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What can Europe learn from China's critical-tech innovation push?

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What can Europe learn from China's critical-tech innovation push?

Alicia García Herrero and Michal Krystyanczuk

Executive summary

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THIS POLICY BRIEF examines China's rapid ascent in frontier innovation across artificial intelligence, semiconductors and quantum computing, and the most important companies behind these breakthroughs. In these three areas, the United States leads overall, but China continues to narrow the gap and now excels in areas including semiconductor fabrication, AI video and audio processing and aerial vision. China lags the most in quantum computing. The European Union lags significantly behind both the US and China in patent breakthroughs, with slightly better relative performance in quantum.

WHEN IT COMES to the diffusion of such breakthroughs, Chinese and US innovators are much faster than their European counterparts at replicating novel patents from other countries. European innovators take more than twice as long to replicate US or Chinese breakthroughs, whether in AI, semiconductors or quantum. That Chinese replication happens nearly as rapidly as US replication, even in areas subject to strict export controls, is another signal of China's rapidly advancing innovation capabilities in critical technologies.

CHINA STANDS OUT in terms of the diversity of companies and institutions that dominate the filing of novel patents. In the US, breakthroughs are heavily concentrated in the big-tech companies. Novel patents originating in the EU are filed by a mix of companies and public research centres, with the telecoms sector dominating more than in other geographies.

FURTHERMORE, CHINA IS MOVING up the ladder in homegrown innovation in basic research. This is offering an edge, especially in semiconductors, to which China has dedicated huge energy and funding resources. By contrast, Europe's fragmented markets and reliance on public research limit scale and hold back commercialisation. To close the gap, Europe must increase research and development in critical technologies while further integrating its national innovation ecosystems.



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1 Introduction

Supremacy in critical technologies, in particular artificial intelligence, semiconductors and quantum computing, has become a cornerstone of economic and strategic power. These technologies underpin everything from autonomous weapons to climate modelling. Control over them shapes global supply chains, national security and economic resilience.

China's ascent in these technologies has been so quick that there is a general belief that it might already have caught up with the United States, guaranteeing the self-reliance that China has long pursued¹. For example, the groundbreaking release of DeepSeek's cost-efficient, open-source AI model in early 2025, which outperformed benchmarks from US giants such as Meta while navigating chip export restrictions, reinforced the perception that China is rapidly outpacing the US in AI innovation. The European Union, meanwhile, is considered to be lagging when it comes to generating breakthroughs in these technologies (Draghi, 2024).

In this Policy Brief, we show, based on analysis using large language models (LLMs; García Herrero *et al*, 2025a), where China stands on AI, semiconductors and quantum computing compared to the US and the EU. We assess the three economies according to their basic research in these fields and examine how quickly each replicates breakthroughs patented by innovators in the others. This question is important because if such technological spillovers happen rapidly, they can mitigate the consequences of a lack of breakthroughs for countries or regions that are not at the frontier of critical technologies.

Finally, we look at the companies or research institutions that create most of these breakthroughs, and how they differ in China, the US and the EU. Our analysis of this is based on García Herero *et al* (2025b).

China appears to be succeeding in AI, semiconductors and quantum computing, though with some caveats. Understanding how China has managed to move up the innovation ladder so quickly, and why the EU may have fallen behind, is crucial if Europe is to design a more effective innovation strategy in these technologies. A better strategy will help close the gap between the EU and the US and, in many cases, between the EU and China.

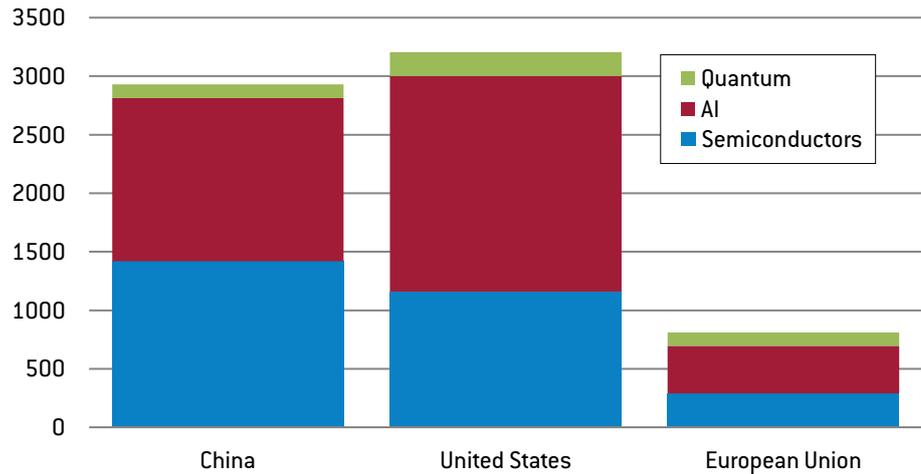
2 Where does China stand?

