Technology and Industrial Policy in an Age of Systemic Competition: Safeguarding Germany's Technology Stack and Innovation Industrial Strength

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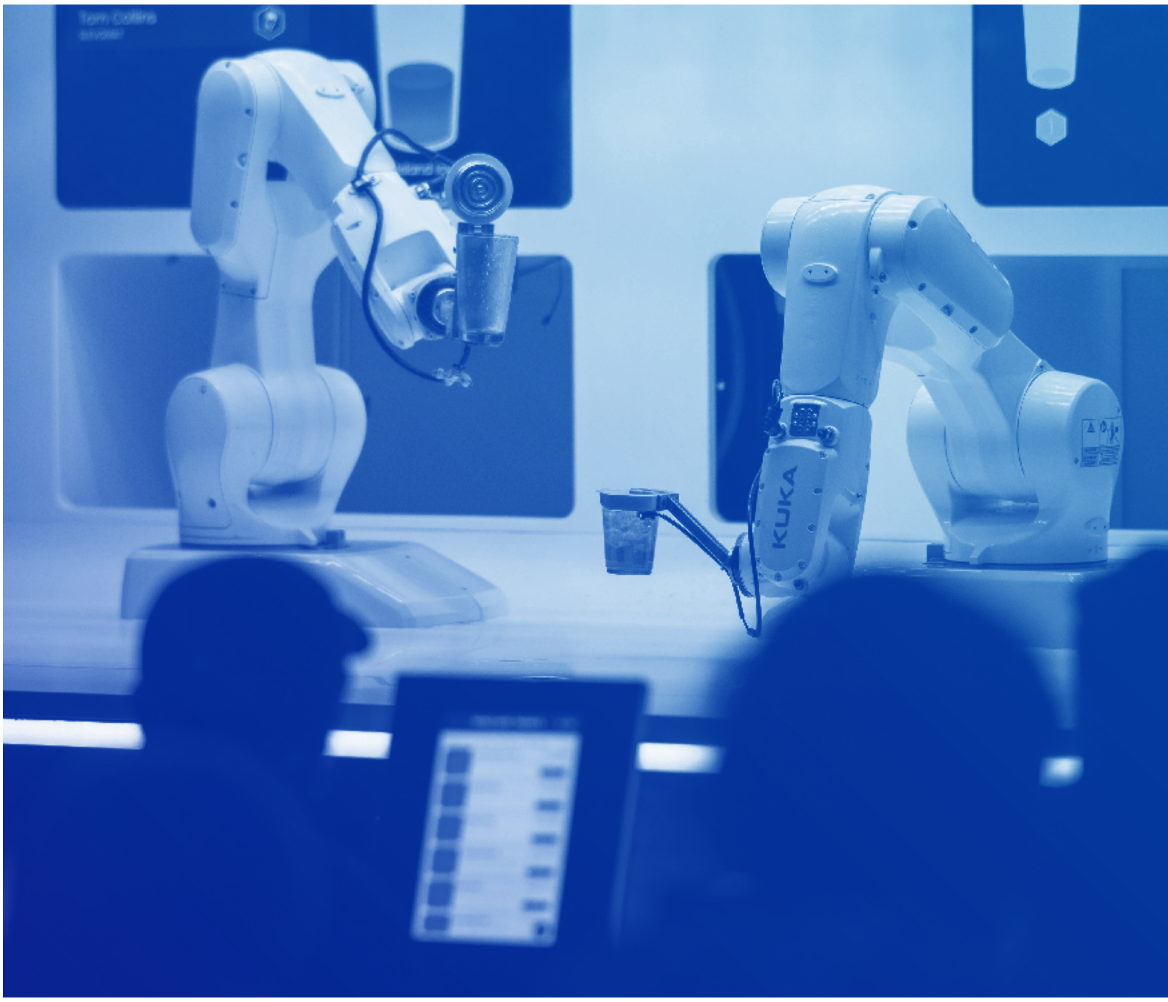


CHAPTER OVERVIEW

Key Takeaways

1 As one of the world's most globalized economies, Germany is confronting a challenging international environment characterized by aggressive subsidies, a global race for control of key technologies such as advanced chips, and vulnerable supply chains for critical components. Increased energy costs – induced by Russia's war on Ukraine – are also straining Germany's industrial model.

2 Germany's industrial economy is simultaneously undergoing a fundamental transformation from precision-based engineering to systems-based manufactured products. With this shift, a competitive digital technology stack is becoming a key repository for future industrial competitiveness. Yet, the country struggles to capture value in fast-growing markets like that for cloud and edge infrastructure. It also faces risks from its exposure to untrustworthy technology vendors and potential geopolitical disruptions to fragile hardware supply chains.

3 The German government is consequently drawing the contours of a new technology-industrial policy. This effort, however, suffers from uneven implementation and the complexities of eff ectively coordinating subnational (across the *Länder*) and supranational (across the EU) industrial policy.

4 To effectively preserve its economic competitiveness, the German government should conduct a systematic assessment of the country's strengths and vulnerabilities in critical technology, increase the cohesiveness between federal and state government initiatives, and work internationally – within the EU and with like-minded partners beyond – to leverage comparative advantages.

Introduction

Berlin's stance on industrial policy is evolving significantly. Specifically, its digital policy, long focused on data rules, competition, and open markets, is now confronting a new global environment characterized by aggressive subsidies, a global race for market share in key technologies such as advanced chips, and vulnerable supplies of critical components. China has become a direct competitor as it moves up the value chain following a transition from labor-intensive manufacturing to advanced production in autonomous and electric vehicles, smart machinery, robotics, and network equipment sectors. The United States, for its part, is investing heavily in its innovation industrial base to defend its technological primacy in domains such as cutting-edge chip design and AI.

