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COUNCIL FOR TECHNOLOGICAL SOVEREIGNTY

Focus on Critical Technologies

The Race for Leadership in Industry and Technology Policy

"Technological Sovereignty" in International Comparison

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Council for Technological Sovereignty

Context

Nation states are investing more in critical technologies than ever before. Numerous governments have launched corresponding programmes in the last two years with the aim of promoting technological sovereignty, focusing on key enabling technologies. However, these programmes are often only partly motivated by innovation policy. Fundamental objectives of national security and competitiveness vis-à-vis other countries are also being pursued. The background is a changing perspective on globalisation: geopolitical fragmentation and the recent experience of broken supply chains during the pandemic have put the issue of technological sovereignty on the agenda. The programmes are generally backed by significant funding. In this paper, the Council for Technological Sovereignty of the German Federal Ministry of Education and Research (BMBF) provides a comparative overview of critical technologies and the institutional governance of technological sovereignty in selected countries.

Disclaimer

Key Objectives of Technological Sovereignty

The claim for "technological sovereignty" has become an important topic in politics and business over the last ten years. Based on the Council for Technological Sovereignty's definition, this can be understood as the ability of a country to **guarantee access at all times to the key technologies that are necessary to realise social priorities and needs**.

The goals of technological sovereignty have changed over time: Originally, the approaches focussed mainly on **military** research. As the digital transformation progressed and the importance of digital infrastructure, platform business models and cloud computing increased, **digital sovereignty** took centre stage. Debates centred, for example, on network components from Chinese manufacturers in domestic mobile networks, regulation of large platform operators and the importance of a European cloud infrastructure. Later, the **fight against climate change** and the associated accelerated energy transition came to the fore: in this context, sovereignty in environmental and energy technologies became the main topic of discussion. In the meantime, the focus has also shifted to **technologies that are expected to make a significant contribution to global value creation in the future**.

One current goal is to **equip** ourselves against **geopolitical risks**. These have arisen due to the increasing polarisation and fragmentation of global markets. Concerns about the developments in China, an autocratic and at the same time technologically rapidly emerging country, the impact of the COVID-19 pandemic on healthcare systems and supply chains, the weakening of the global economy and the urgent need for measures to combat climate change play a central role in this. Trust in transnational solutions has fallen significantly, with countries increasingly relying on national approaches or cooperation with "friendly nations". The spectrum ranges from "as little as necessary" to "as much as possible": China, for example, speaks of "self-reliance", the US of "economic and national security" and the EU of "strategic autonomy".

The Most Important Critical Technologies

Which technologies do selected countries focus on in the context of technological sovereignty? To answer this question, this analysis examines strategy papers of selected governments which address technological sovereignty and national funding of key technologies. The focus of this paper is on Germany and the European Union, the USA, China, Japan and South Korea. In addition to government publications, secondary literature on this topic was considered. Aside from this research, interviews were conducted with experts for the funding programmes of the individual countries studied. The aim of the interviews was to shed light on the strategy and motivation behind the countries' programmes[1].

Overall, the assumption that technological sovereignty is highly relevant internationally is confirmed. However, the terminology used in this context differs from country to country. While some countries speak of “key technologies” or "key enabling technologies", others define "prioritised" or "critical" or “frontier” technologies. The degree of national autonomy that is pursued for these technology areas also varies greatly.

The characteristics and priorities of the lists differ in their basic structures, where some are available as a one-dimensional list and some as a list with super- and subcategories. Sometimes identical technology areas are categorised at different priority levels[2], and some countries even include technology-intensive fields of application or industry-specific solutions in their lists. All these aspects make it difficult to directly compare countries to one another.

Nevertheless, there is significant overlap between the technology lists of countries in our sample. The largest consensus can be found in **artificial intelligence**, **quantum technologies**, **biotechnology**, **microelectronics/semiconductors**, **information and communication technologies,** and **production technologies/Industry 4.0**. But even beyond these, the lists of technologies considered relevant are very similar – although there are certain divergences in some areas. Germany, for example, gives significantly higher importance to research into green hydrogen than most other countries (see complete list in the appendix). The USA and Japan have a special focus on "hypersonic" technologies, which are particularly relevant as the basis for launch vehicles in dual-use applications. Environmental and recycling technologies only receive special attention in the European Union and the USA, while they are not listed in Asia. The Asian countries Japan, China and South Korea also mention deep sea and deep earth exploration as relevant research areas, whereas this is not the case in the European Union and the USA.

The process of selecting technologies differs significantly between countries. Although the details of the process cannot be fully comprehended everywhere, it is clear that the USA and China in particular have institutionalised this process. In the US, for example, the Fast Track Action Subcommittee on Critical and Emerging Technologies was established in 2020 specifically for the purpose of identifying critical and emerging technologies.