Since 2019, numbers of Chinese patent filings in AI, semiconductors and quantum computing have skyrocketed, but, up to 2023, China had not yet outstripped the US (Figure 1)². In terms of patents for 'radical novelties', which we define as new patents for which there are no prior similar patents and which are then repeated at least five times in subsequent patents (García Herrero *et al*, 2025a), China is second after the US in AI and semiconductors. The EU is in a distant third place, except for quantum technologies, for which the EU and China are about on par in terms of radical novelties, though both are still very much behind US.

1 Justin Riggi, 'How China Is Outperforming the United States in Critical Technologies,' *Innovation Files*, 23 September 2025, Information Technology & Innovation Foundation, <https://itif.org/publications/2025/09/23/how-china-is-outperforming-the-united-states-in-critical-technologies/>.

2 Patent data goes beyond the end of 2023, but our approach requires at least an additional year to identify a patent as a radical novelty as it must be replicated five times to fulfil the criteria.

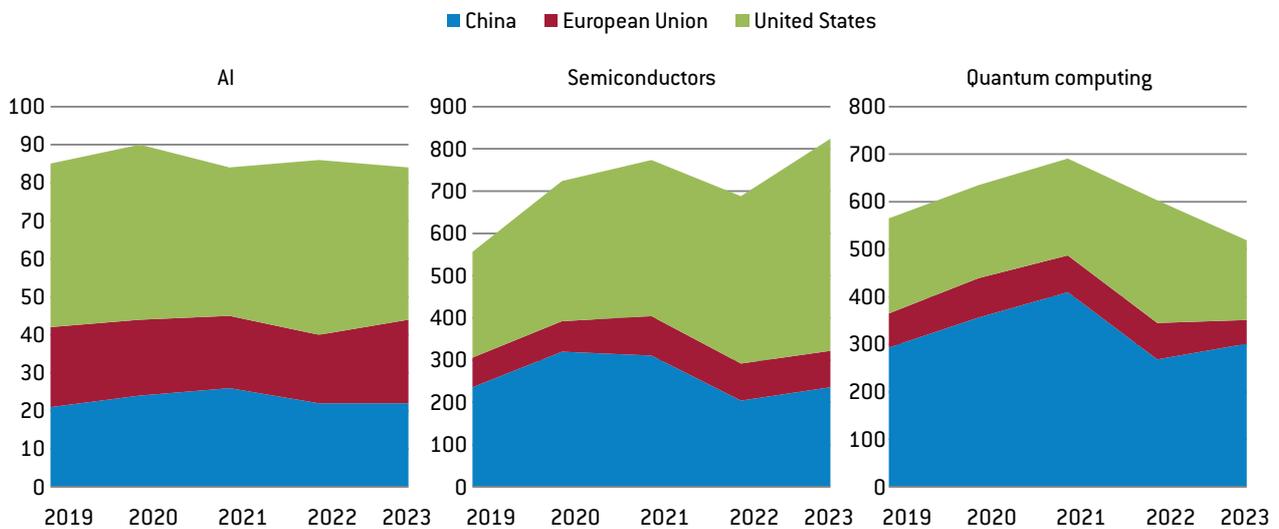
Figure 1: Radical novelties by company headquarters (2019-2023)



Source: García-Herrero *et al* (2025a). Note: see the text for a definition of a 'radical novelty'.

Chinese progress is particularly evident in semiconductor-related radical novelties, followed by AI and, to a much lesser extent, quantum (Figure 2). The US clearly dominates quantum. It also dominates AI, although China is getting closer. For semiconductors, China seems to have moved into the lead but we miss two major players in this field in our analysis: South Korea and Taiwan. These are closer to the US ecosystem and feed it with breakthroughs not captured in our analysis.