These challenges have forced Germany to undertake a more active industrial policy. At stake is the country's future economic prosperity, as its technology-industrial base grapples with a shift from precision-based engineering to systems-based manufactured products reliant on data and algorithms, digital infrastructure, and semiconductor supply chains. Unless the country can skillfully use technology-industrial policy to safeguard its strong position in global high-tech value chains, its economic base and geopolitical influence will diminish. To avoid this, the German government must reconcile such a policy with the open-market and choice-based principles underpinning its domestic economy as well as the geopolitical imperatives for fostering strategic interdependencies with close allies and partners.

The State of Play

Germany's industrial transformation is forcing the country to bring together its excellence in the automotive, machinery, medical engineering, and other sectors with technologies, such as AI and emerging digital ecosystems.[1] This has created acute challenges to its industrial competitiveness, in part because the country's mid-sized businesses – its famous *Mittelstand* "hidden champions" – display relatively low levels of new technology adoption. For instance, a mere 6 percent of them have implemented AI strategies aimed at retaining competitiveness.[2] A large majority (77.1 percent) say, too, that they are ambivalent about the benefits of data sharing despite its importance for securing a competitive edge by optimizing industrial processes and developing new products.[3] Moreover, the country's landscape of industrial Internet of Things (IoT) and data-sharing platforms is fragmented. Initiatives for European data spaces such as Gaia-X advance slowly, reflecting internal quarrels over the participation of non-European players and the political challenge of advancing a common European ecosystem based on interoperability and trust.[4]

Germany, however, has advantages in its existing innovation industrial base. The country embraces networking and automation as the world's fourth-largest spender on IoT,[5] which comprises internet-connected devices such as sensors and meters, and it accounts for a third of Europe's operational industrial robots.[6] Domestic AI development also meets half of German industrial demand.[7] According to estimates, AI-based solutions could provide a major economic boost by increasing German GDP by 11.3 percent, or €430 billion, through 2030.[8] But policies to accelerate the translation of Germany's R&D strengths into data-intensive and systems-centric applications in its domestic industrial base are key to securing the country's position as a top-tier technology power.[9]

With this shift to data-driven value creation, a competitive digital technology stack is becoming a key repository for future industrial competitiveness. A fundamental concern in this regard, however, is the availability of secure and reliable cloud and edge computing infrastructure.[10] This is not just because Germany's continued leadership in core industries, such as autonomous driving, manufacturing, and energy grid management,

1 AI, a key driving force behind this transformation, is anticipated to contribute to a rise in global GDP of about 16 percent by 2030, making it the most significant driver for the global economy. Jacques Bughin et al., "Notes from the AI frontier: Modeling the impact of AI on the world economy," McKinsey & Company Discussion Paper (September 2018): https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy (accessed May 19, 2022).

2 J.P. Singh, "Deutschland kann Krise – aber auch KI?" [Germany Can Handle a Crisis – But Can AI?], *Tagesspiegel Background*, September 6, 2021: https://background.tagesspiegel.de/digitalisierung/deutschland-kann-krise-aber-auch-ki (accessed May 19, 2022). More broadly, a mere 15 percent of German industrial companies are estimated to have implemented AI solutions, compared with 25 percent of US companies, and 23 percent of Chinese companies. acatech, "Künstliche Intelligenz in der Industrie" [Artificial Intelligence in Industry], acatech Horizonte (July 2020), p. 54: https://www.acatech.de/publikation/acatech-horizonte-ki-in-der-industrie/download-pdf/?lang=de (accessed May 19, 2022).

3 According to a 2018 survey of 111 small- and medium-sized enterprises. Companies worry most about third-party access to their data (90.7 percent). Institut der deutschen Wirtschaft, "Datenwirtschaft in Deutschland. Wo stehen die Unternehmen in der Datennutzung und was sind ihre größten Hemmnisse?" [The Data Economy in Germany. Where do companies stand on data use and what are their biggest obstacles?], (February 2021), p. 40: https://www.iwkoeln.de/fileadmin/user_upload/Studien/Gutachten/PDF/2021/Hemmnisse_der_Datenwirtschaft_Studie.pdf (accessed May 19, 2022)

4 Silke Hahn, "Gaia-X in der Unternehmerdiskussion: Tolle Vision, wann kommt die Realität?" [Entrepreneurs Discuss Gaia-X: Great vision, when will reality come?], *Heise Online*, February 2, 2022: https://www.heise.de/news/Gaia-X-in-der-Unternehmerdiskussion-Tolle-Vision-wann-kommt-die-Realitaet-6340570.html (accessed May 19, 2022).

5 Germany accounts for approximately 5 percent of global IoT spending and is currently surpassed only by the United States, China, and Japan. United Nations Conference on Trade and Development, *Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries*, (July 2019), p. 7: https://unctad.org/system/files/official-document/der2019_en.pdf (accessed May 19, 2022).

6 Germany had approximately 230,000 operational industrial robots in 2021. International Federation of Robots, "Jeder dritte Industrie-Roboter in der EU wird in Deutschland installiert" [Every Third Industrial Robot in Europe is Installed in Germany], (October 28, 2021): https://ifr.org/downloads/press2018/Germany-2021-OCT-IFR_press_release_industrial_robots.pdf (accessed May 19, 2022).

7 Results of surveys of 235 German companies from 2021 show that approximately 46 percent of external AI applications bought or rented by German companies are from German developers. Only the United States accounts for another significant share of AI solutions providers (38 percent). Achim Berg, "Künstliche Intelligenz. Wo steht die deutsche Wirtschaft?" [Artificial Intelligence. Where does the German economy stand?], (April 2021), p. 10: https://www.bitkom-research.de/system/files/document/Bitkom%20Charts%20K%C3%BCnstliche%20Intelligenz%2021%2004%202021_final.pdf (accessed May 19, 2022).

