

Mister Chips goes to Brussels: On the Pros and Cons of a Semiconductor Policy in the EU

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Abstract

Is making semiconductors in Europe a good idea? With the introduction of the European Chips Act in early 2022, this is no longer an academic question. In this article we evaluate these plans in light of a wider—but remarkably one-sided—debate on industrial policy in advanced capitalist economies. Instead of focusing on policymakers, as most students of industrial policy have done, we draw attention to two first-order conditions that determine the chances of policy success: the existence of (proto-)competitive incumbents, and the alignment of the policy objectives with the prevailing institutional framework. We rely on that framework to evaluate the successes and failures in European aerospace, German biotech, and French computers, before using these insights to evaluate the European Chips Act. Investing in manufacturing of mature chips is, in that light, not a good idea. We suggest, instead, that the EU should concentrate on market segments that leverage its high-skill workplaces and world-class research system, and in which Europe has either already developed a comparative advantage or will not find itself at an initial disadvantage.

In February 2022, the European Chips Act proposal finally saw the light of day. The background to the renewed attention to semiconductor manufacturing is provided by ongoing supply-chain disruptions that have caused costly stoppages in many manufacturing sectors, including cars. Not only did production plants in Asia, which produce more than half of the world's chips, close during the Covid-19 pandemic, but when they reopened, the surge in chip demand caused long supply bottlenecks, causing inflation and slowing Europe's economies. And although all countries support their semiconductor producers, over the past two decades manufacturing of computer chips in the EU has shrunk, in relative terms, from 24% to less than 10% of world production. Finally, ongoing geopolitical tensions have made Europe aware of its vulnerability to third-country import restrictions, stoking EU initiatives on industrial

policy to safeguard its sovereignty. Enter the European Chips Act.

In this paper, we ask if and how semiconductor production ('fab' in the industry jargon) is a viable economic activity in Europe. Making sense of that question requires a closer look at industrial policy more generally. Somewhat surprisingly, however, the existing debate on industrial policy gives us very few tools to answer the 'chips in Europe' question. The reason: most positions on industrial policy start from the perspective of the policymaker but ignore the needs and interests of the firms targeted by the policies in question. In addition, much of the debate revolves around an analysis of success stories—the Airbuses and DARPA's of the world—while blending out the failures of industrial policy, especially when policy is used to build new firms, networks of firms, or sectors. Finally, industrial policy

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proposals and their analysis have a strong *volontariste* character—in the French sense of the word, along the lines of ‘where there is a will (and enough money), there is a way’. Usually this entails attention to policy design, funding, and implementation.

Yet, policymaking does not take place in a vacuum: historical and institutional legacies matter in all policy (Gourevitch, 1986; Hall, 1986), and perhaps especially in industrial policy, where comparative (institutional) advantages (Hall & Soskice, 2001) and markets intersect. How else could we make sense of a series of well-documented industrial policy failures, other than by examining the institutional preconditions of economic policies (Berger, 1981; Zysman, 1994)? Why was Britain unable to resuscitate a collapsing car industry in the 1970s? Why have four decades of attempts by the powerful French state to construct a German-style dual apprenticeship system gone nowhere (Levy, 1999)? Or why is Germany, a world leader in high-end luxury cars and advanced machine tools (OEC/MIT, 2022), unable to support the emergence of a Microsoft or an Apple? Three strong states, with ample capacity in many areas, appear incapable of reforming some of the most essential elements of their industrial systems—but often we have little to say about that beyond some vague references to psychology, culture, or other ad hoc intangibles.

Our analysis of the semiconductor initiatives in Europe is informed by these critiques. We draw attention to two features that have been blended out in much of this debate. The first is the central role of firms as the implicit targets and ‘co-producers’ of industrial policy. The second refers to the constraints and opportunities associated with historically rooted institutional frameworks and their impact on policy implementation and firms’ strategies.