In Germany, on the other hand, the process is spread across several stakeholders within the federal government. There is no cross-departmental list of critical technologies, even if there is a great deal of agreement between the focal points of the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Economic Affairs and Climate Action (BMWK). The situation is similar in the European Union, where – in particular due to the decentralised structure and diverse perspectives of the member states – new lists with varying degrees of detail and liability are constantly being published[3].

In general, each compilation of the relevant technologies follows the overarching political and economic objectives of the respective country. Competition and industrial policy objectives, as well as the strengthening of the respective lead industries, are reflected in the details of the programmes.

Funding for Technological Sovereignty

In the countries analysed, a variety of approaches are being taken. These include industry - and technology funding programmes, regulatory restrictions on market access for certain companies or restrictions on exports of critical materials. A look at the semiconductor sector illustrates this development: the USA has committed to investing USD 280 billion in chip production and research over the next ten years, while China is providing subsidies totalling USD 145 billion and the EU has passed its own law to promote chip production in Europe with a budget of EUR 43 billion. In Germany - subject to the budget situation - billions in subsidies are planned for the construction of chip production plants, for example by Intel or TSMC. At the same time, there is a trend in some countries to restrict market access to key components that are essential for chip production. For example, China has been restricting the export of critical minerals such as gallium and germanium since August 2023. Prior to this, the USA had already imposed export restrictions on EUV lithography equipment to China, which is critical for chip production.

The diversity of funding approaches makes it difficult to generally quantify the funding volumes across countries and technologies or technology-intensive applications. An attempt at quantification is nevertheless being made by various institutions[4] . The Center for Strategic and International Studies[5] , for example, estimates the expenditure on industrial policy strategies for China and seven other economies (Brazil, France, Germany, Japan, South Korea, Taiwan and the USA). The study suggests that industrial policy is an important part of the policy-making toolbox in these countries.

Similarly, the OECD has developed cross-country methods for quantifying industrial policy for a selection of OECD member countries[6] . According to these methods, an average of around 1.4% of GDP was spent on support measures such as project funding, grants, tax breaks and a further 1.8% of GDP on loans. The approach is largely technology-specific. Funding for explicitly sustainable projects has increased significantly in recent years[7].

Another approach uses Natural Language Processing[8] to classify industrial policy at a high-resolution level (country-industry-year) based on publicly available descriptions of policy measures[9] . The core idea is that textual descriptions of programmes often convey information about the objectives of policy actors and allow researchers to determine whether a policy pursues industrial policy objectives or alternative objectives[10]. Accordingly, industrial policy is often granular and technocratic, and only individual companies benefit from the funds. Furthermore, these support measures are primarily applied in wealthier countries and are usually targeted at a specific industrial sector that is considered central to competitiveness and prosperity.

The following table provides an overview of the number of specifically listed key technology areas, associated strategies, participating institutions, stated goals, corresponding investments and selected funding measures for six countries or communities of states analysed.

	Germany	European Union	USA	China	Japan	South Korea
Number of key technology areas (see appendix for complete list)	12 "Key technologies"	10 "critical technology areas" With 4-5 technologies each (42 technologies in total)	19 "Critical and emerging technologies" With 2-15 "Critical and Emerging Technology Subfields" each (103 subfields in total)	7 "Cutting-edge areas of science and technology" With 3-5 specifications each (28 in total)	20 "technologies as critical fields"	12 "strategic technologies"
Strategies	"Shaping the future with technological confidence", BMBF impulse paper, April 2021	Commission Recommendation on security-relevant technology areas, October 2023[11]	"United States Government National Standards Strategy for Critical and Emerging technology", May 2023	14th five-year plan, March 2021	"Economic Security Strategy", February 2022	"National Strategic technology Nurture Plan", October 2022
Institutions	Distinct projects and initiatives at federal level: BMBF, BMWK, BMDV, Federal Chancellery	Steering Board of Sovereignty	Office of Science and Technology Policy in the White House Special Envoy for Critical and Emerging Technology	Ministry of Science and Technology of the People's Republic of China	Council of Experts on Economic Security Legislation Japan Science and Technology Agency (similar to the DFG)	Ministry of Science and ICT National Strategic Technology Special Committee
Central goal	Preserving values, securing prosperity and jobs	Strengthening the economic basis and competitiveness, protection against risks (disruptive technologies, dual use, risk of misuse)	Economic leadership in future technology, national security and self-sufficiency in selected areas of technology	"Self Reliance"	Economic security	Technological hegemony
Investments (estimate 2019)[12]	$19 billion PPP (0.41% GDP)	n.a.	$84 billion PPP (0.39% GDP)	$406 billion PPP (1.73% GDP)	$27 billion PPP (0.5% GDP)	$15 billion PPP (0.67% GDP)
Selected support measures[13]	$5.4 billion by 2025 for the AI strategy $3.3 billion in quantum computers by 2026	$294 billion for the "Green Industrial Deal" $141.5 billion for "NextGenerationEU" $762 million for 5G infrastructure (Horizon 2020) $980 million for smart networks and services	$369 billion IRA $230 billion for the production of semiconductors $140 billion for electric vehicles and batteries $20 billion for biomanufacturing	$1400 billion for new infrastructure: 5G, AI, IoT, etc. $150 billion for a next-generation AI development plan	Investments are to come primarily from the private sector. In addition, $1.05 trillion is to come from public-private partnerships over the next 10 years.[14]	$262 billion for semiconductors by 2026 $10 billion for biotechnologies by 2026 $73 billion for mobility/vehicles by 2026 $1.3 billion for robotics by 2026[15]

