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# Technology sovereignty

## From demand to concept

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Policy Brief

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## From demand to concept

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# EXECUTIVE SUMMARY

## Background and motivation

Calls for technology sovereignty in Europe were becoming louder even before the current Corona crisis. Growing geopolitical uncertainties and the threat of global trade conflicts are questioning the optimism of recent decades concerning the interdependence of our economies. In Germany, this is triggering a discussion about how independent a state or a federation of states must and can be with regard to critical technologies. It becomes clear that there is an increasing conflict between the call for technology sovereignty on the one hand, and the dominant economic model on the other, in which global specialization and the division of labor combined with open trade increases the welfare of all. Germany, in particular, as an export nation, and the EU as an economic area must consider the question of technology sovereignty carefully and in a differentiated manner.

We present one conception of technology sovereignty in this position paper. Our intention is to enrich the current debate and improve differentiation. We develop the criteria and key analytical steps needed to determine the criticality of technologies and the degree of technology sovereignty. Building on this, we develop modified strategies to safeguard or to produce technology sovereignty.

# What is technology sovereignty?

*We define technology sovereignty as the ability of a state or a federation of states to provide the technologies it deems critical for its welfare, competitiveness, and ability to act, and to be able to develop these or source them from other economic areas without one-sided structural dependency.*

Our definition of technology sovereignty therefore does not imply comprehensive technology autarky that questions the international division of labor and globalization and aims at providing every technology classified as critical. Primarily, it describes preserving options by developing and maintaining own capabilities and avoiding one-sided dependencies. Technology sovereignty is therefore a necessary, but by no means sufficient condition for the self-determined creation and diffusion of critical innovations (innovation sovereignty) and therefore for self-determined economic trade (economic sovereignty). It is insufficient to focus on technology sovereignty alone.

# How do we determine whether technology sovereignty exists and whether we should pursue it?

## Analytical steps

While from the viewpoint of the state, the aim is often to achieve *technological competitiveness* in as many areas as possible, we propose a more differentiated and selective approach to determining whether sovereignty exists or is indeed required for a specific technology:

- The first step is to analyze whether a technology is currently *critical*, meaning indispensable (or will be critical in future) and why, and to what extent access to it could be threatened by external shocks.

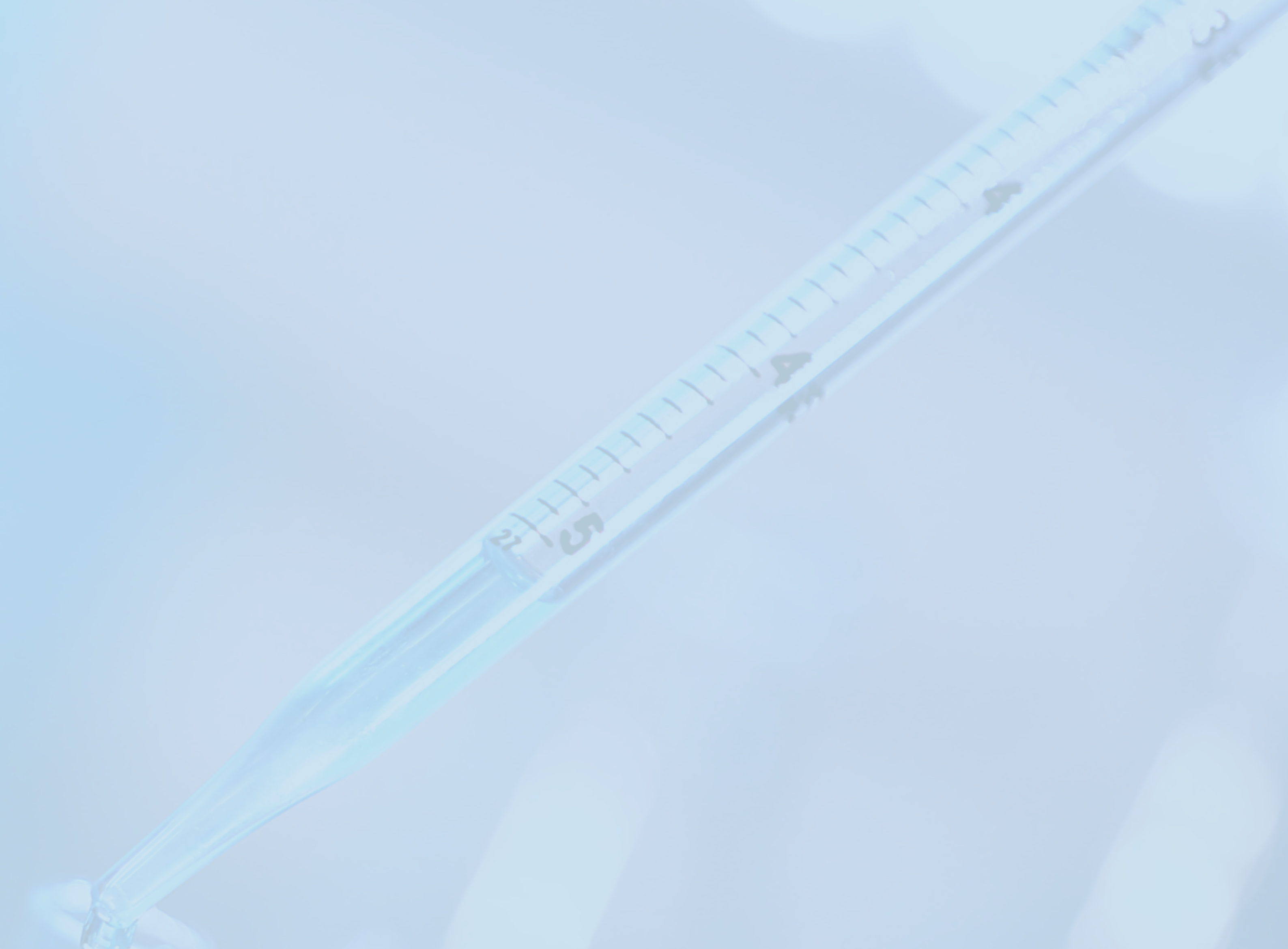
- The second step is to differentiate precisely in which *functional context* a technology is critical. Here, we distinguish between a technology's contribution to *economic competitiveness*, its contribution to *meeting key societal needs* such as healthcare, for example, or energy supply, and to *sovereign tasks*. This distinction is important because it determines whether and for what precisely a particular technology is absolutely indispensable, and whether there may be functional substitutes that eliminate dependence on a specific technology.