On balance, these considerations lead us to conclude that the EU faces a stark but ultimately easy choice. If it goes down the route of supporting the manufacturing of the mature semiconductors found in most consumer durables, it ignores two important elements. Because Europe’s existing capabilities in these parts of the value chain range from limited to nonexistent, they will need to be built from a low basis and at significantly greater cost than in other countries where governments offer heavy subsidies prohibited under current EU state aid rules. Manufacturing activities that rely on high volume and low cost also sit uneasily within the high-skill, high-wage economy that the EU is trying to build. If the semiconductor industry has a future in Europe, we think it will be either in the manufacturing of leading-edge chips or in other segments of the value chain such as R&D, advanced chip design, and advanced manufacturing equipment.

We start with a discussion of the intellectual framework that informs our argument. Section three examines three historical cases—two of success and one

of failure—against the background of our approach. We then take a closer look at the European Chips Act proposal in light of our arguments on industrial policy, before concluding with a few insights that follow from this analysis.

1 | POLICIES, FIRMS, AND INSTITUTIONS: THE NEED FOR CONGRUENCE

Although governments obviously matter in policymaking, the almost exclusive attention to the details of policy has obscured two crucial factors that can change the effects of voluntaristic industrial policy efforts. By defining industrial policy through goals and policies (Mazzucato, 2021), its students have generally ignored the role of firms in the process. Yet, how can there be an industrial policy without industry? After all, firms, not policymakers, create wealth and jobs (Porter, 1990).

This shifts part of the perspective to firms. To create value, firms need to develop competitive advantages, usually by leveraging resources and capabilities that are valuable, rare, hard to imitate, and non-substitutable (Barney, 1991; Teece, 1997). Some of those resources and capabilities are internal to firms, but many others depend on their ability to access and exploit ‘external’ resources that we often recognise as public goods, that is, services and goods that they can access without fully contributing to the cost of their production. By their very nature, such public goods are undersupplied and therefore require public intervention: the classical cases are skills, fundamental research, innovation systems more broadly, technology standards, technical infrastructure, and so forth (Hall & Soskice, 2001). Firms are crucial in industrial policy, in other words, but necessarily rely on tangible and intangible public resources that allow them to gain competitiveness.

This brings us, then, to the match between industrial policies and institutional frameworks. Institutions—sets of explicit and tacit norms that make an economy internally coherent (North, 1990)—serve two important functions in the context of industrial policy. The first one is the flip side of the needs of firms heralded above: institutions offer an organisational matrix for the provision of public goods. Without underlying ‘first-order’ institutions (Ferguson, 2013), many policies that build on them would fail: trade in markets requires rules that construct markets, such as property rights and terms of exchange, for example (Fligstein, 2001; Polanyi, 1944); and without strong employer associations and trade unions, a training system that balances the needs of firms and the autonomy of workers would be very hard to build (Finegold & Soskice, 1988). (Note that producing such associations is itself a collective action problem, as we know since Mancur Olson, 1965, which requires

its own version of institutional solutions). When these first-order conditions are met, however, the exchange of goods or the acquisition of skills becomes not only very simple but appears almost a 'natural' process.

Institutions also play another role in advanced capitalist political economies. They signal to firms which strategic pathways are supported and which ones are not (Porter, 1990; Whitley, 1999). Competitive and comparative advantages that firms develop therefore reflect the costs and benefits associated with the institutional constraints and opportunities that they face (Hall & Soskice, 2001; Zysman, 1994). Patent data for 1984 and 1994—10 years during which globalisation accelerated significantly—demonstrate the influence of institutions in company strategy (Casper et al., 1999). US firms specialised their innovation activities in those sectors that built on the existence of deregulated but deep capital markets and a provision of highly skilled labour receptive to high-powered incentives. The relative patent specialisation of German companies, in contrast, was a mirror image of the US, reflecting the patient capital markets and long-term, specific skill-based labour markets in the country. In short, firms align their strategic priorities with institutional incentives.

Ignoring institutions in industrial policy initiatives will, because of the central role they play in structuring economic action, therefore spell trouble. Government policies that go against the logic of existing institutions may simply not deliver the right signals or the right resources and capabilities to firms, who then spend significant internal resources on a doomed, failed, or otherwise deeply suboptimal strategy. For example, in the absence of supporting institutional arrangements, innovative companies in the US have been forced to deal with scaling up from prototype to mass production by themselves—and not always with positive results (Berger, 2015).

