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Article

Self-sustaining or sustaining cooperation? How Europe can ensure access to semiconductor technologies

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Policy Debate of the Hour

Self-Sustaining or Sustaining Cooperation?

How Europe Can Ensure Access to Semiconductor Technologies*

Key Messages

- R&D in the semiconductor industry is concentrated in a few countries: Japan, Korea, China, the United States, and Taiwan
- European countries' R&D cooperation centers around Europe and the US, with relatively little cooperation with Asia
- Diversifying R&D partnerships may secure access to R&D hubs and key technologies
- Policymakers can strengthen diversification by establishing adequate framework conditions
- Focusing on Europe's comparative advantages can give it a competitive edge and greater bargaining power in global value chains



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Semiconductor products, commonly known as computer chips, are an essential component of any electronic device. The scope of application ranges from communications and computing to transportation, military systems, clean energy, and health services, to name but a few. They are also an important intermediate input for the production and delivery of virtually any good or service (Hillrichs and Wölfl 2026). Without semiconductors, our modern world would basically come to a standstill. Moreover, they are the basis for numerous new technological developments and innovations, such as artificial intelligence (AI) or quantum computing. Therefore, interest in the semiconductor industry and its value chains stems to a lesser extent from the industry's direct contribution to employment or production

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value, but rather from its importance as an input in all other industries and for technological progress (Gros 2026).

Since semiconductors are important determinants of the final product, producers often have specific requirements for the semiconductors they use, and there is often a strong link or cooperation between final producers and semiconductor companies. This is especially true in the design of semiconductors, which marks the first step in the value chain. Therefore, it is in the interest of a developed economy to be able to advance and shape research and development (R&D) in the semiconductor industry.

In principle, there are two strategies to ensure access to key technologies such as semiconductors. The first is self-sustainability, or autarky, which means covering all aspects of R&D and innovation within the country itself to achieve full self-sufficiency. However, this is costly, particularly for a heterogeneous product such as semiconductors with their globally spread value chains, since the advantages of international specialization are forgone. The second strategy is international cooperation. By collaborating with researchers and research institutions in R&D clusters worldwide, the advantages of international

specialization can be harnessed and knowledge and technology transferred.

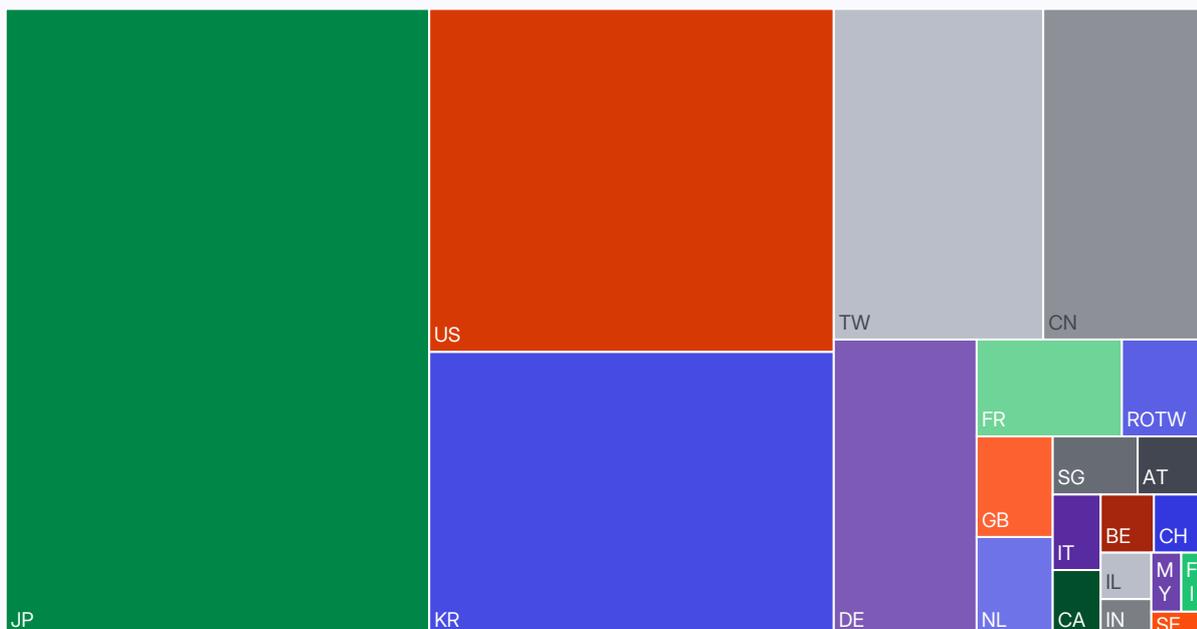
International cooperation can ensure access to technologies, even if a country does not have mastery over all aspects of a given technology. This is analogous to the international trade system. In the era of globalization, complex international supply chains have emerged. These supply chains have bottlenecks, but everyone depends on each other, creating incentives for cooperation. With cooperation crumbling amid a changing political climate, calls for greater self-sufficiency are growing louder. However, as Pinelopi Goldberg describes, diversifying cooperation can also lead to greater resilience (Wulfers 2025).