Figure 2: Evolution of radical novelties, 2019-2023



Source: García-Herrero *et al* (2025a).

However, dominance of a field as broad as AI, semiconductors or quantum computing may not be very informative. Figure 3 on page 5 summarises a more granular analysis of sub-fields of these critical technologies.

Starting with AI, China has made the greatest strides in computer vision for surveillance and autonomous systems. China is responsible for over 40 percent of China/US/EU radical novelties in these fields. China's comparative advantage in these areas has quickly moved to implementation, with the rapid implementation of smart-city digital infrastructure that pro-

The US tends to dominate the most advanced subfields, including machine learning, chip design, materials engineering and quantum systems control

cesses millions of data points daily³. In drone and aerial vehicle AI, Chinese firms lead with 55 percent of all of the China/EU/US breakthroughs. In particular, China has been pioneering swarm intelligence for logistics, surpassing the US, let alone the EU⁴.

In semiconductors, China's lead is anchored in hardware-intensive and production-oriented subfields. In these areas, China accounts for 65 percent of total novel patents filed by China, the EU and the US, with a clear focus on 3D stacking for high-density memory (García-Herrero *et al*, 2025a). This technology is critical for cutting-edge AI devices, meaning that China could probably produce AI chips if it did not face other constraints, especially in lithography⁵. China's rapid chips upgrade has been accompanied by very strong governmental support through programmes such as *Made in China 2025*⁶. The expansion from semiconductor manufacturing and materials to robotics and automation also reflects a deliberate strategy to internalise formerly imported capabilities, turning industrial coordination into a technological multiplier.

The field in which China seems to lag the most is quantum. The US dominates most of the quantum subfields, especially quantum computing. Nevertheless, China excels in some quantum subfields, such trapped-ion systems for scalable sensors that enhance precision measurement for applications such as earthquake prediction (Omaar and Makaryan, 2024).

While China has clearly moved up the ladder in critical technologies, the US remains dominant overall for two reasons. First, the US tends to dominate the most advanced subfields, including machine learning, chip design, materials engineering and quantum systems control. Second, the US has a more vertically integrated structure, focusing on deepening algorithmic and design specialisation, which can then serve as basis for hardware breakthroughs. This interconnection accelerates diffusion across technologies. For example, algorithmic improvements in AI enhance chip design, while advances in quantum control feed back into computing architectures. The same companies and institutions often operate across these boundaries, sustaining innovation cycles even if manufacturing is offshored. The result is an ecosystem in the US that is less diverse than China's, but hard to replicate because it retains control of the design, optimisation and data integration stages, which generate the greatest spillovers throughout the value chain.

Europe remains strong in select subfields, including robotics, medical AI, power electronics, lithography and quantum photonics, but these strengths are clearly more fragmented and isolated than those of the US and China. Opportunities for the EU to catch up emerge in complementary niches. In quantum photonics, the EU has 28 percent of China/US/EU radical novelties, which is more than China. In AI ethics and explainable models, the EU trails minimally at 18 percent versus China's 20 percent, with novelties in bias-mitigation frameworks that align with the EU General Data Protection Regulation (GDPR, Regulation (EU) 2016/679), offering a pathway to exportable standards. For semiconductors, Europe's 15 percent share in lithography understates a clear advantage, bolstered by Dutch company ASML's near-monopoly on extreme ultraviolet (EUV) tools (VerWey, 2024).

All in all, the advantages enjoyed by the US and China advantages are different but both strong, while the EU lags. China's concentration in manufacturing-related technologies

3 Ni Tao, 'From Sensors to Smart Cities: China's Digital Leap Forward', *CKGSB Knowledge*, 17 July 2025, Cheung Kong Graduate School of Business, <https://english.ckgsb.edu.cn/knowledge/article/china-smart-cities-digital-evolution-at-scale/>.