For industrial policy, the key institutions are those that govern competences, wages, and innovation (Rikap & Lundvall, 2021). They provide the highly specialised skills necessary to operate in high-tech industries, help generate the basic research that underpins new product development, thus bridging the gap between the lab and the fab. But these institutions have their own limits, which are sometimes difficult to overcome. Education and training systems, for example, are often organised around one of two sets of skills: either highly advanced, technology-specific skills or general skills. Industrial policy initiatives that rely on highly specialised skills and high productivity will most likely fail if labour markets are characterised by low productivity and low wages, and vice versa. And where labour institutions provide an abundance of high and advanced skills rewarded with high wages, policies that leverage such skills are much more likely to succeed. Similarly, innovation systems

are usually geared either toward upstream research or toward downstream development but are rarely strong in both. In countries that host world-class research institutions, policy initiatives aimed at supporting the introduction of radically new outputs are more likely to succeed than those that require the development and refinement of existing processes and outputs, and vice versa.

Industrial policy success, in sum, depends on meeting two first-order conditions: a potentially sizable share of firms that can leverage public goods to build new competitive advantages, and policies that are congruent with—and will often follow from—existing institutional frameworks. If only one of these is present, industrial policy can work if it can 'produce' the missing condition. When both conditions are absent, industrial policy alone will almost certainly fail.

These two factors can be thought of as a 2 × 2 matrix with four ideal typical situations. On one axis we have the (strong vs. weak) presence of a supportive institutional framework; on the other axis the existence (or absence) of firms that can leverage the public goods generated through skills, competences, and innovation institutions. Combining these two dimensions generates four types of situations. The cases where the two conditions are both present or absent are analytically the least interesting for industrial policy purposes. The first one encapsulates a situation with a thriving firm population and a supportive institutional environment. Because the interaction between institutions and firms already produces the desired outcome, industrial policies to support structural transformation are unnecessary. The second presents a situation with no or very few firms in the types of segments targeted by industrial policy and where the institutional framework is not well aligned with the needs of firms in that industry segment. Under these circumstances, industrial policy will be insufficient to overcome these deficiencies.

In our attempt to make sense of the future of semiconductors in Europe, the remaining two are the interesting cases. Each of these two situations, where one element is strongly developed but the other is weak, has different implications for industrial policy. The one characterised by some pre-existing firms with potential for enhanced innovation capabilities but little institutional backing, provides incentives to create an institutional infrastructure to support further development of the sector and attract additional or new investment. In the other case of a suitable institutional structure but few or no firms in the targeted market, industrial policy efforts also have a chance of succeeding, but primarily when they are aimed directly at stimulating entrepreneurship. This simple framework, which identifies first-order necessary conditions, helps us understand past success and failure and sheds a light on the prospects of industrial policy for semiconductors in Europe.

2 | SUCCESS AND FAILURE IN EUROPEAN INDUSTRIAL POLICY

The two broad conditions in our framework can take many forms in different settings, depending on historical factors and the functional requirements of the industries in question. The European aerospace industry, which follows a standard ‘vertical’ (i.e. sector-focused) industrial policy model, has led to the successes of Airbus: many existing small but advanced companies based across large Western EU countries that were almost certainly unable to survive on their own in rapidly growing markets for mass air tourism were integrated into one multinational consortium built on the comparative (institutional) advantages of each of its members. The international company thus benefited from financial and technical industrial policy support through Brussels and the EU member states (Thurow, 1992), whereas the constituent sites of the consortium across the continent, in economies as diverse as France, Germany, the UK, and Spain, were able to exploit specific local institutional advantages (Storper & Salais, 1997). In addition to the provision of quite advanced training for engineers and skilled workers in these countries, these internal suppliers could also build on the strengths of different local technology transfer regimes and of local training systems.