Identifying Global R&D Patterns in the Semiconductor Industry

This article takes stock of global R&D in the semiconductor technology field. As described above, access to semiconductor technology is crucial for developed economies. We use patent applications as a proxy for R&D and innovation activities. A patent grants exclusive rights to a technical result or process that provides a new way of doing something

Figure 1

Regional Distribution of Semiconductor R&D Based on Patent Applications, 2000–21



Note: Fractional counts of patent families (minimum of two applications) by inventor location, 2000–21. ROTW = rest of the world. Source: PATSTAT; authors' calculations.

or offers a new technical solution – that is, an invention. Typically, a patent application is filed if the applicant anticipates commercial potential from the invention.

We use the PATSTAT database from the European Patent Office (EPO), which contains information on over 150 million patents from more than 100 authorities. Our dataset contains worldwide patent applications filed between 2000 and 2021 that were assigned to the technical field of semiconductors. This field contains not only patents relating directly to semiconductors or computer chips, but also relating to production processes, materials, and the like.

To avoid double-counting inventions, our analysis is based on patent families. A patent family is a set of patent applications in different countries covering the same or similar technical content. We restrict our analysis to patent families with at least two patent applications to ensure global technological novelty and relevance.

We assign a patent to a country based on the location of the inventors listed in the patent document. If all inventors are located in the same country, one patent is counted for that country. If a team of four inventors, for example, has two members located in country A and two in country B, then 0.5 patents are counted for each country (fractional

counting). The location of inventors indicates where the research that led to the patented invention took place. Therefore, we interpret the number of semiconductor patents allocated to a country based on inventor location as a proxy of the size of its semiconductor R&D activities.