Table 1 Overview of the number of specifically listed key technology fields, associated strategies, participating institutions, stated objectives, corresponding investments and selected funding measures for six countries or communities of states analysed. The complexity of the funding landscape of industrial and research policy channels makes it difficult to aggregate all the respective measures and investments. The table therefore contains an exemplary selection. Due to the limited data available, scientific work from 2019 was used in some cases, even if lists of key technology fields were not compiled until later.

Three Observations and Discussion

The brief overview presented here already allows three observations to be made:

(1) Same Thrust - Different Competences

The countries analysed largely focus on the same fields of technology that are expected to generate value in the future. Even if there are certain differences between the countries when it comes to setting priorities within the technology fields, the extent to which the selection process incorporates individual countries' strengths in specific technology fields and possible specialisation advantages can be scrutinised. After all, technological sovereignty does not necessarily mean (further) developing all technologies by oneself. Rather, access to key technologies should be guaranteed at all times.

What does technological sovereignty mean in the technology-intensive application area of robotics, for example? In robotics, Germany is well-positioned in mechanics. Technological sovereignty could therefore be assumed directly in mechanics. AI, on the other hand, which is also becoming increasingly important for smart robotics, is being (further) developed primarily in other countries. This raises the question of the extent to which access to corresponding AI developments is guaranteed at all times in order to ensure technological sovereignty in AI as well.

(2) Promotion of Production Capacities vs. Promotion of R&D

In the measures to promote technological sovereignty, the promotion of R&D activities and the promotion of the development of production capacities are becoming increasingly blurred.

Public funding of R&D activities is largely undisputed due to significant (locally limited) so-called *knowledge spillovers.* A certain mission-oriented approach aimed at solving urgent social problems, such as decarbonisation, has prevailed over the isolated promotion of individual technologies in the R&D funding landscape.

In contrast, public support for the development of production capacities raises the question of the risk of an inefficient international division of labour. Do such measures still fully utilise a country's own strengths and the advantages of international trade? To what extent is the promotion of domestic production a sensible response to new geopolitical tensions and concerns about dependency on foreign countries for certain (intermediate) products? Frequently, expensive re-shoring can probably only be part of the solution to ensure the resilience of value chains for high-tech goods. Multi-sourcing, which can also include friend-, near- or re-shoring, is more likely to be helpful. What does other safeguarding against unforeseeable geopolitical tensions look like? Can suitable measures and framework conditions be used to create mutual dependencies through the production and export of (preliminary) products that yield a strategic advantage?

Public support for production should also take the lifecycle of an industry into account. In the case of an infant industry, public funding could achieve learning effects in production so that new products become competitive more quickly compared to (inferior) old products. However, the infant industry argument only justifies the temporary promotion of young industries, which should be reduced as the industry matures. This often poses a political-economic problem: the difficulty of withdrawing support once it has been granted.

Promoting the establishment of production capacities at the expense of foreign countries is often seen as a zero-sum game. It is assumed that there is a "cake" of a given size that needs to be distributed between countries. However, this view overlooks the growth-generating benefits of international trade and co-operation. In addition, this often starts a spiral of intervention and subsidisation between countries that is not only harmful for all countries in the long term, but also for each individual country. This is because a country's scarce resources - including skilled labour - are not put to their most productive use in that country.

(3) Possibilities for Early Detection of of Technological Trends

Some countries, such as the USA and China, have institutionalised and professionalised the process of monitoring emerging technologies. Even if monitoring is no guarantee for good policy decisions, it does allow policymakers to deal with new technologies at an early stage and, if necessary, adapt political conditions and institutions.