The German biotech industry between 1990 and the late 2000s offers an enlightening example of a different case, where potentially competitive firms existed but where many of the supportive elements were absent, and where, after an initial failure, industrial policy was instrumental in shaping a new subsector. Initially, German ventures into biotech were off to an auspicious start. The number of biotech firms in Germany grew from 52 in 1994 to 332 in 2000, with employment in the sector rising from less than 4000 to more than 10,000 (Casper, 2007: 82). Supported by generous innovation funding—the biotech industry received the bulk of public venture capital or \$527 million between 1996 and 2000 (Casper, 2007: 80)—the sector grew rapidly. After 2000, though, total numbers rose slightly before falling to 350 companies and from more than 13,000 to 10,000 employees in the sector. The explanation for these sudden problems lies in the institutional framework of the German economy. The country lacked deep capital markets, to which firms could turn for initial public offerings; as a result, they remained dependent on very high-cost venture capital. In addition, the highly regulated labour market produced two obstacles to the emerging sector. Not only did strict employment protection legislation make flexible workforce adjustment nearly impossible in a sector with high levels of uncertainty; it also prevented substantial pay differentials within the companies for different groups of employees. Combined, the institutionalised financial and labour market restrictions spelled doom for this new sector.

When the basic underlying technology stabilised, however, the product market differentiated into two very different segments, with different supporting institutional requirements (Casper, 2007: 136). The first, so-called ‘therapeutic’ (i.e. drug-centred) market segments, in which German companies had had a promising start but which they were ultimately forced to abandon, were dominated by a technology regime with three defining characteristics: appropriability (the potential to patent) played a large role; cumulative R&D was not very relevant (most new drugs were newly synthesised); and the knowledge base for innovation was highly codifiable (drug development and testing followed strict protocols). The second, ‘platform’ biotech markets were almost the exact opposite, with low appropriability (including ‘soft’ knowledge that was difficult to patent), highly cumulative R&D (innovations built on the previous generation of innovations), and with a significant share of tacit knowledge residing in employees and between companies. Often such platform technologies take the shape of stored ‘libraries’ of advanced modules that can be customised to match the client’s needs.

Relying on the exact same newly orchestrated industrial policy measures as in the first wave—public funding, university spin-offs, and public–private joint ventures—German companies migrated, almost invisibly at first, from the therapeutic to the platform market segment: instead of making drugs themselves, they produced advanced tools for companies specialising in therapeutics (Casper, 2007: 141). This form of innovation requires close links between companies—the DNA filter producer, for example, needs to understand and anticipate the trajectory of its drug-developing counterpart—but also between engineers and managers within the company, because the former hold detailed, often diffuse, knowledge of the product. The relative stability in inter-firm relations and the large, stable markets also lend themselves more to long-term, patient capital markets of the sort usually associated with Germany. And the inclusive team- or company-based work patterns in platform technologies invite firms to adopt a group-based incentive scheme that is much more compatible with prevailing labour-market norms than the steep individual bonus systems. Building on their presence in these specialised platform niches, some German biotech companies became world leaders in their markets in the late 2000s, posting revenue and profits well above the industry average (Casper, 2007: 144 ff.).

Interestingly, both the early demise and subsequent growth in the sector reflect the specific institutional frameworks—in which longer term, stable product markets matched the long-term capital and regulated labour markets. And although policies did not change much, the strategic reorientation of the sector benefited from the presence of necessary capabilities among existing firms built up over the first 10–15 years in the

sector. Combined, industrial policy, institutional framework, and incumbency produced first significant problems and then a success in a high-tech industry.

Industrial policy failures teach us almost as much as successes. The *Plan Calcul*, launched in 1966 and abandoned in the early 1980s, was France's attempt to match US prowess in computers and to protect its young domestic industry from takeovers (Mounier-Kuhn, 1995). Over the next 10 years, the Gaullist governments launched several initiatives in education and training in the new sector and organised state-led mergers and acquisitions. Between 1967 and 1975, the French state subsidised the venture at the rate of (then) 300 million Francs (adjusted for inflation ca. €316 million in 2020; see Forest, 1971: 20), after which subsidies to the newly formed company CII Honeywell Bull shot up for several years to FF 2 billion annually (ca. €2.1 bn today). The state also used its public procurement system to favour French firms, and by the end of the 1970s, subsidised many companies in computer peripherals and software. But to no avail: the sector permanently limped behind the US giants in PCs—IBM, Apple, and Intel. In the early 1980s, the *Plan Calcul* was silently abandoned, and the state retreated from the sector, leaving a small number of relatively well-performing telecommunication companies but no viable French or European computer industry.