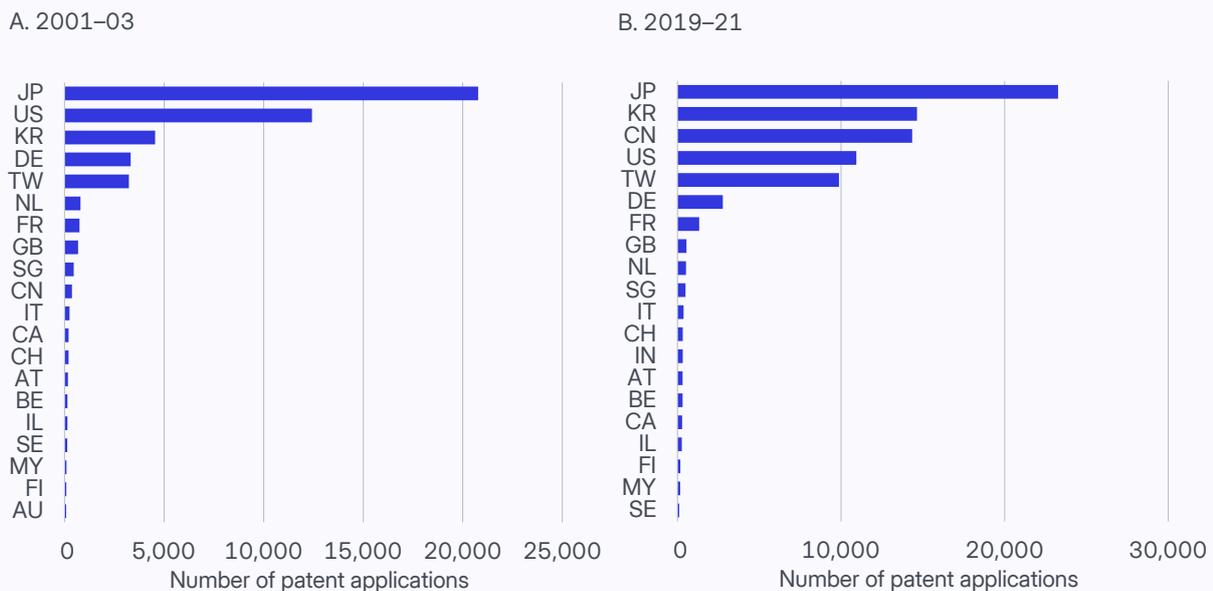
Strong Regional Concentration

The first insight from this data is that semiconductor R&D is strongly regionally concentrated (Figure 1). Over the past 20 years, the top 20 countries have accounted for 99 percent of all semiconductor patents, and the top seven for 93 percent.¹ Of the top 20 countries, 10 are European, together accounting for just under 12 percent of semiconductor patents. Germany has the highest share of semiconductor patents among European countries at 5.6 percent, followed by France at 1.9 percent, and the Netherlands and the United Kingdom at 1.0 percent each. Austria, Belgium, Finland, Italy, Sweden, and Switzerland each have a share of between 0.2 and 0.5 percent.

¹ The top 20 countries in alphabetical order of PATSTRAT country codes are: AT – Austria, BE – Belgium, CA – Canada, CH – Switzerland, CN – China, DE – Germany, FI – Finland, FR – France, GB – United Kingdom, IL – Israel, IN – India, IT – Italy, JP – Japan, KR – Republic of Korea, MY – Malaysia, NL – Netherlands, SE – Sweden, SG – Singapore, TW – Taiwan, US – United States of America.

Figure 2

Regional Distribution of Semiconductor R&D Based on Patent Applications: Top 20 Countries in 2001-03 vs. 2019-21



Note: Fractional counts of patent families (minimum of two applications) by inventor location. Source: PATSTAT; authors' calculations.

A comparison of the earliest three-year period (2001–03) with the latest (2019–21) in our data reveals hardly any change in the top 20 list (Figure 2). Only one new country, India, entered the top 20 at position 13, pushing Australia out. The biggest winners were Korea and China. Korea tripled its number of semiconductor patents, climbing from third to second place and overtaking the US. Starting from a low level, China increased its number of semiconductor patents by a factor of 39 and its share from 0.8 percent to 17.6 percent, thus moving up from tenth to third place. Conversely, European countries lost ground. Their share of semiconductor patents decreased from 13.3 percent to 8.3 percent. Germany, formerly a runner-up to Korea, fell from fourth to sixth place, with its share in semiconductor patents decreasing from 6.8 percent to 3.4 percent. The Netherlands’ share of semiconductor patents decreased from 1.6 percent to 0.6 percent and the United Kingdom’s from 1.4 to 0.7 percent. All other countries’ shares remained relatively stable.

International Cooperation

Next, we differentiate between domestic patents, where all inventors are located in the same country, and international patents, where at least one inventor is located in a different country. Since the total number of patents varies greatly by country, we show the shares of domestic and international patents for each of the top 20 countries, adding up to 100 percent (Figure 3). The left panel shows the shares for the three-year period from 2001 to 2003, and the right panel shows the period from 2019 to 2021.