8 The automotive and healthcare industries, using 2018 German GDP as a baseline, are expected to be those most impacted. PwC, "Künstliche Intelligenz sorgt für Wachstumsschub. Wie groß ist das Potenzial und wie kann Ihr Unternehmen davon profitieren?" [Artificial Intelligence Provides a Growth Spurt. How big is the potential and how can your company profit from it?], (February 2019): https://www.pwc.de/de/digitale-transformation/business-analytics/kuenstliche-intelligenz-sorgt-fuer-wachstumsschub.html (accessed May 19, 2022).

9 Tyson Barker and David Hagebölling, "The Geopolitics of Digital Technology Innovation Assessing Strengths and Challenges of Germany's Innovation Ecosystem", DGAP Report, (August 31, 2022): https://dgap.org/en/research/publications/geopolitics-digital-technology-innovation (accessed October 31, 2022).

10 More than four out of five companies in Germany use cloud computing. Bitkom Research, "Trendstudie Digitalisierung 2019" [Digitalization Trend Study 2019], (November 2019): https://www.bitkom-research.de/de/Trendstudie-Digitalisierung-19 (accessed May 19, 2022).

increasingly depends on cloud-based big data processing.[11] It is also because *decentralized* cloud infrastructure, in particular, will underpin Germany's rapidly growing industrial IoT and the requirements for highly secure and low-latency computing carried out close to the data source, the so-called "edge."[12] Germany is forecasted to remain Europe's largest and fastest growing market for edge computing through 2025,[13] when the majority of business data will be processed outside traditional, centralized data centers.[14]

And yet, Germany, like all of Europe, struggles to capture value in the fast-growing market for cloud and edge technology. German cloud providers such as T-Systems[15] and SAP[16] are turning to operational partnerships with US hyperscalers to reconcile advanced cloud technology with data protection requirements, especially with regard to limiting the legal grounds and technical possibilities for foreign access to data stored on European servers.[17] Meanwhile, the shift to edge computing is also altering the sources of comparative advantage. Unlike more general-purpose cloud infrastructure, edge computing is characterized by wide geographic distribution of data centers and tends to be adapted to specific verticals and applications.[18] This could impact competition between large cloud providers and incumbent telecommunication companies.

Germany's conflicted strategy for secure telecommunications networks, which increasingly fuse with the cloud-based data-processing infrastructure, presents another challenge.[19] Chinese vendors currently play a significant role in German telecommunications networks, with Huawei alone providing almost half of their 4G base stations.[20] Germany is attempting to limit exposure to Chinese firms in 5G networks but is not ready to shift to European providers.[21] German telecommunications operators, after all, have a strong commercial interest in diversifying their equipment providers and limit reliance on European companies Nokia and Ericsson, the second- and third-largest 5G base station vendors.[22] Accordingly, Berlin has supported the O-RAN Alliance,[23] a major industry and research initiative aimed at defining interoperable standards for mobile networks.[24] The support comes despite questions about the security of O-RAN's architecture[25] and discord with key partners, including France and

11 The European cloud market, of which Germany represents around one fifth, is projected to increase tenfold to roughly €500 billion by 2030. Martin Möhle, "Cloud Computing in Germany 2021," *Future Processing*, January 11, 2021: https://www.future-processing.com/blog/cloud-computing-in-germany-2021 (accessed May 19, 2022).

12 Edge computing refers to data processing at the "edge" of networks, closer to the location where data is collected. One key benefit of this is that time-consuming data transfers over long distances are avoided, enabling greater speed and low latency.

13 Reply, "From Cloud to Edge" (December 2020), p. 5: https://www.reply.com/en/Shared%20Documents/from-cloud-to-edge-EN.pdf (accessed May 19, 2022).

14 Some estimates suggest that 75 percent of data processing could move to the edge by 2025. Rob van der Meulen, "What Edge Computing Means for Infrastructure and Operations Leaders," Gartner (October 3, 2018): https://www.gartner.com/smarterwithgartner/what-edge-computing-means-for-infrastructure-and-operations-leaders (accessed May 19, 2022).

15 T-Systems, "Investition in Technologie und gemeinsame Innovation, um Kundenbedürfnisse in Deutschland zu erfüllen" [Investment in Technology and Joint Innovation to Meet Customer Needs in Germany], (September 8, 2021): https://www.t-systems.com/de/de/newsroom/news/t-systems-und-google-cloud-bauen-souveraene-cloud-fuer-deutschland-450414 (accessed May 19, 2022).

16 SAP, "Startschuss zur ersten souveränen Cloud-Plattform für den öffentlichen Sektor in Deutschland: SAP und Arvato Systems kündigen Partnerschaft an" [Start to the First Sovereign Cloud Platform for the Public Sector in Germany: SAP and Arvato Systems announce partnership], (February 3, 2022): https://news.sap.com/germany/2022/02/cloud-plattform-public sector-arvato (accessed May 19, 2022).

17 Notably, these partnerships aim to offer cloud services to German companies and the public sector that limit legal grounds and technical possibilities for accessing data under laws such as the US's CLOUD Act and FISA Act, and the Chinese Cybersecurity Law.

18 Brandon Moser, "Edge Computing Examples Across Vertical Industries," (September 9, 2021): https://www.digi.com/blog/post/edge-computing-examples-across-vertical-industries (accessed October 5, 2022).

