61% respectively. Europe and Japan have a balance of approximately 10% at both respects.

III. WHEN MANUFACTURING GETS INTO THE SCENE

However, this imbalance in the favor of the US is not a sign of a position of strength when the manufacturing of chips comes into play. To get the bigger picture, the semiconductor companies are by and large grouped in three categories. Fabless companies design integrated circuits (e.g., US-based AMD, Nvidia, and Qualcomm); pure play companies (“foundries”) fabricate them; and Integrated Device Manufacturers (IDMs) (e.g. Intel, Samsung, and Texas Instruments) do both. Europe is currently a relatively small player in the design and manufacturing of integrated circuits. The main IDMs in the EU are Infineon, NXP and ST Microelectronics.

In this scenario, pure-play foundries account for about one third of global chip production capacity (nearly 80% for the most strategic logic chips). The Taiwan Semiconductor Manufacturing Company (TSMC) is the world’s most advanced foundry chipmaker and controls about 54% of the global market. The long path that these actors have followed to reach their leadership started long ago in the 1980’s with low-end product fabrication, building up a progressive investment and an accumulated know-how. Consequently, the
American global semiconductor production share has fallen from 37% to just 12% over the last 30 years [6]. In the logic chip segment, the US produces none of the leading edge (under 10 nm) chips, while Taiwan accounts for 92%. The most advanced semiconductor process node—currently 5 nm—is only manufactured by TSMC and Samsung. Following the same trend, European manufacturing share has decreased from 25% at the beginning of the 21st century to 10% [7].

Among the many reasons that may explain this tremendous decrease in Western manufacturing capability, one stands out: The US private market of venture capital and angel investing has focused primarily on software-platform based “tech” companies [8] and data analytics, which, ideally with fewer employees, have the potential to scale to billions in revenue. The side effect of this outlook is that of ignoring the semiconductor and hardware manufacturing space: no private entity will invest in basic infrastructure since no single entity will reap all possible rewards. On top of this, the US national, state, and local governments tax and regulatory policy makes investing in new manufacturing capacity for semiconductors incredibly difficult [8]. As regard to Western policies, the approach to domestic production has prioritized for years efficiency and low costs over security, sustainability and resilience, which has fostered in this way manufacturing outsourcing [3].

This situation contrasts with other nations’ policy, which offer tax credits and outsized deductions for investments in semiconductor tools. Examples of these policies include the Padis tax break program in Brazil, China’s tax holiday for up to 10 years to domestic semiconductor companies [8] etc. Furthermore, large-scale public investment in semiconductor fabrication has allowed other Asian firms, particularly Korean and Taiwanese, to outpace U.S. and European based firms. In this sense, South Korea’s and Singapore’s subsidies effectively lower the total cost of ownership of a semiconductor fab by approximately 25-30% [3]. In this respect, this progress represents a significant evolution for China.

IV. CHINA: A SIMPLE NEWCOMER?

China’s share of the global semiconductor industry is relatively small and its companies mostly produce low-end chips. However, the country is in the middle of major state-led effort to develop an indigenous industry that would lead in all segments by 2030. Although it is a figure difficult to pin down due to the complex interplay between investment funds and public funding in China, with tensions with WTO oversight, the Chinese government support for its domestic industry during the 2015-2025 timeframe could be as high as $200 billion. In this context, China recently announced a five-year support package of $143 billion starting at 2023 (approximately 3 times more than similar counterpart chip acts in US and Europe, respectively). If the current rate of spending holds, then, in a decade the US will be fabricating less than 10% of the world’s semiconductors and China will be fabricating nearly 30% [8]. The American SIA predicts the Asian production share will grow to 83% by 2030. The competition is fueled by the current export controls in the industry led by the US, which hinders Chinese production. The described trend has tremendous consequences for the entire sector and geography. Contrary to what happens in most industrial sectors, a particular feature of the semiconductor industry is that its manufacturing pole exhibits the capability to attract innovation due to the particular complexity of the manufacturing process. In the long term, it would be impossible to decouple innovation and fabrication.

V. THE RACE FOR INVESTMENT IN MANUFACTURING

To get an idea of the level of investment required to keep up, TSMC spent $40-$44 billion in capital expenditures in 2022. Consistently, Samsung, the distant second with a 16.3% market share, has recently announced a $132 billion investment plan to overtake TSMC as the world's top logic chipmaker by 2030. These outstanding figures are backed up by the fact that building a new, state of the art, mega fab from scratch is said to cost up to $20 billion. This budget is far from being a steady figure. Moore’s Second Law holds that the cost of constructing a semiconductor fabrication facility doubles every four years. In this sense, the Chips for America Act announced $52 billion [6] to catalyze more private-sector investments, whereas the European Chip Act of February 2022, considers public and private investments of €43 billion by 2030 [9]. However, is it as “simple” as pumping money in order to build a cutting-edge foundry to catch up?