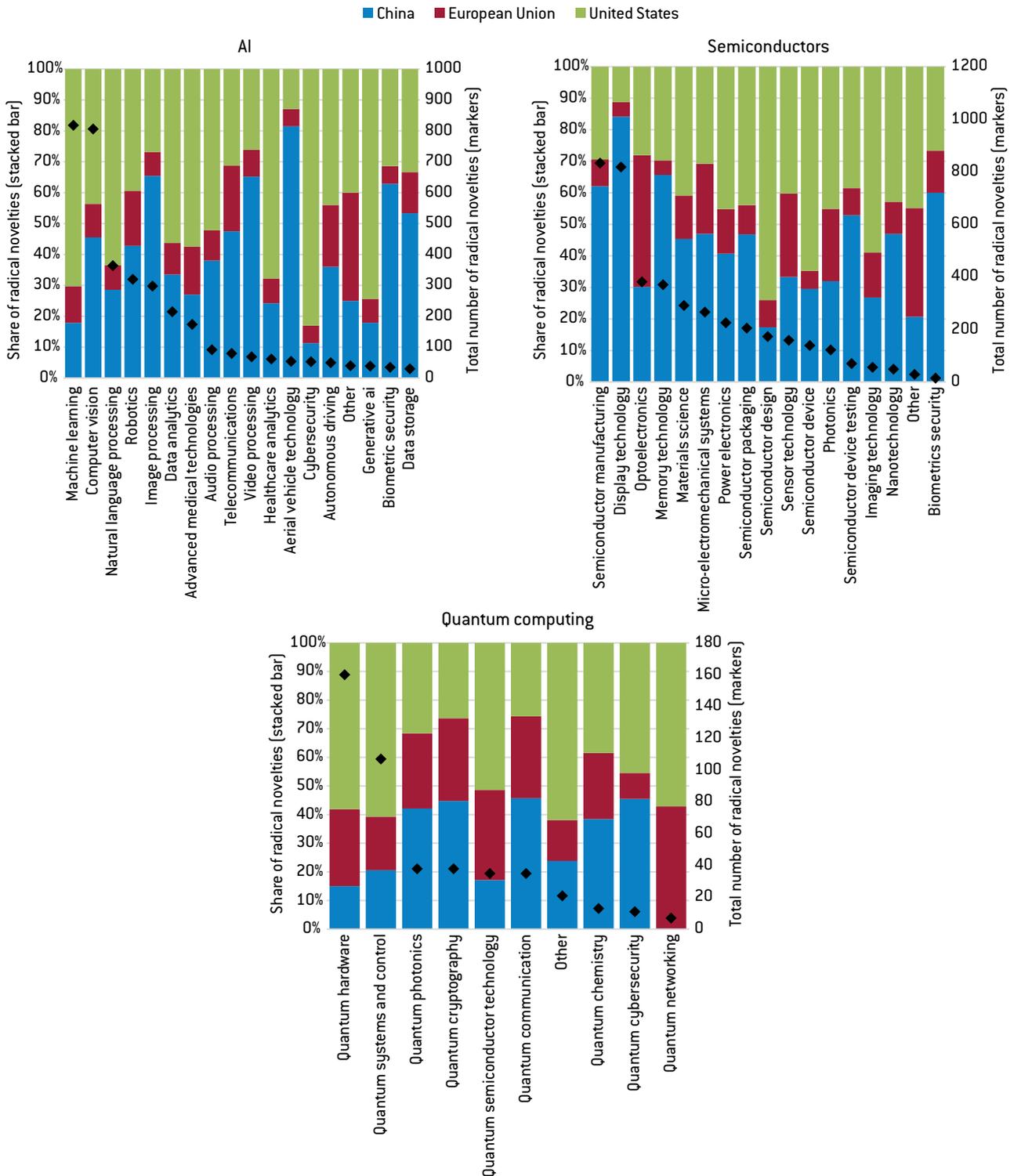
4 Evelyn Cheng, 'AI integration gives China supply chains an even greater advantage', *CNBC*, 4 June 2025, <https://www.cnbc.com/2025/06/04/cnbc-the-china-connection-newsletter-china-supply-chains-ai-edge.html>.

5 Jacob Wentz and Anita Lin, 'Breakthroughs or Boasts? Assessing Recent Chinese Lithography Advancements', *Blog Post*, 24 September 2025, Center for Strategic and International Studies, <https://www.csis.org/blogs/strategic-technologies-blog/breakthroughs-or-boasts-assessing-recent-chinese-lithography>. Note, the numbers of patents originating in Taiwan and South Korea (not included in our analysis) are also likely very large.