19 5G has been rolled out for public mobile networks since 2019, but many applications remain available only in campus networks that connect people and systems in private spaces such as production facilities, hospitals, universities, and ports. Federal Ministry for Economic Affairs and Energy (BMWi), "Leitfaden 5G-Campusnetze – Orientierungshilfe für kleine und mittelständische Unternehmen" [5G Campus Networks Guidelines – Guidance for Small and Medium-sized Enterprises], (April 2020): https://www.bmwi.de/Redaktion/DE/Publikationen/Digitale-Welt/leitfaden-5G-campusnetze-orientierungshilfe-fuer-kleine-und-mittelstaendische-unternehmen.pdf?__blob=publicationFile&v=8 (accessed May 19, 2022).

20 Germany is not an outlier in this regard. About half of all European countries have a similar amount of Chinese vendor equipment. Deutsche Welle, "Germany pressures Huawei to meet security requirements," June 21, 2019: https://www.dw.com/en/germany-pressures-huawei-to-meet-security-requirements/a-49294841 (accessed May 19, 2022).

21 This is happening through stricter requirements to ensure the "trustworthiness" of equipment vendors under Germany's IT-Security Law 2.0 (2021), among other measures.

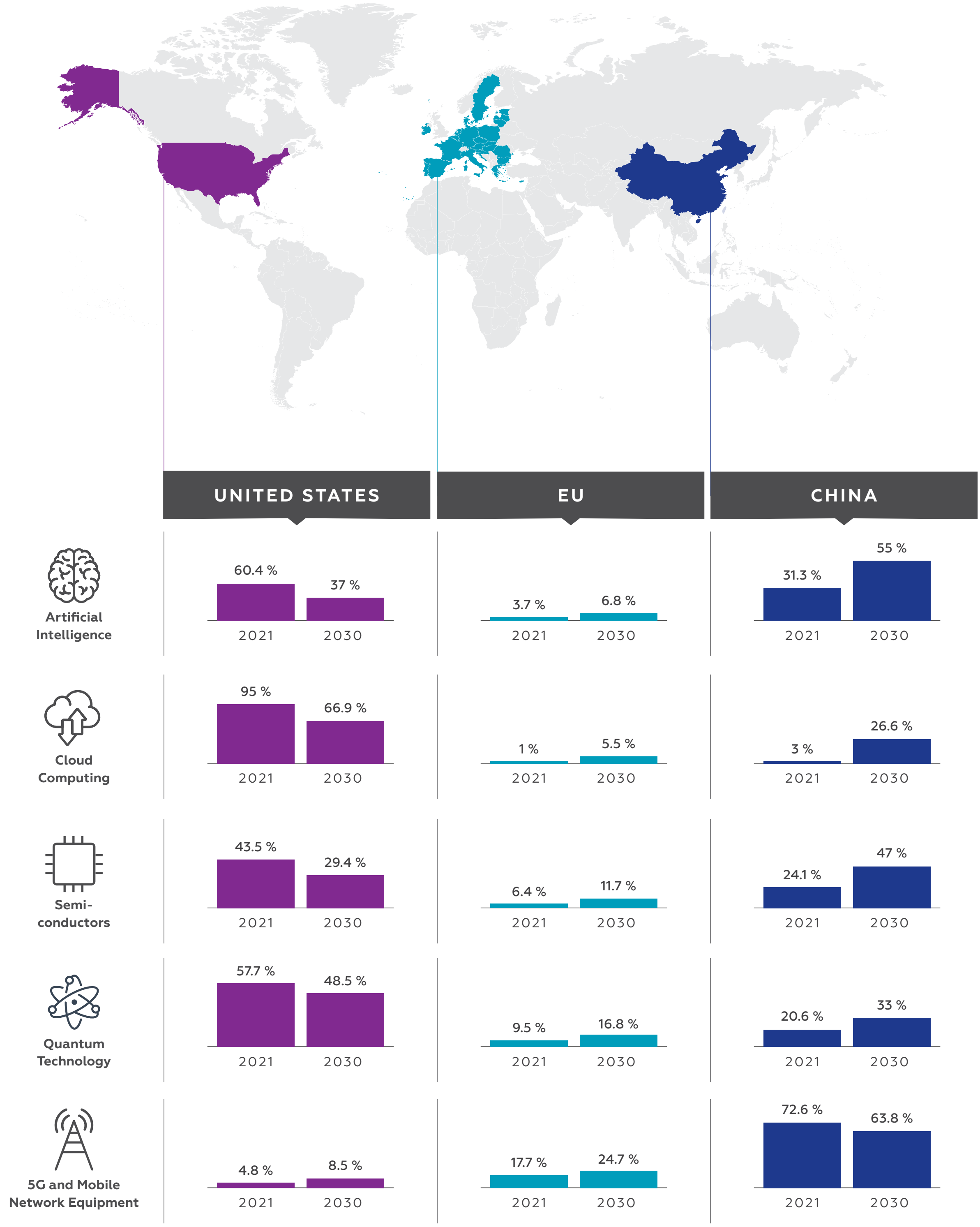
22 Zoefie Cheng, "Market Share of Top Three Suppliers of Base Stations Projected to Undergo Slight Decline in 2021 While Fourth-Ranked Samsung Scores Wins in Overseas Markets, Says TrendForce," TrendForce, (July 28, 2021): https://www.trendforce.com/presscenter/news/20210728-10872.html (accessed May 19, 2022).

23 Federal Ministry for Digital and Transport (BMDV), "BMVI startet Open RAN-Förderung" [BMVI launches Open RAN Funding], (November 9, 2021): https://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2021/126-bmvi-startet-open-ran-foerderung.html (accessed May 19, 2022).

24 Founded in 2018, the O-RAN Alliance is an initiative by network operators, vendors, and research institutions aimed at devising industry standards for "open, virtualized and fully interoperable mobile networks."