- The third step is to define the appropriate *spatial-political system boundaries* within which technology sovereignty should be achieved. The degree of economic and political interdependence determines the security of supply as well as the degree of dependency on actors outside the system. For Germany, this frame of reference should *in principle* be the EU in view of the manifold existing economic, institutional, and political interdependencies.

- In the final step, we consider the factors needed to *produce technology sovereignty*. We distinguish here between:

  - *already existing own* competencies and resources or the possibility to *develop* the necessary competencies and resources ourselves if needed, and
  - *access* to resources, competencies, and upstream services of third parties (*security of supply*).

Constraints on technology sovereignty are to be feared if there is no security of supply from third parties for those



critical resources or competencies that a state or a federation of states cannot provide or develop itself.

The joint analysis of these dimensions can determine the current and the desirable degree of technology sovereignty in a given situation and, where needed, strategies can be developed to preserve or to generate technology sovereignty. A systemic perspective must always be taken here in order to comprehensively assess and develop both resilience to shocks and adaptability in a dynamic global environment.

## Methods and data sources

A series of analytical steps are needed to develop strategies to preserve or produce technology sovereignty. Our position paper presents various methods and data sources for these steps. To gain a *better understanding of our own competencies and resources*, the methods range from patent and publication analyses through analyses of standardization activities to trade statistics grouped and analyzed by technology. Concerning the *dependence on other countries* or access to the resources and competencies of other countries, the analyses include data sources such as technology-specific trade statistics, complexity indices to identify value chains, and information about the governance behavior of countries based, for instance, on WTO compliance analyses or the World Governance index.

We use two case examples in our position paper – 5G technologies, and Industry 4.0/robotics – to illustrate how the concept can be applied and used to define modified strategies that go beyond the current debate.

# How can technology sovereignty be produced and preserved?

## Strategic recommendations

The position paper's first general recommended strategy is to provide the *competencies* for the complex analysis to determine the necessity of technology sovereignty and to develop the *necessary methods*. This is a prerequisite to developing modified strategies to produce and preserve technology sovereignty. It must remain clear at all times that *technology sovereignty is a necessary, but not sufficient condition for innovations* which ensure economic competitiveness and that society's needs are met. The consideration of technology sovereignty must supplement and cannot replace what is required of a future-oriented innovation policy.

The concrete recommended strategies comprise a number of actions:

- Sufficiently broad *investments in research and development* are the basic prerequisite for establishing sovereignty in critical technologies now and in the future. Any reduction of existing R&D competencies that are currently used or could easily be mobilized in areas where there is a threat of dependence on third parties should be avoided.
- *International research cooperation and technology partnerships* are an important instrument for mobilizing complementary competencies and achieving technology interdependence with other selected countries by means of knowledge interdependencies, thus reducing one-sided dependency on third parties.
- Actively *influencing standards* to direct international markets towards our own technologies as well as patent pools or Open Source software and hardware which prevent monopolization and thus structural dependencies.
- Creating *regulatory framework conditions* in critical technology fields that *foster innovation and production*.
- Promoting *innovation-oriented procurement* that provides our own companies with the necessary incentives to invest in critical technologies.
- Strengthening *international organizations* such as the WTO to ensure compliance with agreed multilateral

regulations as much as possible despite global trade conflicts. This is important since, in addition to the single European market, free world trade with its strong competition incentives remains an important boundary condition for technology sovereignty.