6 See for example, Kaiser Kuo, 'Made in China 2.0: The future of global manufacturing?' *Deep Dive*, 26 June 2025, World Economic Forum, <https://www.weforum.org/stories/2025/06/how-china-is-reinventing-the-future-of-global-manufacturing/>.

underpins its capacity to scale up following the logic of industrial breadth. The United States achieves rapid feedback between design and application through tight integration. Europe's flatter profile reflects excellence in individual areas but weak connectivity. In other words, Europe exhibits depth without density or scale.

Figure 3: Evolution of radical novelties by subsector



Source: García-Herrero et al (2025b).

3 Which companies are driving innovation?

Innovation ecosystems in China, the US and the EU differ sharply (García-Herrero *et al*, 2025b). Chinese innovators by type are much more diverse than in the US, while Europe lies in between, though it relies more on public research centres.

In the US, tech companies dominate the whole spectrum of radical novelties. Microsoft, IBM, Intel and Qualcomm stand out for involvement in multiple critical technologies, while Micron Technology, Google and Amazon also among the top-ten US innovators by number of novel patents. This high concentration in tech is a risk, but also offers the advantage of fostering synergies. Furthermore, this concentrated ecosystem, backed by the world's largest venture capital market, ensures rapid commercialisation, though it risks siloing innovation in the digital realm, rather than diversifying across industries.

US companies are strongest in design and software-driven areas. In particular, AI companies including Microsoft, Google, IBM and Nvidia lead breakthroughs in machine learning and natural language processing, while Amazon focuses on applied natural language processing. In semiconductors, US companies innovate more than Chinese or EU companies in chip design, materials and power electronics, with Intel, Qualcomm, Applied Materials and Micron building a dense network of cooperation across the value chain⁷.

In quantum computing, IBM, along with some key universities, leads in hardware and control systems, combining research with early commercial products. These links between AI, semiconductors and quantum show strong cross-sector spillovers, helping new ideas move fast from labs to market. For example, Google's Willow quantum chip, built with advanced semiconductors and AI error correction, enables quick qubit scaling for battery and drug simulations, with open-source tools speeding lab ideas to market in minutes for tasks beyond classical supercomputers⁸.

The heavy concentration of tech companies in the US innovation ecosystem for critical technologies points to the US's real strength: the deep integration of research, engineering and commercialisation. This translates cutting-edge science into scalable technologies. This is especially true for critical technologies because their ecosystems reinforce one another: AI depends on advanced chips and quantum progress relies on AI-assisted design.

However, the concentration of basic research in a few companies also has limits. First, smaller innovations are easily captured by the big-tech companies, which might inhibit new routes, potentially leading to technological path dependence. In other words, the dominance of tech companies, while positive in terms of synergies, may stem from innovation by smaller players that cannot compete with such big companies, and which are quickly taken over by those tech companies, making it difficult to move into different innovation paths. Second, the realms of scientific excellence tend to be closely linked to what these companies need: digital and algorithmic technologies, with less attention paid to industrial or hardware applications. In sum, the US critical technology ecosystem is successful but narrow. For the US to stay ahead, maintaining its speed and depth in 'research and development might not be enough, unless wider participation across industries is fostered.

In semiconductors, US companies innovate more than Chinese or EU companies in chip design, materials and power electronics

7 See Applied Materials news release of 22 May 2023, 'Applied Materials Convenes Leaders from Industry, Academia and Government at "Summit to Advance Semiconductor Leadership"', <https://ir.appliedmaterials.com/news-releases/news-release-details/applied-materials-convenes-leaders-industry-academia-and/>.

8 Hartmut Neven and Vadim Smelyanskiy, 'Our Quantum Echoes algorithm is a big step toward real-world applications for quantum computing', *Google Blog*, 22 October 2025, <https://blog.google/technology/research/quantum-echoes-willow-verifiable-quantum-advantage/>.

Table 1: Top-ten US critical tech patentees

Artificial intelligence	Semiconductors	Quantum computing
Qualcomm	Onsemi	Zapata Computing
Oracle	Texas Instruments	University of Maryland
Nvidia	Qualcomm	Rigetti
Microsoft	Microsoft	Red Hat
Micron	Micron	Microsoft
Intel	Lumileds	IonQ
IBM	Intel	Intel
Google	IBM	IBM
Amazon	Applied Materials	Google
Adobe	Apple	Amazon

Source: García-Herrero *et al* (2025b).

