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COUNCIL FOR TECHNOLOGICAL SOVEREIGNTY

Discussion paper

Focus on technological sovereignty

Key technologies at the centre of geopolitics

Council for Technological Sovereignty

Disclaimer

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Merging technology and industrial policy: technology-orientated interventions as part of the industrial policy toolbox

The role of the state in the economy has considerably expanded: globally, interventions to promote selected domestic industries, technologies or companies have increased significantly over the last six years (see Figure 1) – typically with the aim of enhancing the competitiveness and technological sovereignty of the respective country. Such structural measures are generally described as industrial policy. In addition to direct trade policy measures such as tariffs or export subsidies, these state interventions also include financial support. Examples include subsidies for establishing production facilities for technology-intensive products or subsidies for the use of low-carbon production processes. Subsidies (excluding those for exports) account for approximately 50% of state interventions in high-income economies since 2023, and increasingly focus on technologies or technology-intensive goods.[11] But within today's highly interdependent global economic and trade systems, such measures can also have harmful effects on international trade.

The sharp increase in competition-distorting measures since 2018 has been primarily driven by high-income economies, led by the USA. However, Germany has also significantly contributed to this rise in recent years. Subsidies remain the most frequently used policy instrument in this context. The increase reflects attempts to respond to new geopolitical challenges as well as to events precipitated by the COVID-19 pandemic, such as supply chain disruptions.

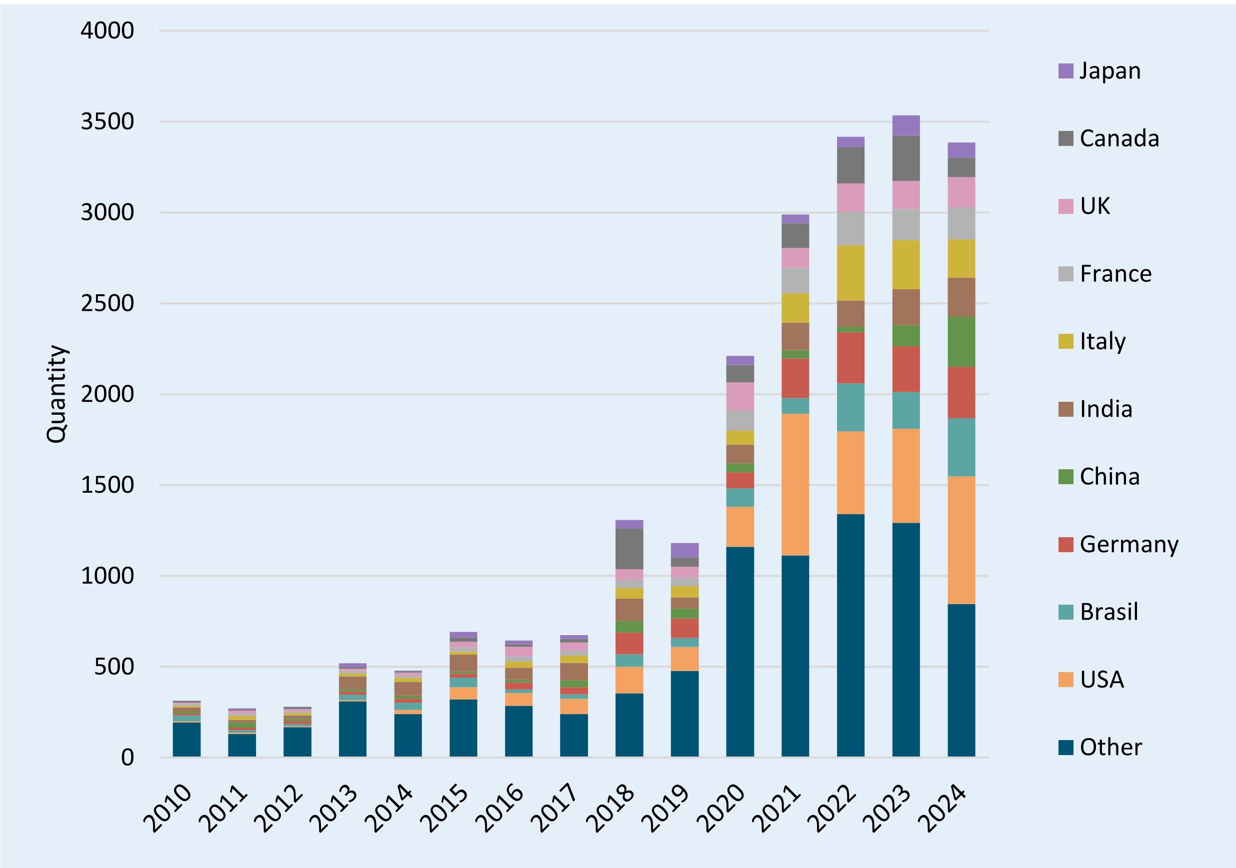


Figure 1: Trade-relevant, competition-distorting, harmful policy measures[1] worldwide. The ten largest economies are responsible for half of the harmful measures since 2010 and for two-thirds in the last three years. Source: Global Trade Alert database[2,3]