The Goal of Technological Sovereignty

This paper also illustrates that very different goals and therefore policy measures may lie behind the concept of technological sovereignty in different countries. In a world of rapidly changing geopolitical conditions and new technological developments and trends, perhaps the most compelling goal of technological sovereignty is to avoid one-sided dependencies in access to key technologies that are necessary to serve societal priorities and needs. Measures to promote technological sovereignty should therefore be gauged against the achievement of this goal.

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Appendix

The following table contains the complete technology lists of the countries and communities of states analysed. The terminology used differs for each country ("critical technologies", "key technologies", etc.).

Country	Key technologies
Germany[16]	Next-generation electronics; information and communication technologies; software and artificial intelligence; data technologies; quantum computing; production technologies; recycling technologies (circular economy); material innovations; battery research; green hydrogen; vaccine research and development; photonic technologies and quantum technologies; biotechnology; environmental technologies; analytical technologies and metrology; IT security research; high performance and supercomputing; research for civil security
EU[17]	Advanced semiconductor technologies; artificial intelligence technologies; quantum technologies; biotechnologies; advanced connectivity, navigation and digital technologies; advanced sensing technologies; space & propulsion technologies; energy technologies; robotics and autonomous systems; advanced materials, manufacturing and recycling technologies
USA[18]	Advanced Computing; Advanced Engineering Materials; Advanced Gas Turbine Engine Technologies; Advanced Manufacturing; Advanced and Networked Sensing and Signature Management; Advanced Nuclear Energy Technologies; Artificial Intelligence; Autonomous Systems and Robotics; Biotechnologies; Communication and Networking Technologies; Directed Energy; Financial Technologies; Human-Machine Interfaces; Hypersonics; Networked Sensors and Sensing; Quantum Information Technologies; Renewable Energy Generation and Storage; Semiconductors and Microelectronics; Space Technologies and Systems
China[19]	Quantum Information; Photonics and Micro-Nano Electronics; Network Communication; Artificial Intelligence; Biomedicine; Advanced Energy Systems; Integrated Circuits; Life and Health; Brain Research; Biological Breeding; Aerospace Science and Technology; Deep Sea and Earth; Safety from Infectious Diseases and Biosafety Risks; Pharmaceuticals and Medical Devices; New Generation of Artificial Intelligence; Quantum Information; Integrated Circuit; Brain science and brain-inspired research; Genes and biotechnology; Clinical medicine and health; Space, deep earth, deep sea and polar exploration; New high-end materials; Major engineering equipment; Intelligent manufacturing and robotics; Aircraft engines and gas turbines; Beidou industrial application; New energy vehicles and intelligent connected vehicles; High-end medical devices and innovative drugs; Agricultural machinery and equipment
Japan[20]	Biotechnology; medical and public health technology; artificial intelligence and machine learning; advanced computing; microprocessor and semiconductor technology; data science, analysis, storage and management; advanced engineering and manufacturing technology; robotics; quantum information science; advanced surveillance, positioning and sensing technology; neurocomputing and brain interface technology; advanced energy and energy storage technology; advanced information, communication and networking technology; cybersecurity; space technology, marine technology; transport technology; hypersonics; chemical, biological, radiation and nuclear technology; and advanced materials science
Korea[21]	Semiconductor and display; secondary cells; leading-edge mobility; next generation nuclear energy; leading edge bio; aerospace and marine; hydrogen; cybersecurity; AI; next generation communications; leading edge robotics and manufacture; quantum

Table 2 Technology lists of the countries and communities of states analysed

[1] The EU as a community of states is also included; for the sake of simplicity, we refer only to “countries” in the text.
[2] For example, in a top-level category or as a sub-item of a category.
[3] e.g. Advanced Technologies for Industries (2020), 4+6 Critical Technology areas for Economic Security (COM proposals in 2023: https://defence-industry-space.ec.europa.eu/commission-recommendation-03-october-2023-critical-technology-areas-eus-economic-security-further_en; https://www.euractiv.com/section/economy-jobs/news/stricter-eu-controls-on-critical-technologies-possible-from-spring-2024/).
[4] Source of the summary: "The New Economics Of Industrial Policy "; Réka Juhász, Nathan Lane, and Dani Rodrik; August 2023
[5] DiPippo, Mazzocco and Kennedy, 2022
[6] Criscuolo, Lalanne and Diaz (2022)
[7] https://www.oecd-ilibrary.org/docserver/5f2dcc8e-en.pdf?expires=1702559143&id=id&accname=ocid44013871&checksum=48E794485049A8E8781326D9650E3F37
[8] Juhász, Lane, Oehlsen and Perez (2022)
[9] Global Trade Alert database or GTA; Evenet (2009
[10] Juhász, Lane, Oehlsen and Perez (2022)
[11] Mentions of strategic autonomy since 2013 Source: https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733589/EPRS_BRI(2022)733589_EN.pdf
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