25 Germany's Federal Office for Information Security (BSI) raises concerns in a 2021 risk analysis study about Open RAN security. The study notes that Open RAN's specifications are not developed in accordance with the paradigm of "security/privacy by design/default" and that it is a system that displays "numerous security risks." Stefan Köpsell et al., "Open-RAN Risikoanalyse 5GRANR" [Open-RAN Risk Analysis 5GRANR], Federal Office for Information Security (February 2022), p. 73: https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Publikationen/Studien/5G/5GRAN-Risikoanalyse.pdf;jsessionid=9E7EE4E27FFCF263EC0710664967F076.internet472?__blob=publicationFile&v=9 (accessed May 19, 2022).

1 – EXPERT ASSESSMENT OF EUROPE'S LEADERSHIP IN KEY TECHNOLOGIES, 2021 VS 2030



Source: Authors' illustration based on data from Kaan Sahin and Tyson Barker, "Europe's Capacity to Act in the Global Tech Race," German Council on Foreign Relations (April 2021): https://dgap.org/sites/default/files/article_pdfs/210422_report-2021-6-en-tech.pdf (accessed September 14, 2022).

the European Commission, over O-RAN's ramifications for Europe's 5G champions.

Germany also faces risks in the fragile supply chain for semiconductors, the foundational technology that powers industrial IoT, smart grids, electric and autonomous vehicles, and other industrial components and products. Europe's share of global semiconductor manufacturing capacity has fallen from 44 percent in 1990 to just 8 percent today.[26] In 2020, Infineon was the only German company (and one of only four European companies) among the 20 largest semiconductor manufacturers in terms of revenue.[27] More than three quarters of chip production now occurs in Asia, primarily in Taiwan, South Korea, and China.[28] Disruptions in this geopolitically precarious region would have a profound economic impact on Germany, one likely much greater than that of severed Russian gas supplies.

Germany and its EU partners need a strategic and measured approach to industrial policy in this highly complex and diversified market. Given high capital barriers to entry,[29] re-shoring (cutting-edge) manufacturing requires substantial and sustained subsidies.[30] This means diversifying global sourcing options should be a priority, as is identifying comparative advantages in the semiconductor value chain. Crucially, Germany still boasts legacy strengths in certain supplier markets and production segments. Precision-engineered components and specialized chemical products from German companies such as Zeiss and BASF are critical ingredients for semiconductor production.[31] And Infineon, Bosch, STMicroelectronics, and NXP excel in specialized chips,[32] including those for industrial applications, automotive, and defense.[33]

Yet, Germany must not lose sight of future disruptions. An increasing number of (industrial) companies design their own specialized chips while intellectual property holders and Electronic Design Automation (EDA) tool vendors are almost exclusively located in the United States.[34] Developments in quantum and high-performance computing give Germany an opportunity to secure a stronger position in the hardware segment in the future.[35] But German companies, despite strengths in basic research, lack competitive hardware products,[36] a sector that changes increasingly rapidly.[37]

26 Antonio Varas et al., "Government Incentives and US Competitiveness in Semiconductor Manufacturing," Boston Consulting Group (September 2020), p. 7: https://www.semiconductors.org/wp-content/uploads/2020/09/Government-Incentives-and-US-Competitiveness-in-Semiconductor-Manufacturing-Sep-2020.pdf (accessed May 19, 2022).

27 GlobalData, "Top 20 semiconductor companies by revenue recorded healthy growth, days Global Data," (July 8, 2021): https://www.globaldata.com/top-20-semiconductor-companies-revenue-recorded-healthy-growth-says-globaldata (accessed June 21, 2022).

28 Alex Irwin-Hunt, "In charts: Asia's manufacturing dominance," *Financial Times,* March 24, 2021: https://www.ft.com/content/2b0c172b-2de9-4011-bf40-f4242f4673cc (accessed May 19, 2022).

29 Taiwan's TSMC accounts for roughly 90 percent of cutting-edge chip manufacturing. Yang Jie et al., "The World Relies on One Chip Maker in Taiwan, Leaving Everyone Vulnerable," The *Wall Street Journal,* June 19, 2021: https://www.wsj.com/articles/the-world-relies-on-one-chip-maker-in-taiwan-leaving-everyone-vulnerable-11624075400 (accessed May 19, 2022).

30 For example, TSMC's Arizona fabrication plant, currently under construction, is estimated to cost $12 billion. Sebastian Moss, "TSMC starts work on $12bn Arizona semiconductor fab, gets funding for Japanese chip R&D," DCD, June 2, 2021: https://www.datacenterdynamics.com/en/news/tsmc-starts-work-on-12bn-arizona-semiconductor-fab-gets-funding-for-japanese-chip-rd (accessed May 19, 2022).

31 Zeiss, "Semiconductor Manufacturing Optics": https://www.zeiss.com/semiconductor-manufacturing-technology/products/semiconductor-manufacturing-optics.html (accessed September 30, 2022); BASF, "Chemical Solutions for Semiconductors": https://electronics-electric.basf.com/global/en/electronics/semiconductors_solutions.html (accessed September 30, 2022).

32 Automotive, industrial, and communications electronic system markets are among the most rapidly expanding, exceeding even the growth of the consumer segment. ICInsights, "Outlook Remains Bright for Automotive Electronic Systems Growth," November 19, 2018: https://www.icinsights.com/news/bulletins/Outlook-Remains-Bright-For-Automotive-Electronic-Systems-Growth (accessed May 19, 2022).

33 Jan-Peter Kleinhans and Nurzat Baisakova, "The global semiconductor value chain. A technology primer for policy makers," Stiftung Neue Verantwortung (October 2020).