Even though there might be legitimate reasons for industrial policy measures[4] - a commonly cited example being the support of emerging industries to accelerate learning effects and quickly realise economies of scale - the introduction of such measures unfortunately often follows a logic of reciprocity aligned with political cycles. One state's implementation of industrial policy measures strongly correlates with previous similar measures taken by others.[5] This raises concerns that industrial policy often follows a 'tit-for-tat' logic rather than being primarily focused on achieving well-founded economic or societal goals. The risk is a mutual escalation that leads to increasing competitive distortions on all sides, a dynamic particularly evident in the context of elections.[6] For example, Daniel Gros, Director of the Institute for European Policymaking at Bocconi University, described the European Chips Act as a reactive measure that embodies all the negative characteristics of other countries' industrial policy measures in this field.[7]

This discussion paper (i) examines the extent to which technological sovereignty can serve as a convincing justification for structural (industrial policy) measures, (ii) identifies the key technologies that are the focus of policy measures in the ten wealthiest economies, (iii) describes, using patent applications, how Germany performs in these key technologies compared to other countries, and (iv) concludes with a catalogue of questions for policymakers from which actionable recommendations can be derived.

State intervention to support technological sovereignty

Innovation policy and government support for private research and development (R&D) are broadly discussed in the economic theory of market imperfections. Even with a functioning patent protection system, private R&D activities generate economic returns not only for the researching company but also for other firms. These other companies can build upon the new knowledge and use it as a basis for their own inventions. As a result, companies systematically underinvest in R&D. The state attempts to internalise these external benefits through direct and indirect support measures, creating incentives for more R&D in companies.

The rationale for innovation policy is initially technology-neutral. However, how can a policy that deliberately promotes specific technologies be justified?

Addressing demographic change, combating climate change, and ensuring national defence capabilities present significant challenges that new technologies can address. For example, smart robots can provide support in healthcare; materials and recycling research can make drive decarbonisation; and artificial intelligence can play a central role in defence and cybersecurity.

Policy aimed at supporting the technologies required to fulfil societal priorities and needs may indeed be justified. This is particularly true in an era where research efforts in various key technologies are increasingly concentrated outside Europe and geopolitical tensions are rising. In the event of conflict, dependencies on certain countries can lead to the loss of access to key technologies, and result in high societal costs. Promoting research and the (further) development of key technologies that are crucial to society within individual countries can therefore be an important measure to safeguard against geopolitical risks. The stakes are high: we are already in a "cold technology war" as described by Moritz Schularick, President of the Kiel Institute for the World Economy (IfW).

To strengthen technological sovereignty, both promoting the research and development of selected key technologies within a country and also the local application of these technologies can be justified. This is particularly relevant when there are strong spillover effects between the individual stages of the value chain - (basic) research, development, production and application. These effects are often insufficiently considered by companies but are crucial for ensuring technological sovereignty. For instance, production must be considered during the development of new technologies, and insights from production and application must be incorporated into further development.[8]

Access to key technologies, however, does not imply developing all key technologies in autarky. Technologies can also be imported from "friendly" countries or developed and utilised transnationally. Countries should leverage their own strengths and focus their research efforts specifically on those technologies for which they have a comparative advantage in research. This is dictated by the need to economise on limited public budgets.

Despite the need for specialisation, it must also be ensured that no one-sided dependency on individual countries arise. There are often close interdependencies between key technologies in technology-intensive areas such as smart robotics. Within these complex networks, unilateral dependencies can be avoided by creating mutual dependencies. This illustrates that focussing on individual technologies is insufficient; rather, the interactions between technologies are crucial.

Technology-intensive products and applications in the spotlight of policy

Industrial policy measures are increasingly targeting technology-intensive products or applications that combine key technologies. Figure 2 illustrates the number of competition-distorting government interventions for technology-intensive products or applications in the ten largest economies.

A focus on individual key technologies falls significantly short. Major innovations in recent years, such as the metaverse or generative AI chatbots, are not inherently new technologies, but rather clever combinations of existing ones. This is explained below using smart robotics as an example.

Example of smart robotics

Robotics clearly illustrates how the integration of artificial intelligence (AI), multimodal sensors, control systems, and communication technologies can create innovative solutions which unlock socio-economic potential and address key challenges such as the shortage of skilled labour.[9]

Robotics as an interface of multiple technologies

By combining multimodal sensor technologies and AI methods, robotic systems can dynamically adapt to individual needs and analyse human behaviour. Such systems facilitate intuitive human-machine interaction (HMI) by utilising natural communication forms such as speech and gestures.

An example is "active learning", where robots acquire specific skills through interaction with humans. These combinatorial approaches enable continuous adaptation to user needs and at the same time increase the accessibility of technical solutions for people without technical expertise.[10]

Socioeconomic potentials

The integration of various technologies in robotics lowers access barriers and enables broader utilization. This facilitates deployment in new application areas, enhances productivity, and supports social acceptance.