Contrasting clearly with the US, China has a balanced mix of private and public entities, but its true differentiator is the involvement of very different companies from varied sectors, making the ecosystem more diverse and with different types of synergy. While Huawei dominates all three breakthrough fields (AI, chips and quantum), underscoring its importance, there is much greater variety in types of companies working in these areas than in the US. Innovation champions in semiconductors (TCL Technology, Changxin Memory, Yangtze Memory and SMIC) coexist with telecoms giants such as Huawei, but breakthroughs also come from, for example, Ping An, an insurance firm, which leads in AI novelties for predictive health analytics, adapting models from finance to biotech for nationwide telemedicine.

Tech platforms including Tencent and ByteDance innovate in video-processing AI, but so do robotics players Autel and UBTECH, pioneering quantum-enhanced sensors for industrial automation. Consumer goods firm Haier contributes to efficient cooling for data centres. This diversity – spanning more than 15 sectors with tight industry-academia ties, such as via Tsinghua University’s hubs – enables diffusion into areas including surveillance AI and e-commerce logistics. China’s model incentivises any firm with high R&D intensity, via industrial policy programmes such as ‘Little Giants’ (García Herrero and Krystyanczuk, 2024).

China’s more diverse ecosystem has a different strength to the US: it blends industrial policy with market experimentation. Public funding and coordination provide direction, while private firms compete to deliver practical applications at scale. The result is a fast-moving innovation base that links digital technologies with manufacturing, in line with national priorities.

Table 2: Top-ten Chinese critical tech patentees

Artificial intelligence	Semiconductors	Quantum computing
UBTECH Robotics	Yangtze Memory	Tencent
Tencent	TCL Technology	TCL Technology
Ping An	SMIC	South China Normal University
Oppo	Ningbo Semiconductor	Shenzhen Polytechnic
Huawei	InnoScience	Shenzhen Jingtai Technology
CloudMinds Robotics	Huawei	QuantumCTek
ByteDance	Enkris Semiconductor	Origin Quantum
Baidu	Changxin Memory	Huawei
BOE Technology Group	BOE Optoelectronics	Hengtong Qasky Quantum
Autel Robotics	AAC Acoustic	China Electronics Technology Group

Source: García-Herrero *et al* (2025b).

Europe relies more heavily on public research centres, particularly in quantum for which institutions including CEA (France) and universities (RWTH Aachen, Valencia, Delft) lead novelties, generating 60 percent of EU quantum radical novelties. Private company involvement is more limited than in the US and China, especially in AI and semiconductors. There are, however, notable exceptions, including Ericsson and Nokia in AI for 5G computing, and Infineon at 42.9 percent of total China/EU/US novelties in power semiconductor devices (García-Herrero *et al*, 2025b).

Europe also has two entities that excel in all three fields: Sweden’s Ericsson and France’s CEA (*Commissariat à l’énergie atomique*, Atomic Energy Commission). While very different in nature (a private telecoms company and a public research centre), they have very important factors in common: more R&D expenditure than their peers⁹ and extensive cooperation with other research leaders¹⁰.

Notwithstanding these relatively more successful cases, the reality is that the number and depth of European breakthroughs in digital technologies is simply less than in China and the US. This is probably associated with the lack of an integrated market for basic research and with the fragmentation of the single market, which constrains the ability of companies to commercialise innovation in a profitable way.

Table 3: Top-ten EU critical tech patentees

Artificial intelligence	Semiconductors	Quantum computing
Stanley Robotics	Siemens	equal1.labs
Siemens	STMicroelectronics	RWTH Aachen
Safran	Robert Bosch	Polytechnic University of Valencia
SAP	Osram Opto Semiconductors	IQM Finland
Robert Bosch	Nexperia	Ericsson
Nokia	Infineon	Delft University of Technology
Ericsson	Ericsson	Compsecur
Carl Zeiss	CEA	CEA
CEA	Aledia	Bull
Accenture	ASM IP Holding	Buendia Jose

Source: García-Herrero *et al* (2025b).

4 Speed of knowledge spillovers: quick for China and the US, slow in Europe

While competition for top positions in novel patents is important, so is the ability to replicate great innovative ideas. To assess how China, the EU and the US replicate breakthroughs in critical technologies, García-Herrero *et al* (2025b) conducted a spillover analysis, yielding really sombre results for Europe. Spillovers in this context refer to the spread of new technologies or ideas from one region to others. They are calculated by measuring the time lag between the publication of an original, radically novel patent and the appearance of

9 CEA receives more than €2.5 billion in public funding annually, while Ericsson invests heavily in R&D: approximately €4.7 billion in 2024, up from from €4.3 billion in 2023.