34 Jan-Peter Kleinhans, "The lack of semiconductor manufacturing in Europe. Why the 2nm fab is a bad investment," Stiftung Neue Verantwortung (April 2021), p. 20: https://www.stiftung-nv.de/sites/default/files/eu-semiconductor-manufacturing.april_.2021.pdf (accessed May 19, 2022).

35 Quantum computing (QC) remains in an early stage, but its potential is significant. Building on quantum physics, QC uses "qubits," which, as opposed to classical "bits," can take on different values at one time. This unlocks computing possibilities that greatly exceed those of classical digital computing. Quantum computers are exponentially more performant in certain computational tasks that are key to German industrial competitiveness, including drug development, real-time processing of industrial and car sensor data, and supply chain management. The technology has great economic potential and will transform cryptography, rendering breakable even advanced classical encryption methods.

36 The Fraunhofer research consortium, for example, depends on US cloud-based quantum computing resources and physical access to IBM's Q System One in Ehningen. Fraunhofer Gesellschaft, "Fraunhofer Competence Network Quantum Computing: Understanding and using qubits!": https://www.fraunhofer.de/de/institute/kooperationen/fraunhofer-kompetenznetzwerk-quantencomputing.html (accessed May 19, 2022).

37 While IBM's Q System One operates with 27 qubits, the company aims to finalize its 1000+ qubit-chip as soon as 2023. Jay Gambetta, "IBM's roadmap for scaling quantum technology," IBM (September 15, 2020): https://research.ibm.com/blog/ibm-quantum-roadmap (accessed May 19, 2022).

The Current Policy Approach

The German government is aware of all these shifts and is drawing the contours of a new industrial policy. In a range of high-level documents, most notably its “High-Tech Strategy 2025” (released in 2018)[38] and “Industrial Strategy 2030” (released in 2019),[39] Berlin adopted a more strategic outlook on critical technologies that dovetails with the bigger €750 billion NextGenerationEU plan.[40] German policy remains anchored in its long-standing ordoliberal principles of open markets and freedom of choice, but it now acknowledges a greater role for state intervention to preserve industrial value creation. Pandemic-related economic disruption solidified this outlook, leading Germany to frame its €130 billion recovery stimulus package as a “package for the future” that prioritizes digital investment for economic recovery.[41]

Germany has promised significant public investment in critical technology. The country’s first-ever AI strategy, released in 2018, featured a €3 billion investment, later increased to €5 billion,[42] through 2025 to support talent development, computing facilities, and internationally competitive AI ecosystems.[43] The federal government also committed in 2019 €650 million to strengthen Germany’s quantum physics research.[44] That funding was increased in 2021 to €2 billion, with the explicit goal of obtaining a competitive “Made in Germany” quantum computer by 2025.[45]

And yet, this transition to a more state-led technology-industrial policy still faces challenges. Germany may outspend other EU member states in this domain, but it struggles with uneven implementation. While the country has, for example, achieved its goal of hiring 100 AI professors,[46] it has, as of mid-2021, only disbursed €250 million of its €5 billion AI investment package.[47] Besides bureaucratic holdups, this reflects the government’s lack of a coherent process for following through on strategic priorities.

In addition, Germany’s federated structure complicates synergies between federal and state (*Länder*) policy. German federalism can create healthy competition among *Länder* that highlights different strengths and that experiments with policies to attract international investment and talent for cutting-edge technology. But to realize the desired “leveraging effect” between federal and *Länder* initiatives, such competition must be embedded in a coordinated approach that assesses potential synergies.[48] A potentially significant advantage exists in the interlocking of federal funding priorities and *Länder* investment policies that have launched regional initiatives. These efforts include Bavaria’s €300 million

38 Federal Ministry for Education and Research (BMBF), “Forschung und Innovation für die Menschen. Die Hightech-Strategie 2025“ [Research and Innovation for People. The High-Tech Strategy 2025], (September 2018): https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/1/31431_Forschung_und_Innovation_fuer_die_Menschen.pdf?__blob=publicationFile&v=6 (accessed May 19, 2022).

39 Federal Ministry for Economic Affairs and Energy (BMWi), “Industriestrategie 2030. Leitlinien für eine deutsche und europäische Industriepolitik“ [Industrial Strategy 2030. Guidelines for a German and European Industrial Policy], (November 2019): https://www.bmwk.de/Redaktion/DE/Publikationen/Industrie/industriestrategie-2030.pdf?__blob=publicationFile (accessed May 19, 2022).

40 European Commission, “State of the Union: Commission proposes a Path to the Digital Decade to deliver the EU’s digital transformation by 2030,” (September 15, 2021): https://ec.europa.eu/commission/presscorner/detail/en/ip_21_4630 (accessed May 19, 2022).

41 The Federal Government, “Milliardenhilfe beschlossen” [Billions in Aid decided] (June 2020): https://www.bundesregierung.de/breg-de/themen/coronavirus/konjunkturpaket-geschnuert-1757558 (accessed May 19, 2022).

42 Federal Ministry for Economic Affairs and Climate Action (BMWK), “Kabinett beschließt Fortschreibung der KI Strategie der Bundesregierung“ [Cabinet Approves Updated German Government AI Strategy], (December 2, 2020): https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2020/12/20201202-kabinett-beschliesst-fortschreibung-ki-strategie-bundesregierung.html (accessed May 19, 2022).

43 The Federal Government, “Die entscheidende Zukunftstechnologie des 21. Jahrhunderts” [The Most Critical Future Technologies of the 21st Century] (December 2, 2020): https://www.bundesregierung.de/breg-de/suche/fortschreibung-ki-strategie-1824340 (accessed May 24, 2022).