Simultaneously, such robotic systems can address structural issues such as the shortage of skilled workers. The ability to embed technologies in work and home environments thus strengthens competitiveness and creates new opportunities for value creation.

Investments in key technologies and their integration are crucial to fully exploit the potential of robotics. Robotics demonstrates how the combination of technologies drives innovation and addresses social challenges. Synergies between AI, sensor technology and user-centred interfaces create systems that adapt to human needs and thus potentially gain broad acceptance. The ability to combine key technologies is a decisive lever for long-term competitiveness in this growing sector.

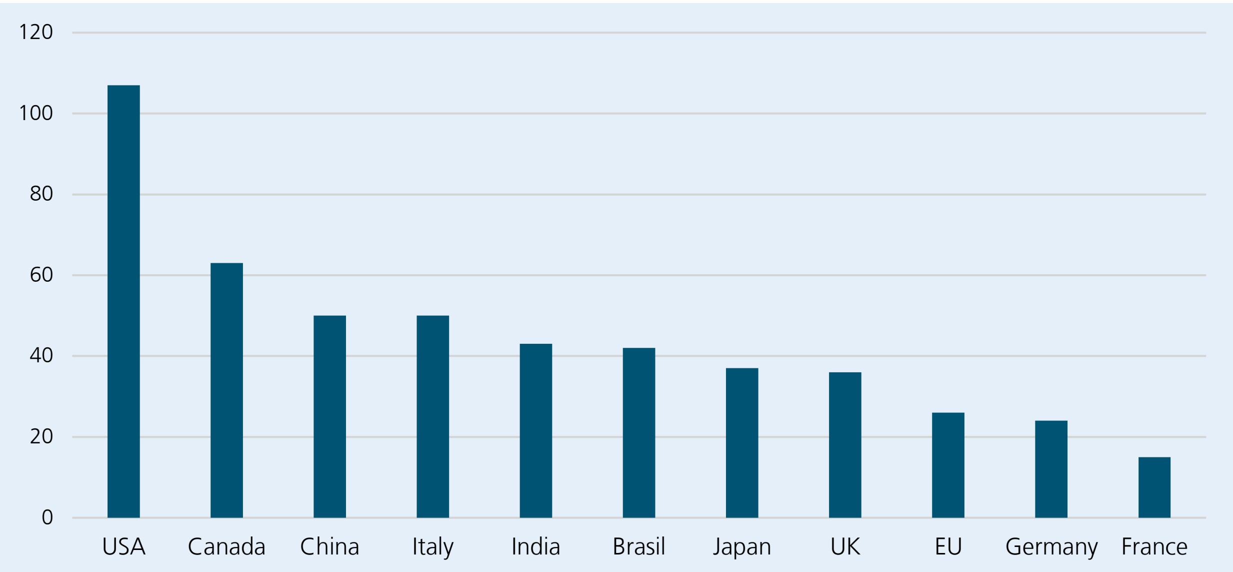


Figure 2: Number of competition-distorting policy measures in the area of "Advanced Technology Products" worldwide in 2023. These include, for example, financial support for companies l. Sources: Global Trade Alert database[2], NIPO[11]

Strategies for securing technological sovereignty: an international comparison

All major economies, including the EU, pursue specific strategies in varying degrees by which they define key enabling technologies (Table 3 in the appendix). Table 1 provides an overview of the key enabling technologies explicitly listed in the relevant strategy documents from various countries and the EU. The analysis shows that the number of defined technologies varies, but there is a common core that almost all countries focus on. Artificial intelligence, quantum technologies and biotechnology are the most widely represented globally. The EU, USA, China, Japan and Canada address the largest number of key technologies, followed by Germany and South Korea. Other key technologies are microelectronics and semiconductors, as well as information and communication technologies. Health and medical technologies, photonics and hypersonic technologies are comparatively less widespread globally. Environmental, climate protection and recycling technologies are also mentioned less frequently. Notably, France favours fewer key technologies and pursues other priorities, such as nuclear.

While some countries pursue a broad, innovation-oriented approach (e.g. USA, Japan, Canada), China and the EU focus strongly on strategic independence and risk minimisation. The majority focus on key technologies to ensure economic competitiveness and national security.

State institutions play a central role in this context: in the USA, the "Office of Science and Technology Policy" in the White House and, the Chinese National People's Congress develop recommendations and policies. In the EU, governance is provided by the Steering Board of Sovereignty as well as through the European Commission's "Competitiveness Compass"[12] and the newly appointed Commissioner for Tech Sovereignty, Security and Democracy, Henna