10 CEA cooperates with Europe’s top research labs, including IMEC (Belgium) and Fraunhofer (Germany), as a ‘crown jewel’ in semiconductor R&D. Ericsson partners with companies including Intel and IBM, leaders in these fields in the US.

similar technologies in patents from other regions.

Among the three critical technologies analysed, AI spreads the fastest (Figure 4). China excels by replicating novel patents from the US or EU in only in six months. Bidirectional US-China flows (eg Nvidia designs inspiring Huawei alternatives) are quite obvious as the US also replicates Chinese patents quickly. When it comes to chips, China is about half as fast than it is in AI and quantum in replicating US patents. This resonates with most US export controls relating to semiconductors¹¹.

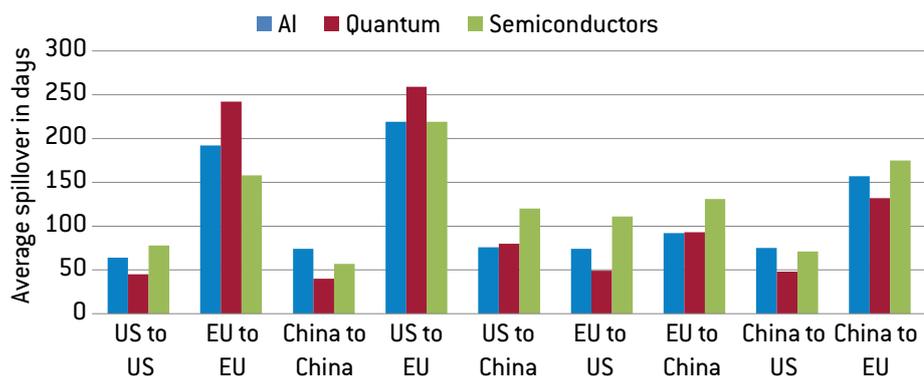
EU countries, meanwhile, take 18-24 months to replicate novelties from China or the US, whether AI, chips or quantum. Interestingly, EU innovators take slightly less time to replicate Chinese novel patents than US novel patents, especially in AI and quantum. For chips, the EU’s replication lag is about the same for US and Chinese patents.

Europe’s much slower replication of US or Chinese patents is clearly a problem. It is further aggravated by the fact that, within the EU, the speed of replication is also very slow. In other words, the average time for a breakthrough from one EU country to be replicated by an innovator in another EU country is as long, if not longer than the time taken by a European innovator to replicate a Chinese patent (with replication of US breakthroughs still the slowest).

This finding is as striking as worrying, warranting a further analysis of the reasons why this is the case. Our analysis on the fragmentation in the fields of research excellence in Europe, and the differences in the profiles of its innovators compared to the US and China, offers some hints:

1. Dependence on public funding in the EU versus the depth of the US venture capital markets, with private investment the most important source of funding for critical technologies in the US.
2. The lack in the EU of cash-rich tech companies, which can take on bold innovation and replication tasks.
3. Language and regulatory complexity in the EU, and potentially excessive data protection standards.
4. The fragmentation of the single market and the difficulties to scale when commercialising innovation is surely relevant (Draghi, 2024).

Figure 4: Cross-regional spillovers by direction (average number of days)



Source: García-Herrero *et al* (2025b).

¹¹ It should be noted that export controls imposed by the US Department of Commerce’s Bureau of Industry and Security (BIS) are on products and not patents but, at the highest end of the technology spectrum, the correlation between the two is high.

5 Implications and recommendations

The US continues to lead in the production of radical novelties across AI, semiconductors and quantum computing, bolstered by a concentrated ecosystem of private tech giants that excel in high-value subfields and foster rapid commercialisation. This model sustains a 35 percent to 40 percent of China-EU-US radical innovations, turning theoretical breakthroughs into trillion-dollar industries.