Several aspects are noteworthy. First, the share of international patents is lowest among the top Asian countries (Japan, Korea, Taiwan, and, more recently, China). Second, European countries, as well as more recently the US, have relatively high shares of international patents. Third, the pattern of Chinese patents has changed significantly. While nearly half of all Chinese patents were international in the

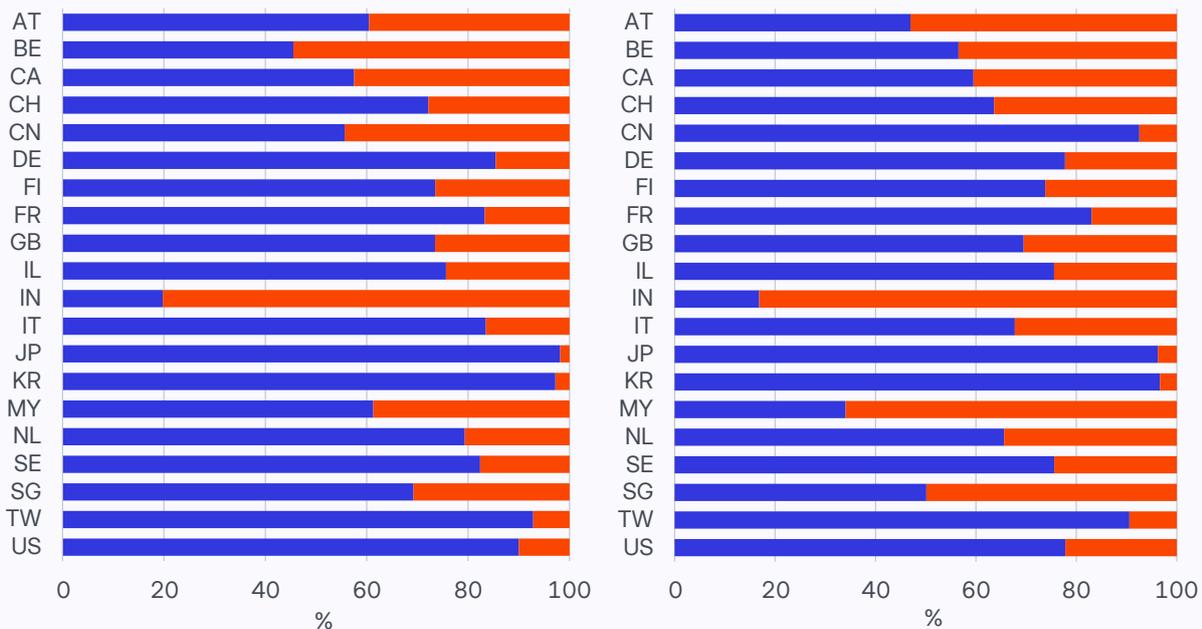
Figure 3

Patterns of International Cooperation in Semiconductor R&D Based on Patent Applications: Top 20 Countries in 2001–03 vs. 2019–21

■ Domestic ■ International

A. 2001–03

B. 2019–21



Note: Patent families (minimum of two applications) by inventor location. Source: PATSTAT; authors’ calculations.

Table 1

Difference Between Actual and Potential Shares of International Cooperation by Country Pair, 2000–21