Key technology	EU	US	CN	EN	JP	IN	GB	FR	IT	BR	CA	KR	Σ
Artificial intelligence	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**11**
Quantum technologies	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**11**
Biotechnology	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**		**X**	**X**	**10**
Microelectronics and semiconductors	**X**	**X**	**X**	**X**	**X**		**X**		**X**		**X**	**X**	**9**
Information and communication technologies	**X**	**X**	**X**	**X**	**X**		**X**			**X**	**X**	**X**	**9**
Energy and battery technology	**X**	**X**	**X**	**X**	**X**			**X**			**X**	**X**	**8**
Production technologies and Industry 4.0	X	X	X	X	X						X	X	7
Cybersecurity	X	X	X	X	X						X	X	7
Data technologies, HPC and big data	X	X	X	X	X		X				X		7
Robotics and autonomous systems	X	X	X	X	X						X	X	7
(Deep) Space and propulsion technologies	X	X	X		X			X			X	X	7
Nuclear technologies	X	X	X		X			X			X	X	7
Sensor technologies	X	X	X	X	X						X		6
New materials / material innovations	X	X	X	X	X						X		6
Environmental, climate protection and recycling technology	X	X		X	X	X		X					6
Deep Earth / Deep Ocean Exploration			X		X	X						X	4
Genetics	X	X	X								X		4
Health/medical technology					X	X		X			X		4
Photonics	X		X	X									3
Emission-free/electric vehicles/aircraft						X		X			X		3
Hypersonic technologies		X			X								2
Agriculture					X			X					2
Σ	**17**	**17**	**17**	14	**19**	7	6	7	4	3	**17**	12	

Table 1: Overview of the key technologies explicitly listed in relevant strategy documents by country or community of states.

Virkkunen.[13] Germany relies on the Federal Ministry of Education and Research (BMBF), while the UK and Japan operate through specialised ministries and expert councils. It should be noted that the effects of the new US administration and the German federal elections will only become apparent after this report is published.

Using the example of semiconductor technologies,Figure 3 andTable 2 illustrate that individual technology strategies are underpinned by a multitude of specific measures backed by substantial government funding. These measures demonstrate diverse approaches—ranging from direct subsidies and tax incentives, to comprehensive, long-term support packages.

International patent applications under the Patent Cooperation Treaty (PCT) can serve as a benchmark to better assess Germany's position in the six most frequently mentioned key technologies: artificial intelligence, quantum technologies, biotechnology, microelectronics and semiconductors, information and communication technologies and energy and battery technology. Patent analyses are heavily dependent on the choice of data sources and are subject to time lag effects due to the long reporting and examination procedures. Nevertheless, they provide important indicators of innovation-specific focal points and enable a comparative overview of how different countries are positioned in key technological areas over time. Figure 4 shows the development of the global patent share of the ten largest economies and the EU for the six examined key technologies.

The period from 1990 to 2022 is shown in five-year increments, with the caveat that, due to the described time lags, the data for more recent years may not yet be complete.

The analysis shows that China's share is growing, at the expense of the USA and Europe in particular. China has established itself as a key player in the global competition for "technological supremacy". In contrast to the USA and Europe, Japan's share has remained relatively stable, and the country has even been able to increase its patent share in the field of artificial intelligence. Although Europe

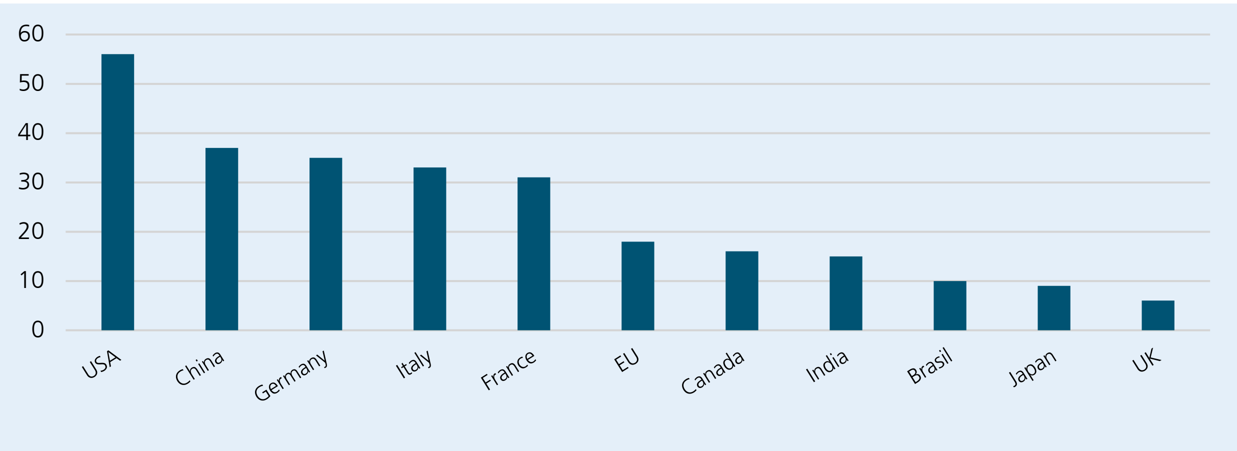


Figure 3: Number of competition-distorting policy measures in the semiconductor technology sector worldwide in 2023. These include, for example, financial support for companies or government bonds. Sources: Global Trade Alert database[2] , NIPO[11]