The concept of technology sovereignty is also congruent with increased investment in the resilience of the EU's economic and social systems so that these can recover rapidly from shocks and disruptions, and adapt quickly to changing contexts. This is an important cornerstone of any consideration of future-proof technology sovereignty. The EU states already have the right prerequisites for this as their economies are strongly oriented towards open competition, and their societies are influenced by subsidiarity and, above all, are democratically organized. All this means the EU's ability to adapt is fed by a diverse pool of economic, political, scientific, and civil society resources. Fostering the broadest possible basis of competencies and capacities in critical technology fields is an important element in lowering the vulnerability of the EU to potential disruptions and shocks – especially in times of increasing global uncertainty. In line with a systemic approach to resilience, key technological abilities should therefore be promoted, innovation networks built, and experimental learning enabled, for example, in regulatory sandboxes.

# Introduction

During the course of the coronavirus crisis, it has been increasingly pointed out that a country needs to be able to provide its population with essential supplies using its own domestic capacities in order to avoid dependencies on other countries. It is argued that, in the event of a crisis, states or federations of states must be able to provide or produce in their own countries the infrastructures, services and products, e.g. medicines, needed for society and the economy and for carrying out their own public tasks, and must have the appropriate technologies and sufficient research capacities for innovative solutions.

This aspiration is linked to a demand that was already experiencing a renaissance in the EU and in Germany even before the corona crisis, namely to actively expand one's own technology sovereignty.

*We define technology sovereignty as the ability of a state or a federation of states to provide the technologies it deems critical for welfare, competitiveness, and its ability to act, and to be able to develop these or source them from other economic areas without one-sided structural dependency.*

The discussion about technology sovereignty at European level is determining the debate both in terms of the priorities in the new Framework Programme, as well as European industry and digital strategies. In addition, it forms a key component of the discussion on how to overcome the corona crisis in Europe.[1] Federal Minister for Economic Affairs and Energy Peter Altmaier and industry associations[2] have put technology sovereignty (back) on the agenda in the context of Germany's industrial strategy as well. At present, the most intensive discussions about sovereignty are taking place in the technology fields of vaccine development, 5G technology infrastructure, and artificial intelligence.[3] These are considered critical technologies that not only generate huge markets for themselves worldwide, but also act as key technologies for almost all industrial and service sectors. They are pivotal to fulfilling sovereign tasks in terms of providing public services such as civil security, healthcare, energy, and transport infrastructures. In view of the current coronavirus pandemic, this also concerns mobilizing sufficient research capacities and generating technologies at home, in order to be able to contain the spread and impacts of the virus using protective measures, innovative treatments, and medication. Here, it is essential to have technologies available to maintain important economic and social activities that are restricted by the virus.

However, the concepts and interpretations of technology sovereignty vary depending on economic and political interests. In order to support (innovation) policy, a more differentiated analysis is required of the area of potential conflict between global trade, integrated value chains and technology and knowledge transfer on the one hand, and the need for state sovereignty on the other.

With this position paper, we would like to provide a conceptual basis for the debate and offer an invitation to an informed dialogue. We argue that, in view of global challenges such as climate change or pandemics, closely interconnected value chains, and geopolitical uncertainties, only a consistently European perspective of technology sovereignty is future-proof. The integration of value added in the European single market and the positioning vis-à-vis the increasingly protectionist USA and China makes the national level within the EU appear insufficient, even counterproductive for producing technology sovereignty, if only because of the size differences.

Our concept of technology sovereignty is characterized by a degree of differentiation that goes beyond the current often politically driven discussion. We place technology sovereignty in the wider context of economic and innovation sovereignty. In addition, we distinguish the various functions that technologies fulfill in government, society, and the economy and, based on this, propose criteria and methods able to determine the need for and degree of European sovereignty in terms of key technologies. We formulate recommended strategies to avoid one-sided dependencies in technologies classified as critical and to strengthen the resilience of EU member states to external shocks. We illustrate our concept using two case examples – 5G technologies and Industry 4.0/robotics – before we close the paper by summarizing several core statements.

# What is technology sovereignty?

At its core, the term technology sovereignty describes the ability to generate scientific-technological knowledge either autonomously or to be able to access such in stable partnerships without constraints. Technology sovereignty does not imply comprehensive technology autarky that calls into question the international division of labor or globalization and strives to provide every technology classified as critical. Primarily, it describes preserving options by developing and maintaining own capabilities and avoiding one-sided dependencies.