	AT	BE	CA	CH	CN	DE	FI	FR	GB	IL	IN	IT	JP	KR	MY	NL	SE	SG	TW	US
AT		0.5	-0.1	3.2	-5.7	48.8	-0.1	-1.0	-0.2	-0.2	0.3	0.2	-26.5	-9.1	1.4	1.2	0.7	0.0	-5.7	-5.5
BE	0.4		0.4	0.8	-1.0	4.2	2.1	4.3	1.4	0.0	1.2	0.8	-23.4	-7.7	0.0	14.2	0.9	0.3	-1.1	4.3
CA	-0.3	0.3		0.0	1.4	-1.5	-0.2	0.8	1.9	0.5	3.1	-0.1	-22.9	-5.5	0.3	0.0	0.0	0.9	-1.4	24.8
CH	4.1	1.2	0.2		-4.6	19.7	1.1	8.4	2.4	0.2	0.9	2.5	-24.3	-7.6	-0.1	2.4	1.1	1.4	-6.1	-0.8
CN	-0.4	0.6	1.1	-0.1		-3.2	0.1	-0.9	0.0	0.3	3.0	0.1	-14.8	-0.2	0.6	-0.3	0.0	2.1	8.2	12.9
DE	12.2	2.0	0.6	4.2	-3.8		0.1	3.2	2.6	0.4	1.1	1.0	-21.9	-6.5	2.0	4.5	0.4	1.2	-3.1	7.2
FI	-0.3	8.6	-0.4	3.2	-1.0	-0.6		0.4	4.0	-0.2	2.6	2.0	-19.4	-7.2	0.0	4.4	1.6	1.8	-1.3	3.7
FR	0.0	4.1	1.6	5.1	-3.1	9.3	0.2		2.6	0.1	2.1	2.8	-23.3	-8.7	-0.1	4.0	0.2	0.6	-3.9	10.1
GB	0.1	1.5	2.0	1.6	-2.3	6.2	0.8	2.1		0.7	1.8	1.5	-21.8	-8.5	0.5	3.5	0.5	1.0	-4.7	15.9
IL	-0.3	0.2	1.3	0.3	0.0	0.4	-0.1	-0.7	1.7		2.7	1.1	-20.6	-5.9	0.0	0.4	0.0	0.5	-2.4	23.2
IN	-0.3	0.4	1.4	0.0	2.4	-2.5	0.2	-0.1	0.3	0.4		0.3	-22.7	-4.9	0.9	0.6	-0.1	2.1	-0.1	23.6
IT	0.6	1.7	0.2	3.3	-1.7	4.4	0.9	5.7	3.3	1.0	2.4		-22.9	-5.7	0.3	3.4	0.2	0.1	-1.9	6.8
JP	-0.2	0.1	0.1	-0.1	-1.0	-2.9	0.0	-1.1	-0.3	0.0	0.8	-0.1		15.8	0.4	-0.3	-0.1	1.2	11.3	11.4
KR	-0.3	0.0	0.1	-0.1	-1.6	-3.4	-0.1	-1.4	-0.6	-0.1	0.8	-0.2	2.0		0.4	-0.6	-0.1	1.1	10.8	9.4
MY	1.3	-0.2	0.2	-0.3	-1.3	5.0	-0.1	-1.6	0.0	-0.2	2.4	-0.1	-19.3	-3.4		-0.6	-0.1	8.8	5.9	5.5
NL	1.1	11.8	0.4	1.6	-3.8	12.2	0.9	3.6	3.5	0.2	2.2	1.6	-23.4	-9.2	0.0		0.3	-0.2	-4.5	4.5
SE	3.4	4.7	0.7	4.1	-1.3	5.6	2.0	0.8	3.2	0.0	0.7	0.5	-24.7	-8.8	0.1	1.7		0.2	-1.8	10.7
SG	-0.2	0.0	0.4	0.3	0.7	-1.7	0.1	-1.0	0.0	0.0	2.4	-0.3	-16.8	-1.1	3.8	-0.7	-0.1		8.4	8.2
TW	-0.4	0.1	0.1	-0.3	0.7	-3.8	0.0	-1.4	-0.7	-0.1	1.0	-0.2	-5.5	8.7	0.7	-0.6	-0.1	2.1		10.2
US	0.0	0.7	1.9	0.2	1.8	-0.4	0.1	0.1	1.1	0.7	3.8	0.3	-7.8	5.9	0.8	0.4	0.1	2.0	8.8	

Note: Values indicate percentage point differences.
Quelle: PATSTAT; authors' calculations.

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first three-year period (2001–03), less than 10 percent were international in the last period (2019–21). At the same time, the pattern of patents by inventors in India, the other BRIC country in the top 20, remained largely unchanged: about 80 percent of patents were international in both time periods.

We interpret the developments of China and India within the context of technology transfer. It seems that both countries used to rely on international cooperation for new technologies. This appears to still be the case for India. Despite entering the top 20, most of its R&D is conducted through international cooperation. In contrast, China has successfully pursued a tech transfer strategy to catch up to the international technological frontier. China has facilitated knowledge transfer by sending students and researchers abroad, attracting international talent, acquiring foreign tech firms, and lately also through return programs for Chinese scientists working abroad. Having caught up to the technological frontier, China today possesses the

knowledge and capacity to push the frontier forward independently.