Several complementary explanations exist for this failure. In an industry that required agile exchanges of information between different groups of employees inside and outside the company, French organisational culture, built on hierarchy and low trust, impeded performance (Zysman, 1977). In addition, the Plan was a classic top-down French plan, thought out in Paris by distant elites without any business experience in this or related sectors. But most importantly, perhaps, existing French firms were very weak in the sector—that was why industrial policy had become necessary in the first place. In short, none of our conditions for a successful industrial policy were present in the case of the *Plan Calcul*. Failure was preordained.

These three examples—Airbus, biotech, and computers—suggest that our framework is useful to understand past successes and failures of industrial policy in Europe. If incumbent firms are strong and product market strategies dovetail with existing institutions in skills, wages, and innovation, industrial policy is not necessary. If one condition—capable and potentially competitive firms, or a broader institutional framework aligned with the objectives of the policy—is present, an industrial policy that is organised around constructing the missing or weak dimension can provide a basis for the development of those industries. If none are present, industrial policy will almost certainly be expensive and ineffective, because of the many inertia-producing forces. What, then, does this framework suggest about the current semiconductor initiatives in the EU?

3 | THE POSSIBILITIES FOR SEMICONDUCTORS IN EUROPE

Without semiconductors the digital economy would not be possible. Chips are the building blocks of current and future infrastructures and applications including 5G/6G telecommunications networks, smart energy production and distribution networks, transportation systems, supercomputing, cloud computing, and AI. Industrial policy is an essential component: since the industry's emergence in the 1950s, there is probably not a single country that has not resorted to active industrial policy (Sandholtz, 1992).

Perhaps the most basic feature of the semiconductor industry is its high-capital and research intensity. R&D expenditure as a percentage of revenue ranges between 15% and 20% (European Commission, 2020). Building a state-of-the-art fab can cost up to €20 bn, and operating costs of such a fab can run as high as €5 bn per year (Codagnone et al., 2021). Developing advanced chips for a flagship cell phone can cost up to €1bn. This high level of capital and research intensity has driven concentration and specialisation: although the US once dominated the industry, today no single firm or country has all the resources and capabilities to control the entire value chain. The world's capacity to manufacture leading-edge logic chip manufacturing (i.e. nodes smaller than 10 nanometres or nm) is concentrated in only two countries: Taiwan's TSMC, with 92%, and South Korea's Samsung, with 8% (Varas et al., 2021). This level of concentration in terms of countries and firms makes the industry very vulnerable to disruptions caused by sudden shifts in demand, geopolitical tensions, health crises, and natural disasters. Moreover, as digitalisation has accelerated, governments have become increasingly aware of the risks of missing out on a €440 billion industry (European Commission, 2021; Breton, 2021) with very strong growth perspectives.

Governments have responded by announcing industrial policy plans of unprecedented size. The *Made in China 2025* strategy has pledged \$150 billion over 10 years (Codagnone et al., 2021), and the CHIPS for America Act has set aside \$52 billion in federal investments between 2022 and 2025 (US Congress S1260, 2021). The level of investment in support of the European Chips Act is estimated at more than €43 billion by 2030 (European Commission, 2022).

The proposed European legislation addresses concerns about innovation, production, and supply-chain security through three mutually reinforcing programmes: an industrial programme focused on research for chip design and deployment; a funding programme for 'first of its kind' facilities (an ambiguous term that covers any type of activity not currently conducted in Europe, which could include mature semiconductor nodes as well as other types of activities such as packaging and

testing); and a set of measures by which recipients of EU funding would commit to share critical business information with EU authorities and prioritise the fulfilment of EU orders in the event of a supply-chain crisis.

Expanding Europe's presence in semiconductors makes political sense. Semiconductors is a strategic industry for advanced economies: the US considers it critical for economic and national security (H.R. 4521, The America Competes Act of 2022). Growing geopolitical tensions, including the war between Russia and Ukraine, two of the world's largest producers of some of the raw materials for semiconductors, increase the risk of supply-chain disruptions, with negative effects for important European industries.