44 Stefan Krempl, “Zitis: Staatliche Hacker sollen Verschlüsselung mit Quantencomputer knacken“ [Zitis: State Hackers to Crack Encryption with Quantum Computer], Heise Online, September 26, 2018: https://www.heise.de/newsticker/meldung/Zitis-Staatliche-Hacker-sollen-Verschluesselung-mit-Quantencomputer-knacken-4175352.html (accessed May 19, 2022).

45 Sebastian Grüner, “Deutschland fördert Quantencomputer mit 2 Milliarden Euro“ [Germany Funds Quantum Computers with 2 Billion Euros], Golem.de, May 11, 2021: https://www.golem.de/news/grundlagenforschung-deutschland-foerdert-quantencomputer-mit-2-milliarden-euro-2105-156422.html (accessed May 19, 2022).

46 Werner Pluta, “Forschungsministerium besetzt 100 zusätzliche KI-Professuren“ [Research Ministry Fills 100 Additional AI Professorships], Golem.de, May 6, 2022: https://www.golem.de/news/kuenstliche-intelligenz-forschungsministerium-besetzt-100-zusaetzliche-ki-professuren-2205-165144.html (accessed May 19, 2022).

47 As of May 31, 2021. German Bundestag, “Schriftliche Fragen mit den in der Woche vom 07. Juni 2021 eingegangenen Antworten der Bundesregierung“ [Written Questions with Federal Government Answers for the week of June 7, 2021] (Circular 19/30613, June 11, 2021), p. 159: https://dserver.bundestag.de/btd/19/306/1930613.pdf (accessed May 19, 2022).

48 A “leveraging effect” (“*Hebelwirkung*”) is posited, for example, in the government’s AI strategy. However, only the 2020 strategy update makes substantial reference to areas – other than education, which is primarily a state responsibility – that could involve collaboration with the states.

2 – GERMANY'S PARTICIPATION IN DIGITAL TECHNOLOGY IPCEIS

FIELD	TIMELINE	MEMBER STATES	GERMAN FUNDING	TECHNOLOGY FOCUS	PROJECTS
Microelectronics I	**2018:** EU Commission approval **2020:** start of projects **2022:** end of projects (planned)	**4 EU member states:** France, Germany, Italy, and Austria (joined 2021) + United Kingdom	Total: ≈ €3.6 billion Government: €1 billion Private: €2.6 billion	Energy efficient chips; Power semiconductors; Sensors; Advanced optical equipment; Compound materials	EU: 43 Germany: 18
Microelectronics II	**2021:** pre-notification **2022/23:** pending EU Commission approval **2023+:** start of projects (planned)	**20 EU member states:** Austria, Belgium, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain	Total: €10 billion Government: €450 million (for 2023) Private: n/a	Photonics, next generation sensors, processors, AI/ML/DL; Next generation power, actuators, energy efficiency; Softwarised networks, 5G/6G enabling technology, optical connectivity, short range wireless	EU: n/a Germany: 32
Cloud Infrastructure and Services	**2022:** pending EU Commission approval (pre-notified) **2022:** start of projects (planned) **2026:** end of projects (planned)	**12 EU member states:** Belgium, Czech Republic, France, Germany, Hungary, Italy, Latvia, Luxembourg, Netherlands, Poland, Slovenia, and Spain	Total: n/a Public: €750 million Private: n/a	Establishing a cloud-edge infrastructure, especially for industrial applications through: Digital infrastructure; Interconnections; Foundation services; Platforms and smart processing services	EU: ≈80 Germany: 22

Source: Authors' compilation based on publicly available information

financing for its Munich Quantum Valley[49] to promote quantum sciences and technologies, and an initial €160 million package for Baden-Wuerttemberg's Cyber Valley, currently Europe's largest AI research consortium.[50]

Coordination at the supranational level likewise remains an important challenge to effective implementation. EU institutions have clout in defining the digital rulebook, but the member states drive industrial policy. Germany has a played a key role in overcoming this division of labor and advancing more coherent policymaking. This includes, notably, a commitment to several Important Projects of Common European Interest (IPCEIs),[51] including those for microelectronics, cloud infrastructure, and batteries. But the IPCEI for cloud infrastructure and services (IPCEI-CIS),[52] with €750 million of German funding, is entangled in disputes about the French-German GAIA-X initiative,[53] which allows American and Chinese hyperscalers to participate in establishing standards for Europe's federated data

49 Bavarian State Ministry of Science and the Arts, "Munich Quantum Valley: Münchener Initiative will Quantencomputer in Bayern entwickeln" [Munich Quantum Valley: Munich initiative wants to develop quantum computers in Bavaria], (January 11, 2021): https://www.stmwk.bayern.de/pressemitteilung/12124/munich-quantum-valley-muenchener-initiative-will-quantencomputer-in-bayern-entwickeln.html (accessed May 19, 2022).

50 Ministry of Science, Research and the Arts Baden Württemberg, "Fünf Jahre Cyber Valley" [Five Years of Cyber Valley], (December 15, 2021): https://mwk.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/fuenf-jahre-cyber-valley (accessed May 19, 2022).

51 An IPCEI may receive member state subsidies if it is an integrated European project that addresses a market failure in a key sector or technology, and if it has positive spillover effects for the EU economy as a whole.

52 Federal Ministry for Economic Affairs and Energy (BMWi), "Förderbekanntmachung zur geplanten Förderung im Bereich Cloud und Edge Infrastruktur und Services im Rahmen des IPCEI-CIS" [Funding Announcement for Planned Funding in Cloud and Edge Infrastructure and Services within the IPCEI-CIS Framework], (April 2022): https://www.bmwk.de/Redaktion/DE/Downloads/F/forderbekanntmachung-zur-geplanten-forderung-im-bereich-cloud-und-edge-infrastruktur-und-services-im-rahmen-des-ipcei-cis.pdf?__blob=publicationFile&v=6 (accessed May 19, 2022).