Technology transfer via international collaborations can take place across different companies and organizations, or within the same company in teams of researchers based in different locations. The literature on the economics of innovation has shown that knowledge spillovers are highly localized and that agglomeration and cluster formation are key characteristics of R&D and innovation activities. Even today, the importance of personal interactions for knowledge spillovers persists, also in technology-intensive fields (Atkin, Chen and Popov 2022; Abou El-Komobz, Fackler and Goldbeck 2024). Therefore, innovative companies seek proximity to research institutions and other companies in the same or complementary fields to tap into local knowledge and benefit from knowledge spillovers.

The next obvious question is which countries cooperate, and to what extent. To answer this question, we proceed

in three steps. First, we calculate a cooperation potential based on a country's share in all global semiconductor patents. For example, Japan accounts for about one-third of global semiconductor patents – or global semiconductor R&D. Therefore, one might expect all other countries to conduct one-third of their international R&D projects in cooperation with Japan, ignoring all other factors such as geographic proximity, language, or subfield of semiconductor R&D. Second, we calculate each country's actual share of international R&D projects conducted with the other countries. Third, we subtract the potential shares from the actual shares. If the resulting value is positive (negative), this indicates that the countries cooperate more (less) than the purely size-based potential would suggest (Table 1).

Table 1 should be read by line. Each field shows the calculated percentage point difference for cooperations with the country named in the column header. Reading the line for Germany, for example, reveals positive values, marked in purple, for most countries. This means that Germany has more collaborations with these countries than one might expect based on their share of R&D. There are negative values for cooperation with China, Japan, Korea, and Taiwan. Thus, Germany has fewer cooperations with these countries than expected based on their share of R&D.

The country co-inventor matrix reveals an interesting pattern:

- European countries cooperate more with each other and with the US than the potential shares suggest.
- Most countries cooperate substantially less with the top Asian countries than might be expected based on their large share in R&D.
- The US is the most important cooperation partner for nearly all countries.

Conclusions and Policy Implications

There are two main strategies for increasing the resilience of supply chains and access to key technologies: autarky and diversification of cooperations and supply chains. The EU Chips Act of 2023 targeted the former. Its measures mainly aim to strengthen the European semiconductor ecosystem across the entire value chain and for all types of chips. Relatively little attention has been given to the second strategy so far.

Our analysis of semiconductor technology patents has shown that, although there is strong cooperation within Europe, relatively few collaborations take place between Europe and Asia's semiconductor hubs. Thus, there is potential for Europe to profit from new technologies

and knowledge created elsewhere. Policymakers can strengthen diversification of cooperation and technology transfer by setting adequate framework conditions. This may include student exchange programs, attracting foreign talent by facilitating work and residence permits, and increasing opportunities for cooperation with non-EU countries in EU programs. Of the Asian countries in the top 20, only Korea is associated with Horizon Europe, the EU's primary funding program for research and innovation. Korea became the first Asian country to join Horizon Europe in July 2025.

Regarding semiconductor R&D in Europe, it may be worth abandoning the idea of doing everything in lieu of a more focused approach.

- First, there is probably no need for direct support for the types of semiconductors that are currently in demand by European industries (mature chips). Policy support should be limited to favorable framework conditions.
- Second, the focus should be put on semiconductors for key technologies capable of solving major societal challenges and creating growth in the future. Since the benefits of these technologies will only become apparent in the future and will be broadly distributed throughout society and the economy, incentives for private companies to invest in these fields will likely be insufficient, justifying direct support. However, before providing support, clear goals or missions must be defined (Bunde, Czernich and Falck 2025; Javorcik and Plekhanov 2026).
- Third, focus on Europe's comparative advantages. Germany and the Netherlands are net exporters of semiconductor-related equipment (Hillrichs and Wölfl 2025). The Dutch company ASML, for example, is the sole supplier of the photolithography machines needed to manufacture the most advanced chips (Gros 2026). Assessing its comparative advantages and creating a competitive edge in these areas may make Europe a sought-after partner and increase its bargaining power in other areas of the value chain. •

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