A priori, the idea of expanding Europe's presence in the semiconductor value chain also makes economic sense. Not only is demand growing, but the semiconductor industry combines several characteristics that could make it one of the few high-tech sectors where the continent thrives. The chips sector features (some) high value-added products, requires high-quality design and production and high-level workforce skills, and takes place in very specialised manufacturing settings (clean rooms). Because Europe already excels in a few of these segments, such as R&D, some types of manufacturing equipment, and AI chip design, it would seem to be in a strong starting position.

There are important obstacles, however. Start with the European Chips Act's ambitious policy goal of increasing semiconductor production from the current 10% of global supply to 20% by 2030. Because the global industry is expected to double in size by that year, this would mean quadrupling current production capacity—a huge challenge, not least because of the recent history of semiconductors in Europe. In 2013, the New European Industrial Strategy already stated the same goal with an original deadline of 2020–2025 (Electronic Leaders Group, 2014; European Commission, 2013). The verbatim repetition of this goal a decade later, and under more challenging circumstances, should give pause.

Moreover, the economics of semiconductor fabs are complicated. Manufacturing plants have extremely high set-up costs, and because margins per chip are small, fabs can profitably operate only at very high levels of capacity, approximately 90%–95% (CLEPA, 2021). Demand for chips is hard to predict, however, and can vary significantly across the lifetime of a product. Risks derived from demand fluctuations are compounded by the rapid introduction of new generations of semiconductors and 2–3-year lead times between investment decisions and the moment a fab comes online. In other words, boom-and-bust cycles are almost baked into the structure of the industry. In addition, although digitalisation across different economic activities is expected to vastly increase demand for chips across most industries, demand and supply bottlenecks caused by the Covid-19 pandemic are expected to persist throughout

2022. Leading producers Samsung, TSMC, and Intel have responded with plans to increase their production capacity (including in leading-edge chips) in the US and Japan, which could make it difficult for Europe to attract investment and accurately forecast the evolution of markets.

In the standard view of industrial policy, these practical and economic problems require good policy, a good policymaker, and a lot of money—in this case provided through the EU's Important Projects of Common European Interest (IPCEI), which funds projects with a common European benefit. That also seems the most likely trajectory of the European Chips Act. But our framework suggests that understanding the problem requires a very different perspective. Many semiconductor projects, now and in future, have suffered from the same latent limitations: the weakness of existing incumbents; the low level of public subsidies in the EU compared with those offered by other regions; and, in the case of the relatively simple memory and analogue chips, the comparably greater weight of labour compared with knowledge and skill intensity.

The first of these addresses the weakness of existing firms. Although Europe has some production capacity in chips, no single European firm is among the world's 10 largest producers. In an industry based on economies of scale, this absence of scale of European manufacturers is a major obstacle. Although cross-country European alliances may alleviate the problem somewhat, the limited size of European chip demand (ca. 10% of global demand) and its fragmentation across different types of chips, means that producing at scale for the European market alone will be very difficult. Looking for markets beyond the EU will not be easy either because it will require seizing market share from well-established rivals. Moreover, although Europe has a strong record of fostering cross-country alliances, it took the 2018 microelectronics IPCEI three years to get off the ground: in other words, although EU alliances could overcome the scale problem, building and sustaining them turned out to be almost as problematic as the issue they were trying to solve in the first place.

The up-front investment costs are likely very important as well. Although the variety of semiconductor products in terms of maturity, function, and customisation makes a calculation difficult, a recent study by the Center for Security and Emerging Technology in the US estimates that meeting one-fourth of global demand for 3 nm nodes in 2023 would require building two new 35,000-node fabs at a cost of \$24 billion each.

Attempts to boost profitable manufacturing of older memory and analogue chips would be even more difficult than focusing on leading-edge chips because these chips are less knowledge- and more labour-intensive than the latter. Europe's institutional framework, with comparatively high wages and low levels of subsidies owing to state aid rules, makes the region a

priori not very suitable as a location for production in a sector with low profit margins. Some estimates suggest that the cost, over a decade, of operating a fab with an annual production of 35,000,300mm wafers in Europe is 33% higher than in South Korea and 63% higher than in mainland China (AT Kearney, 2021). In sum, if chips have a future in Europe, it is not in mature nodes.