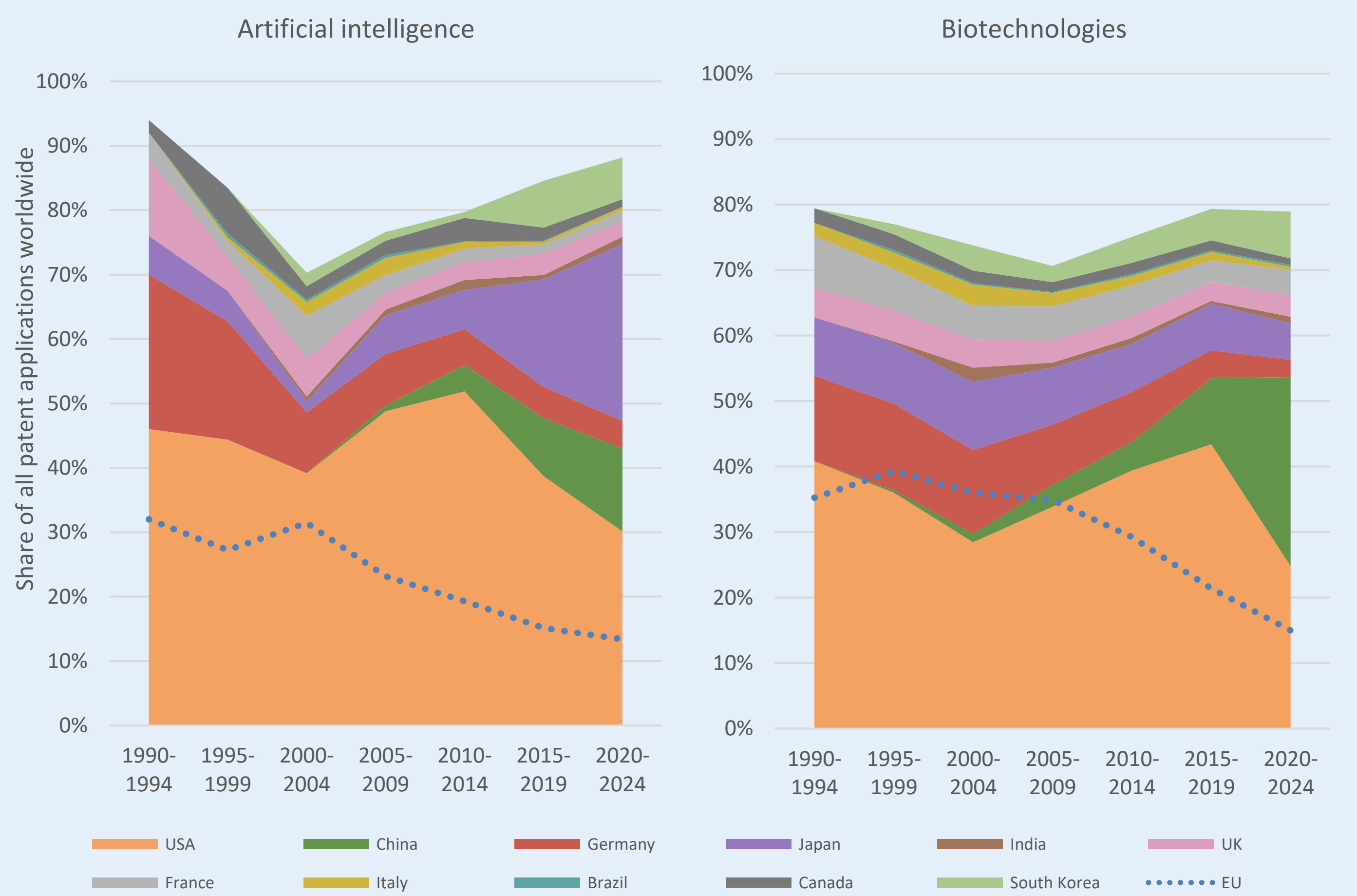
Region	Programme	Volume	Additional tax credits and incentives
USA	Chips for America	>$53bn by 2026[14]	Credit: 25% of the investment costs
EU	EU Chips Act & IPCEI	>$30bn by 2030	
China	Semicon package	$143 billion15 by 2028	Exemption: Income tax exemption for 2-10 years depending on the technology
South Korea	K-Chips Act	Tax benefits until 2032	Credit: 20% of investment costs, 50% of R&D costs
Japan	Semicon ecosystem strategy	$65bn by 203016	
Taiwan	Taiwan chip act	Tax benefits until 2029	Credit: 15-25% R&D, 5% tooling, no limit for tax expenses

Table 2: Comparison of microelectronics funding programmes in leading regions in the semiconductor sector. Source: ZVEI[17]

and Germany are still important players, they are losing ground. Overall, the number of patents in these key technologies is increasing. However, the shifts in share indicate varying rates of growth in the number of patents between countries.