53 Gaia-X European Association for Data and Cloud AISBL, "About Gaia-X": https://www.gaia-x.eu/what-is-gaia-x (accessed May 19, 2022).

infrastructure. Moreover, the IPCEIs for microelectronics[54] face slow German and European Commission bureaucracy, and questions remain about these projects' alignment with the €17 billion Intel fab project in Magdeburg, to which German public subsidies are slated to contribute approximately €6.8 billion.[55]

On top of these policy inconsistencies, Germany's other fiscal and geopolitical priorities compete for federal funding. The current German government faces intense pressure to promote fiscal consolidation starting in 2023 even as the recent *Zeitenwende* envisions a €100 billion special fund (*Sondervermögen*) for modernizing Germany's armed forces in the face of rising geopolitical conflict.[56] Russia's invasion of Ukraine has also put inflationary pressures on energy and food, which is simultaneously accelerating and frustrating Germany's climate transformation goals. There is a growing sense that technology-industrial policy could become less of a priority.

Recommendations

Germany must use its industrial policy tools effectively to develop and secure access to critical technologies and preserve its economic competitiveness. To that end, it should:

Undertake a comprehensive mapping of goals and capacities in critical technology. Mirroring partners' efforts, the German government should kick-start an interagency effort to map out three industrial policy ambitions: technological leadership, peer status with competitors, and necessity to mitigate dependency risks.[57] These assessments should match strategic economic and security priorities with domestic and partner capabilities.

Increase strategic industrial policy cohesiveness between federal and state governments as well as among the *Länder*. Germany should prioritize ensuring that states' industrial policies align with national technology objectives. The Federal Ministry for Education and Research (BMBF) should establish a dashboard of state-level industrial initiatives that highlights unmet potential for asymmetric R&D and industrial alliances. Senior state officials, research consortia, and industry could use this tool to identify and realize synergies among initiatives in individual research fields and across industries, for example between hardware- (e.g., quantum computing) and software-related (e.g., natural language processing) R&D efforts.

Expand transnational industrial consortia in Europe and among like-minded states. The EU has a technological choice: hang together or hang separately. As the EU's largest economy, Germany has significant agency to advance a strategic and coherent European technology-industrial policy. It should foster cross-border innovation industry consortia by advocating a streamlined IPCEI notification process, ensuring adequate staffing for caseloads, and dedicating funds that match its high-tech ambitions. Where like-minded states provide key value chain components, Germany should encourage the European Commission to create an IPCEI scheme involving foreign suppliers to amplify positive spillover effects.

Focus on domestic – and European – competitive advantages and strategic interdependencies within a larger community of like-minded partners. Global supply chains are often too complex to reshore complete technology stacks. Germany should design its industrial policy to promote a larger community of like-minded partners that has the EU at its core but includes key partners such as the United States, Japan, and South Korea. This community should have

54 As a co-initiator of the IPCEI for Microelectronics, the German government is mobilizing nearly €1 billion through 2023 to support the building of modern chip factories and production of energy-efficient microelectronic components. It is also a major participant in a new IPCEI Microelectronics II that targets high-performance and specialized chips, e.g., for AI and autonomous driving applications. Federal Ministry for Economic Affairs and Energy (BMWi), "IPCEI Mikroelektronik: Zwei europäische Großprojekte für eine Schlüsseltechnologie der Zukunft" [IPCEI Microelectronics: Two Major European Projects for a Key Technology of the Future] (September 2021): https://www.bmwi.de/Redaktion/DE/Downloads/I/infopapier-ipcei-mikroelektronik.pdf?__blob=publicationFile&v=6 (accessed May 19, 2022).

55 Joachim Hofer, „Die Chip-Industrie entdeckt Deutschland – das neue Intel-Werk ist nur der Anfang" [The Chip Industry Discovers Germany – The New Intel Plant is Just the Beginning], Handelsblatt, October 7, 2022: https://www.handelsblatt.com/technik/it-internet/halbleiter-die-chip-industrie-entdeckt-deutschland-das-neue-intel-werk-ist-nur-der-anfang/28711740.html (accessed October 31, 2022).

56 Christian Mölling and Torben Schütz, "Zeitenwende in der Verteidigungspolitik. Bundeswehr-Sondervermögen effektiv und nachhaltig ausgeben" [Turning Point in Defense Policy. Spending the Bundeswehr Special Fund Effectively and Sustainably], DGAP Policy Brief No. 16, German Council on Foreign Relations (May 2022): https://dgap.org/sites/default/files/article_pdfs/dgap-policy%20brief-2022-16-dt_1.pdf (accessed May 19, 2022).

57 For the US example, see The White House, *National Strategy for Critical and Emerging Technologies* (October 2020): https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/10/National-Strategy-for-CET.pdf (accessed May, 19 2022).

three goals: IT security, supply chain resilience, and industrial competitiveness. Within these areas, industrial policy aimed at boosting competitiveness should link directly to German comparative advantages such as edge computing and industrial domain expertise (e.g., in the automotive, medical, and energy grid sectors) for specialized chips.

Structure public procurement to mitigate IT-security and supply chain vulnerabilities. Germany's largest purchaser of IT systems is its federal government, which can leverage its purchasing power to reduce strategic vulnerabilities, particularly in security-critical layers of its technology stack. Procurement requirements should support the scaling of a secure European cloud infrastructure for public services. Reforms should eliminate disadvantages for open source solutions by making security, openness, and interoperability key criteria. Reforms should also facilitate the entry of (smaller) European competitors through a simplified tendering process and more transparent approval timelines.

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