But European firms can (and do) thrive in very different segments of the industry besides fabrication. Currently, it is competitive in three related markets. One, the development and production of state-of-the-art manufacturing equipment. Another is AI chip design, in which new European firms do not compete directly with well-established foreign incumbents, as they do in mature chip segments and leading-edge logic chips. And a third case is more generally R&D in semiconductors. These examples of a propitious future in semiconductors combine three features of Europe's broad institutional framework: a world-class research infrastructure, an advanced skills system, and a suitable environment to perform knowledge- and skill-intensive scale-up functions.

The successful cooperation between the Interuniversity MicroElectronics Center (IMEC) and ASML, the world's leading manufacturer of lithographic equipment, is a case in point. With more than 5000 research scientists from 95 countries, a €2.5-billion-euro, 300mm semiconductor pilot line, more than 600 world-leading industry partners and a global academic network (IMEC, 2021), IMEC has been deemed 'one of the most essential industrial research-and-development centres on the planet' (The Economist, 2021; Van Den Abeele, 2021). IMEC has a strong record of generating boundary-pushing innovation through collaboration with specialised European firms. IMEC's 30-year research partnership with ASML has been instrumental in developing Extreme UltraViolet (EUV) machines, the world's most advanced lithographic tool. Today, ASML is the world's only producer of EUVs, which enables the European company to control a critical node in the semiconductor value chain.

4 | CONCLUSIONS

This paper has examined recent European policy initiatives in semiconductors from the perspective of industrial policy successes and failures over the past few decades. Making mature chips at the low end of the market, when very few firms today do so competitively in the EU, and in an institutional framework that broadly aims for a high-wage, high-skill economy, strikes us as a poor strategy. In the absence of both competitive and comparative advantages, making mature chips is best left to those who already make them—even if that means that we occasionally face bottlenecks. But Europe's disadvantages in one market segment also offer advantages for expansion into another.

World-class research and training institutes allow the continent to leapfrog into advanced chip design, manufacturing equipment, and fabrication of cutting-edge AI and quantum chips—all activities that benefit from what Europe already has and what it has to offer. The European Chips Act is a welcome step in that direction, but we think it should concentrate on those parts of the value chain in which European firms have already established a competitive position.

This conclusion sheds a wider light on current discussions of 'Open Strategic Autonomy', broadly the idea that Europe should develop the ability to secure its own production (and defence) when standard trade and cooperation no longer does. The fundamental question on OSA is not if Europe would benefit from more capacity in some industries such as semiconductors, but whether that is a good idea given the starting point. Scaling up fab capacity to what is needed (or even just half of that) would be an immensely expensive endeavour, with very small returns. Furthermore, decades of international economic integration have forced countries to hone their comparative advantages based on indigenous skills and innovation capacities. Returning to a future that the EU never had therefore seems to have more to do with misplaced nostalgia than with strategic thinking. In the case of semiconductors, we think, the future lies in becoming a central player in supplying necessary, high value-added tools, products where technologies are stable, or in markets that are not yet fully established. Mastering advanced design, development, and manufacturing is a much stronger insurance against geopolitical hold-ups and supply-chain crises than semi-autarchy. Because such products are strategic bottlenecks for others that compensate for Europe's dependence on them, mutually guaranteeing supply is in both parties' interest.

This leads to our final point, about industrial policy more generally. Thinking about industrial policy is often reduced to analyses of industrial policy-makers and their abilities. But industrial policy has, in the most literal sense, a past and a future. Policy is always made in a historical context, which finds its expression in institutional frameworks that offer opportunities and impose constraints. Although we do not know what exactly is possible, these frameworks offer a good guide to what is *impossible*: go against them, and you will surely fail. Industrial policy also casts a shadow forward, because of how it requires firms to use the resources that policies and institutions offer. If those firms are very weak or simply do not exist, industrial policy faces an uphill battle. Again, we do not know what type of industrial policy may succeed in any given area, but we do know that the absence of (embryonically) competitive firms spells trouble. In sum, industrial policy is deeply embedded in existing historical processes and economic structures. Thinking about industrial policy, both as

policymakers and as observers, should therefore reflect that.

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