To ensure that Europe—and Germany in particular—remains competitive in this dynamic environment, a united approach is essential. European countries need to strategically leverage their comparative advantages, consolidate their strengths and consider new partnerships to secure a leading role in global technology development over the long-term. An initial approach to achieving this is through the Important Projects of Common European Interest (IPCEI).[18]

Figure 4: Share of the countries analysed in the total number of worldwide patent applications for the period 1990 to 2024. The analyses focused on international (PCT) patent applications in the six most frequently identified key technology areas (see Table 1). For better clarity, values were aggregated in 5-year intervals (thus, the charts displays each country's share of all patents filed worldwide during each 5-year period). Data in more recent years may be incomplete due to delays in the reporting and examination procedures. Source: Patsnap



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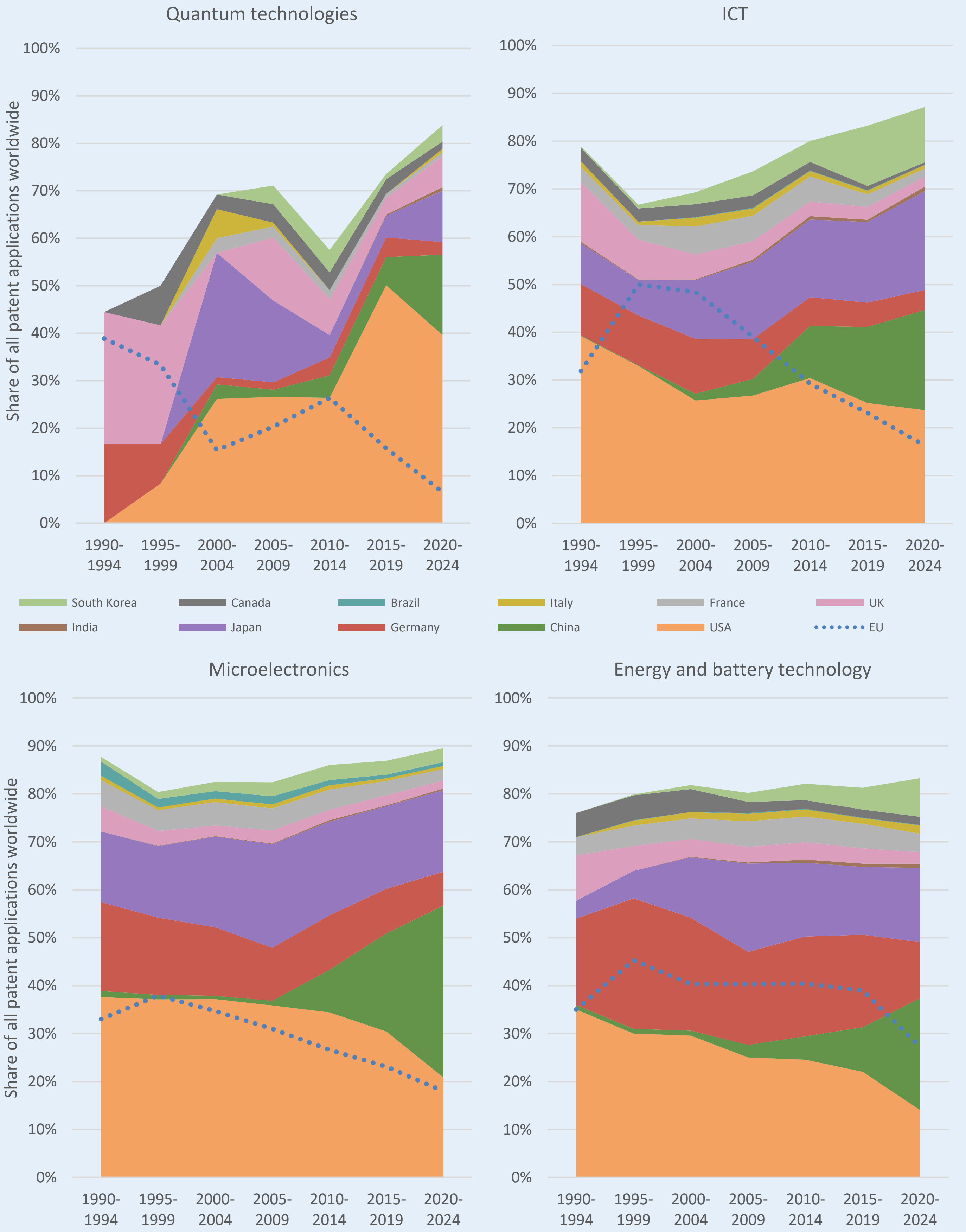

Key questions for policymakers

As outlined in this brief discussion paper, technology-orientated policy measures are gaining momentum worldwide. Due to their structural impact, these measures can be described as industrial policy initiatives. The introduction of such measures often occurs reactively in response to actions taken by other countries and follows political cycles. Merely reacting to other nations' measures – a "tit-for-tat" policy – reinforces internationally harmful competitive distortions. **Instead, a proactive, technology-orientated industrial policy should act as a form of insurance and contribute to addressing overarching societal challenges.**

Unilateral technology dependencies on specific countries can result in high costs for society as a whole in the event of conflict and the associated loss of access to key technologies. In such cases, industrial policy aimed at technological sovereignty is both justifiable and potent, although the design of the measures is challenging. The question then arises such measures should be developed (see key questions).