VI. 360º VISION OF THE MEGAFAB IMPLEMENTATION

There are many aspects to ponder before choosing the place for a new foundry. It can consume as many as 100 megawatts of power, making it more energy intensive than many automotive plants and oil refineries, and can use as much water as a small city. Furthermore, the required gases, photoresists and chemicals (e.g., a memory chip requires over 400 chemical products) demand a cluster of production/service companies nearby. So far so good for the European case. However, Europe does not have a complete network of clients, suppliers, knowledge institutes [7] to definitively encourage semiconductor companies to establish a nearby presence, which in turn serves to increase the attractiveness of setting up a semiconductor-related business there. The inherent weakness is the low margin of the manufactured products: discrete semiconductor, optoelectronic devices, sensors and non-integrated circuit semiconductors mainly made for automotive and industrial sectors.

VII. THE EUROPEAN CHIP ACT

Synergies with US administration are not so clear. On the one hand, a US-EU Trade and Technology Council (TTC) has
been established to strengthen the global supply chain. However, when closely analyzed the American alliances [3] with other players (e.g., India, Australia and Japan), they seem to rank higher than the EU. As such, it is fairly obvious (and not an exaggeration) to state that Europe has to find its own way: The European Chips Act.

As described in the Act – which was proposed in February 2022 and voted in January 2023 – Europe will base its strategy on subsidizing the agents awarded by the title of “Integrated Production Facilities” and “Open EU Foundries”. After a centralized application process, once granted, they will be considered “public interest”. In exchange for public funding, The European Commission “may oblige (...) to accept and prioritize an order of crisis-relevant products”. It can also act as a “central purchasing body” for these products. Even if the member states are still considered accountable, there is a scaling-up of the problem in an effort to achieve critical mass and pool the available resources. The bottom line is laudable, although there are some points that are still difficult to articulate. The initiative stresses the idea of attracting private sector investment. However, one of the main disadvantages is that the EU has found itself incapable to offer comprehensive and attractive tax reduction incentives, as this matter is tied up by local regulations. From this point of view, one can gather the impression that some EU member states are at the same time independently seeking to attract investments to set-up megafabs, in particular with face to face deals with other IDMs. Thus, for example, Intel has its own investment plan over the coming decade in Germany (Magdeburg, €30 billion, the largest foreign direct investment in German history), Italy (€4.5 billion for back-end processes), France (new R&D and design hub), Ireland (Leixlip expansion project, an additional €1.7 billion) and Poland (€4.2 billion), which sets another “decentralized” growing vector in the continent. In this tension between the global politics and the private initiative, individual EU members may inadvertently create competition with other members in order to safeguard their own interest. Success will depend on the interplay between the European strategy as a whole and the interests of individual state members.

VIII. A CLOSER LOOK TO SPAIN

In the case of Spain, its “PERTE” plan has recently been released, setting aside €12.5 billion of public investment until 2027 to promote an integral ecosystem for semiconductors [10]. The biggest chunk in the budget will be geared to the manufacturing asp (€4,5 billion). The biggest chunk in the budget will be geared to the manufacturing asp (€4,5 billion). As described in the Act – which was proposed in February 2022 and voted in January 2023 – Europe will base its strategy on subsidizing the agents awarded by the title of “Integrated Production Facilities” and “Open EU Foundries”. After a centralized application process, once granted, they will be considered “public interest”. In exchange for public funding, The European Commission “may oblige (...) to accept and prioritize an order of crisis-relevant products”. It can also act as a “central purchasing body” for these products. Even if the member states are still considered accountable, there is a scaling-up of the problem in an effort to achieve critical mass and pool the available resources. The bottom line is laudable, although there are some points that are still difficult to articulate. The initiative stresses the idea of attracting private sector investment. However, one of the main disadvantages is that the EU has found itself incapable to offer comprehensive and attractive tax reduction incentives, as this matter is tied up by local regulations. From this point of view, one can gather the impression that some EU member states are at the same time independently seeking to attract investments to set-up megafabs, in particular with face to face deals with other IDMs. Thus, for example, Intel has its own investment plan over the coming decade in Germany (Magdeburg, €30 billion, the largest foreign direct investment in German history), Italy (€4.5 billion for back-end processes), France (new R&D and design hub), Ireland (Leixlip expansion project, an additional €1.7 billion) and Poland (€4.2 billion), which sets another “decentralized” growing vector in the continent. In this tension between the global politics and the private initiative, individual EU members may inadvertently create competition with other members in order to safeguard their own interest. Success will depend on the interplay between the European strategy as a whole and the interests of individual state members.

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As the local demand in the country is dictated by the automotive and general industry, different from the computation and processing, careful consideration should be given before implementing the envisaged massive investment. As the opinion of some experts, such as Alfonso Gabarrón, manager of the Spanish Association of the Semiconductor Industry (AESEMI), seem to point out, the local demand should drive the type of manufacturing for a balanced ecosystem. Thus, Spain being the second automotive European manufacturer and being the country with the highest number of manufacturing companies in Europe [11] are strengths that should be exploited. The European Semiconductor Industry Association (ESIA) announced that yearly semiconductor sales in the European market reached the record figure of $53.809 billion in 2022, a 12.3% increase versus the year 2021. The sector turns around automotive (37%) and industry (25%). These figures are higher than the worldwide average (10% and 12%, respectively). A new car, for example may require more than 5.000 semiconductors for touch screens, engine controls, driver assistance cameras etc, not to mention the estimated 14.000 required for a brand new electric vehicle. This being the case, it is worth recalling the recent dramatic impact that chip scarcity has made in the sector (estimated in €100 billion losses in Europe in the 2021-22 period).