China has emerged as a formidable second-place contender, particularly in semiconductor fabrication and selected AI applications, such as surveillance vision and aerial drone swarms. This is thanks to its hybrid model and state-supported scale that allows for quick absorption and adaptation of breakthroughs. By contrast, the EU, despite pockets of strength in quantum photonics and explainable AI, generates far fewer novelties than the US or China, and struggles with sluggish spillovers, limiting its ability to keep pace. In certain niches, Europe dominates – such as ASML's EUV monopoly – but fragmentation of innovation is a clear shortcoming.

The disparity could worsen if the EU does not quickly step up efforts to innovate more on critical technologies and to create the right ecosystems to enable faster replication of breakthroughs. It must also expand the number of innovators. One important aspect in China's rapid catch up with the US, compared to Europe, is funding. Ironically, the EU spends more on basic research than China – \$47.5 billion in 2024, compared to China's \$34.7 billion (OECD, 2025). However, China's growth in basic research expenditure is double that of the EU (over 10 percent versus 5 percent). In other words, convergence is happening very rapidly.

Beyond this, China has stepped up its industrial policy, with particular attention paid to critical technologies, especially semiconductors. China's push for semiconductors started with the industrial policy master plan China launched in 2015, Made in China 2025. The industrial effort on chips was funded by two major efforts, the Big Fund I and the Big Fund II, which pulled in the equivalent of \$90 billion (García Herrero and Weil, 2022). The results of those efforts are now starting to be appreciated. China has moved up the ladder in particular in the fabrication of chips, while challenges remain in terms of design. More generally, China's enormous economies of scale help make basic research more easily commercialisable, with deployable products for which a large single market exists, in addition to China's huge export machine.

While industrial policy is an important factor behind China's innovation drive, a simplistic judgement attributing China's success to large subsidies should be avoided. China's industrial policy strategically aligns long-term objectives outlined in Five-Year Plans with flexible implementation mechanisms, including the selection of specialised firms through programmes such as the 'Little Giants'. These prioritise R&D intensity and sectoral concentration to channel resources efficiently into different technologies, including the critical areas we have analysed. The policy levers also include tax breaks for R&D and underscore China's ability to take the lead in targeted domains.

The EU cannot copy China's industrial policy given the marked institutional differences, but must do more on innovation. A critical lesson for Europe is that in a world in which scale and speed define technological leadership, fragmented excellence risks obsolescence. The US's private vigour and China's state-orchestrated agility contrast with Europe's regulatory caution. Without reform, the EU will continue to cede ground to the US and China. By learning from China's ascent, particularly its precision with subsidies, spillover efficiency and cross-sector dynamism, the EU can reshape its innovation policies. The EU also needs to focus, much more than the US and China, on the scale of its market, not only for goods and services, but also for innovation.

Europe should implement a multifaceted strategy to enhance basic research while also accelerating diffusion, integrating the single market and strengthening commercialisation linkages. In addition to funding, this requires institutional redesign, drawing selectively from China's industrial playbook, especially on the innovation focus, while preserving EU values of openness and sustainability. Specifically:

In certain niches, Europe dominates, but fragmentation of innovation is a clear shortcoming

1. EU-wide sandboxes (or testing environments) should be established for patent licensing and technology transfer. Such dedicated regulatory environments would support cross-border research collaboration and reduce bureaucratic barriers that currently mean Europe's replication times are double those of China.
2. EU research funding (Horizon Europe) might need to be focused more on critical technologies, especially on deployment, by incorporating direct financial incentives for private firms to prototype and commercialise novelties – much like the Chinese subsidies that have propelled its semiconductor ecosystem.
3. Leveraging public procurement as a demand-generation tool is essential. By requiring the incorporation of critical technologies in public contracts – from AI in public services to quantum-secure communications in infrastructure – the EU can create immediate markets that pull innovations from labs to deployment, fostering the virtuous cycle of product diffusion and reinvestment that sustains China's current edge over the EU. The EU's €2 trillion public procurement market could be expanded through a 'critical tech mandate' that would require 30 percent of contracts (eg defence, transport) to feature EU-sourced AI or semiconductors by 2028, with penalties for non-compliance.
4. An EU Critical Tech Observatory should be created, possibly under the European Commission, to provide real-time monitoring of global patent trends, enabling proactive 'fast-follower' strategies that identify and replicate high-potential novelties.
5. Finally, Europe's push for increased – but also more integrated – military spending should create demand for dual-use technologies.

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