KEY QUESTIONS

Industrial policy for technological sovereignty should follow and answer the following key questions. These questions should be asked continuously and institutionally anchored to systematic, forward-looking technology monitoring:

1. What are the **future key technologies relevant** to addressing societal challenges?
2. In which areas of technology does Germany have **comparative advantages**? Where do **unilateral dependencies** exist within the complex technological landscape?
3. Are the identified technologies being **sufficiently developed** in Germany or Europe? If not, why are individual technologies not being sufficiently researched despite potential advantages in their development? Are there **decisive spillover effects** between research, production and application and are these being realised?
4. How can **suitable policy measures** be **designed** to solve **the underlying** problem? Can measures promoting **collaborative projects** contribute to the internalisation of spillover effects along the value chain? **At which federal level** should the policy measures sit (EU vs. Germany)?
5. How can measures be **meticulously designed** to consider interactions with other policy initiatives, minimise restrictions on competition and simultaneously reduce the risk of political influence (see political cycles)?

Appendix: Overview of technology strategies of various countries and communities of states

Country / Community of states	Strategy / Publication	Publisher / Institution	Central goal	Key technologies / fields
European Union	Commission recommendation on critical technology areas[19]	Steering Board of Sovereignty	Strengthening the economic basis and competitiveness, Protection against risks (disruptive technologies, dual use, risk of misuse)	10 "critical technology areas" with 4-5 technologies each (42 technologies in total)
USA	Critical and Emerging Technologies List Update[20]	Office of Science and Technology Policy in the White House Special Envoy for Critical and Emerging Technology		18 "Critical and emerging technology areas" with a total of 131 "key subfields"
China	14th Five-Year Plan[21]	National People's Congress of the People's Republic of China	Reduce economic dependence on foreign countries ("self-reliance") and achieve global market leadership in future technologies	7 "cutting-edge areas of science and technology" with 3-5 specifications each (28 in total)
Germany	Framework programme: "Research and Innovation for Technological Sovereignty 2030 (FITS2030)"[22]	German Federal Government (Federal Ministry of Education and Research, BMBF)	Strengthen technological sovereignty, avoid one-sided dependencies; be world market leader in key technologies and innovative products; strengthen European and international cooperation; assert "Made in Europe" as an independent global player in selected technology areas	8 digital and 4 industrial key technologies
Japan	Economic Security Protection Act (ESPA)[23]	Japanese Government (Council of Experts on Economic Security Legislation)	Economic security	20 "technologies as critical fields"
	Integrated Innovation Strategy 2024[24]	Cabinet	Promote synergy in science and technology cooperation; enable foresight; formulate and coordinate S&T missions; create a favourable ecosystem for tech entrepreneurship; foster innovation and technology, develop innovation clusters and promote effective public-private linkages	12 key fields
India	[Individual reports on missions][25]	Government of India (The Prime Minister's Science, Technology and Innovation Advisory Council (PM-STIAC))	Taking on a pioneering role in the aforementioned technologies, shaping global technology development in line with its own interests	9 Missions and Initiatives
Great Britain	"The UK's International Technology Strategy"[26]	British Government (Department for Science, Innovation and Technology (DSIT))	Promote technological competitiveness through strategic investments; create new industrial and technological sectors that support the green and digital transitions	6 "Priority technologies" (prioritised technologies)
France	"France 2030"[27]	French government	Accelerating the digital transformation and promoting sustainable innovation	10 "Objectif" across three domains
Italy	National Innovation and Digitalisation Plan 2025[28]	Italian government (Ministry for Technological Innovation and Digitalisation)		20 measures in the areas of digitalisation, technological innovation and ethical and sustainable development
	Cohesion decree[29]	of Ministers		6 strategic sectors / 4 key technologies
Brazil	Study: From Science and Technology to Innovation Diplomacy: Their Future and the Relationship with International Security[30]	Institute for Applied Economic Research (Ipea) (a public organisation that provides technical assistance to the federal government in the field of public policy)		4 technology areas
Canada	Sensitive Technology Research Areas[31]	Canadian Government	Promoting strategic technologies in an era of global technology competition	11 technology categories with a total of 76 subcategories
South Korea	National Strategic technology Nurture Plan[32]	Korean government (Ministry of Science and ICT - National Strategic Technology Special Committee)	Strengthening the economic basis and competitiveness, protection against risks (disruptive technologies, dual use, risk of misuse)	12 "strategic technologies" with 50 "sub-specific technologies"

Table 3: Overview of the number of specifically listed key technology areas, associated strategies, participating institutions, stated goals and corresponding investments for the ten countries with the highest GDP, supplemented by South Korea and the European Union.

[1] "Harmful" policy measures are those that restrict free trade and pursue protectionist objectives. This includes, for example, subsidies, tariffs and trade barriers.

[2] Source: https://web.archive.org/web/20250214155840/https://globaltradealert.org/ (accessed 19/02/2025) Restrictions applied: GTA Evaluation: harmful.