One would think that having priority access to a chip manufacturing facility is required to ensure strategic supply for the industry. Unfortunately, the reality is not so simple as international dependency is inevitable. Chip manufacturing supply chain is so broad and includes so many processes (polysilicon grown into ingots, sliced into wafers, manufacturing of the circuit itself, die production, bonding, packaging…) that the semiconductor supply chain may cross international borders as many as 70 times before reaching its final destination [3]. The small size and weight of semiconductors is a factor that enables such a geographically and logistically complex supply chain—the costs of transporting them is minimal compared to their value. However, even with these constraints, focusing on less-advanced manufacturing like the one required by cars, which usually employ 40 nm technologies or more mature, may have a two-fold positive impact.

Firstly, 90% of current worldwide printed circuit board production is done in Asia, over half of which occurs in China. This fact sets the priorities to address foundries’ incoming orders, favoring neighboring ones at the expenses of foreign ones. Thus, in this situation the European board manufactures are relegated to uncertainty and are forced to retain unsustainable stocks of material in case of supply shortage
Therefore, setting a local fab in Europe would tend to balance the situation and back up local industry.

Secondly, in a country where there is virtually no previous experience on chip manufacturing, a medium range fab (e.g. 40 nm), even if it is not profitable in the short term, would serve as pole of attraction for more advanced technology in the future. The semiconductor industry is the second only to biopharmaceuticals as the world’s most R&D-intensive industry [3]. Creating and retaining talent is essential for a balanced ecosystem in a world where Electrical Engineers (EE) numbers are falling in favor of Computer Science (CS) engineers [13]. The quest for talent would be virtually impossible without this driving force in a sector where innovation follows manufacturing in the long term. It has taken 40 years for Taiwan to reach a top position in the world, signaling that the bottom-up approach is not the shortest, but the most solid. It is never too late to initiate the process to build up experience and local know-how as long as reasonable technology transfer agreements are set.

IX. A PLAN FOR THE FUTURE

The current strengths of the Spanish semiconductor industry are based on promising disrupting technologies such as the RISC-V project that would democratize microprocessor design out of the big corporations, and the photonic chip research that poses an alternative to the electronic chip. Without turning a blind eye on these potentials, the fact is that current European demand on current electronic chips is on high, as mentioned in the previous section, and meeting the current demand is a way to address the future. Traditional tax rate incentives to foster implantation of foundries (the “Irish way”) have been recently questioned within Europe along the OECD agreement on minimum corporate tax rates. It is expected though that the EU policy of subsidizing the sector, a real exception derived from its strategic value, will permeate national policy approaches, and the aforementioned Spanish PERTE is not an exception. However, companies establishing new chip fabrication facilities cite qualified labor and government regulations (including levels of bureaucracy) as key when selecting the location even above the amount of subsidies or tax incentives [14]. Once this public funding is already there, the challenge lies in attract private investment and that is what makes the difference. Following other European examples, the foundry of Leixlip (Ireland) has seen its investment grow step by step from 1989. In the last push, Intel has invested €17 billion in the Irish ecosystem. There are some contradictory signs on the Spanish case at this respect: on the one hand, its largest well-known infrastructure company Ferrovial SA has recently moved its HQ to the Netherlands among other reasons for the uncertainty of the legal framework. At the other end, the country has shown its capability to attract foreign investment like the recent implantation of ADIA lab, a worldwide reference for AI technology, in Granada as its European HQ.

Within this framework, the roadmap for the final implantation of a foundry of 40 nm to meet local demand may well consist of a long process. Firstly, a period of two years to set the regulatory basis to catalyze the implantation of the foundry while initial contacts are made. Secondly, one year of formal agreement negotiations with semiconductors corporations. Thirdly, five years of facility construction and talent hunting. Then, two years to improve the technical processes, make the way through the international market and gather experience. Finally, it is estimated that ten years more would be necessary for market share increase up to 25% of the European market. This twenty year envisaged process is similar to the one followed by other countries, like Taiwan or the closer Ireland. However, local industry could benefit from it starting in year ten. That makes the bid more appealing for local industries. Many of them could be ready to have their share on the future outcomes (their “technology sovereignty”) in exchange for part of the current provision of private investment that is expected to trigger the process now. In vision of the authors, the coordination of Spanish and European corporations, ready to assure their future supply in uncertain world-trade conditions, may well provide the private sector investment catalyzer that the country needs to make its technology sovereignty true. If other countries have managed to do so, Why not in this case?

REFERENCES


Bantec Group, “PERTE CHIP Microelectrónica y Semiconductores: Objetivos y Líneas de Actuación.”

Hit Horizons, “Breakdown of Manufacturing Industry in Europe.”

IKOR, “Interview with IKOR engineers,” 2022.

Tom Dillinger, “A Crisis in Engineering Education – Where are the Microelectronics Engineers?”

European Commission, “European Chips Report.”