[3] Reporting lag adjustment: "2024-12-31"

[4] Czernich, Falck (2025): "Industriepolitik: Auf dem Vormarsch, aber Motivation und Wirkung meist nicht überzeugend" (Industrial policy: On the rise, but motivation and impact mostly unconvincing), https://www.ifo.de/DocDL/sd-2025-01-czernich-falck-bundestagswahl-industriepolitik.pdf

[5] Evenett et al. 2024, https://web.archive.org/web/20250214090716/https://www.imf.org/en/Publications/WP/Issues/2023/12/23/The-Return-of-Industrial-Policy-in-Data-542828

[6] EBRD 2024

[7] https://web.archive.org/web/20250316095913/https://www.ceps.eu/

[8] The study on the German innovation system by the Commission of Experts for Research and Innovation (EFI | Nr. 7-2022 – "Schlüsseltechnologien" (Key Technologies), see Figure A53) shows that Germany was the world leader in patent applications for production technologies in the years 2016 to 2018. This therefore continues to be a relevant pillar of the German research and innovation system.

[9] Council for Technological Sovereignty (2023): Position paper "Smart Robotics", https://projekttraeger.dlr.de/sites/default/files/2025-09/documents/Position-Paper-Smart-Robotics-rat4ts.pdf

[10] Council for Technological Sovereignty (2024): Adapting technology to humans to promote technology adoption and technological sovereignty - Significance in a modern society on the example of robotics, https://projekttraeger.dlr.de/sites/default/files/2025-09/documents/discussion_paper_adapting_technology_to_humans_rat4ts.pdf

[11] Source: /web/20250219081108/https://www.imf.org/en/Publications/WP/Issues/2023/12/23/The-Return-of-Industrial-Policy-in-Data-542828

[12] Source: https://ec.europa.eu/commission/presscorner/detail/de/ip_25_339

[13] /web/20250219083040/https://commission.europa.eu/about/organisation/college-commissioners/henna-virkkunen_en?prefLang=de

[15] Figure includes direct public investments and a small proportion of joint investments with the private sector

[16] Includes funding for the semiconductor and AI industry (programme currently being finalised)

[17] Source: ZVEI 2024, " Von Chips zu Chancen – Die Bedeutung und Wirtschaftlichkeit der Mikroelektronikförderung " (From chips to opportunities - the importance and cost-effectiveness of microelectronics funding)

[18] https://web.archive.org/web/20250218202607/https://competition-policy.ec.europa.eu/state-aid/ipcei_en

[19] Source: /web/20250219102243/https://defence-industry-space.ec.europa.eu/commission-recommendation-03-october-2023-critical-technology-areas-eus-economic-security-further_en

[20] Source: https://web.archive.org/web/20250219132051/https://www.govinfo.gov/content/pkg/CMR-PREX23-00185928/pdf/CMR-PREX23-00185928.pdf

[21] Source: /web/20250219121200/https://www.ifw-kiel.de/de/publikationen/kiel-focus/chinas-neuer-fuenfjahresplan-wirtschaftliche-kernelemente-und-implikationen-fuer-deutschland-und-europa/

[22] Source: https://web.archive.org/web/20250219124539/https://www.bmbf.de/SharedDocs/Kurzmeldungen/DE/2025/01/fits2030.html?templateQueryString=fits

[23] Source: https://web.archive.org/web/20241219052901/https://www.europarl.europa.eu/RegData/etudes/ATAG/2023/751417/EPRS_ATA(2023)751417_EN.

[24] Source: https://web.archive.org/web/20241206005228/https://www8.cao.go.jp/cstp/tougosenryaku/togo2024_honbun_eiyaku.pdf

[25] Source: https://web.archive.org/web/20241224220914/https://www.psa.gov.in/pm-stiac

[26] Source: https://web.archive.org/web/20241005150544/https://assets.publishing.service.gov.uk/media/6419f93fe90e0769ebc31f08/uk-international-technology-strategy-web-version.pdf

[27] Source: https://web.archive.org/web/20230925141420/https://www.economie.gouv.fr/files/files/2021/France-2030.pdf

[28] "Strategia per l'innovazione tecnologica e la digitalizzazione del Paese", source: https://web.archive.org/web/20241202231606/https://assets.innovazione.gov.it/1610546390-midbook2025.pdf

[29] Source: https://web.archive.org/web/20250123202420/https://www.governo.it/it/articolo/comunicato-stampa-del-consiglio-dei-ministri-n-79/25547

[30] Source: https://web.archive.org/web/20250219133359/https://portalantigo.ipea.gov.br/agencia/images/stories/PDFs/rtm/218569_rtm_28_artigo_1.pdf

[31] Source: https://web.archive.org/web/20241119195133/https://science.gc.ca/site/science/en/safeguarding-your-research/guidelines-and-tools-implement-research-security/sensitive-technology-research-and-affiliations-concern/sensitive-technology-research-areas

[32] Source: https://web.archive.org/web/20230328061314/https://k-erc.eu/korea-to-announce-national-strategy-to-become-a-technology-hegemon/

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