To start with, the concept of technology sovereignty must be distinguished from the broader concepts of innovation sovereignty and economic sovereignty (see Figure 1):

We can describe economic sovereignty as the ability to generate value added and prosperity through independent activities or through a mutual exchange with other economic regions without becoming unilaterally dependent on external actors. In a similar way, this applies to the original sovereign tasks and to the independent provision of public services by both private and state actors. Economic sovereignty and sovereignty in performing public tasks are traditionally based on the need for unimpeded access to natural resources and capital by relevant actors and unimpeded access to technologies, innovations, competencies, and data.

In the efforts made by economic, innovation and technology policies to establish economic sovereignty, there is a growing interest in technology sovereignty alongside the exploitation of raw materials and the advantageous positioning of economic actors in global production and value chains.[4]

Technology sovereignty plays a special role in the bigger picture of state sovereignty, because it enables economic sovereignty and autonomous state actions over and over again, and because it is in itself renewable, in contrast to resource stocks, for example.

In modern, globally networked economies, value creation and welfare as well as guaranteeing public services are based on innovations being generated and widely applied. Innovations,

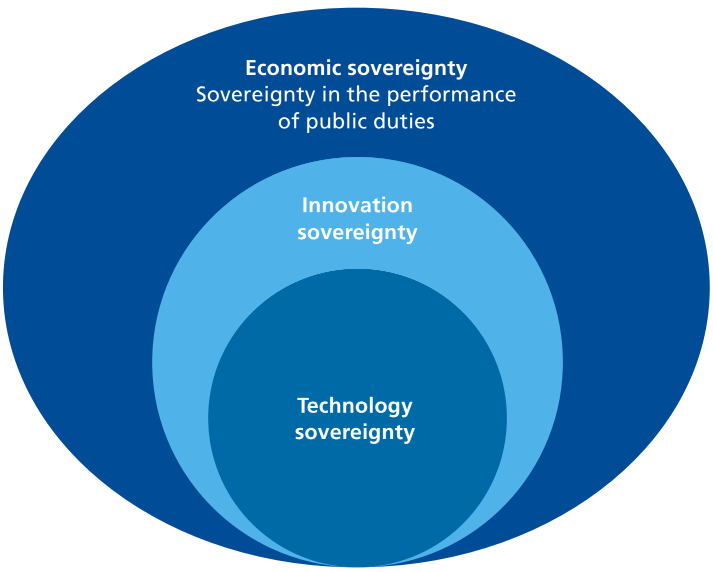



Figure 1: Technology sovereignty as part of innovation and economic sovereignty

in turn, depend on being able to generate the technological basis for current and future economic activities locally (scientific-technological competencies and qualifications) or to obtain these from reliable partners (application competence).

However, scientific-technological competencies on their own have no effect and are without relevance for the innovation sovereignty of Germany and the EU unless the abilities needed to exploit technological insights are also available, and the necessary system prerequisites exist, such as the required infrastructures, production capacities, regulatory framework conditions etc.

Technology sovereignty is therefore a necessary, but by no means sufficient basis for achieving innovation sovereignty.

In turn, such innovation sovereignty is indispensable, but not sufficient for achieving wider-ranging economic sovereignty. This applies equally to the sovereignty in guaranteeing public services that also depends on other criteria such as access to competencies, capital and resources (see Figure 1).

The concept of technology sovereignty introduced here does not aim at a general expansion of technological activities in fields in which our own international competitiveness is perceived as too low or as capable of being developed. While, from a state's perspective, efforts are often made to achieve *technological competitiveness* in as many fields as possible, the search for *technology sovereignty* is usually in selected fields that are considered particularly important according to criteria that will be defined in the following subsection.[5]

## Technology functions and rationales

Three functions of technologies can be differentiated to determine when a technology is classified as critical for a state or a federation of states (see Table 1):

- *Safeguarding the original sovereign tasks* that government bodies perform by using the available technologies (e.g. civil security, defense, administration).
- *Meeting the needs of society* (e.g. food, shelter, energy and water, mobility, communications, health): on the one hand, satisfying basic social needs through public services such as healthcare or supplying – partially critical – infrastructures. On the other hand, in regard to changes that are mainly initiated and controlled by government, such as targeted socio-technical transformations (e.g. the energy transition, transformation of mobility).
- *Ensuring the medium and long-term success of a national economy and its technological competitiveness*, which is mainly supported by private actors, although this can be substantially shaped by state support and financing.

Legitimate reasons to pursue technology sovereignty result from all three functions. While the state's ability to act in the domain of original sovereign tasks constitutes the most direct representation of the necessity for technology sovereignty, meeting the needs of society and technological competitiveness are also dependent on the unimpeded access of the actors of a state of a federation of states to a broad portfolio of technologies and development competencies.

The transition between these three bundles of functions and rationales is fluid and often not sharply delineated. Technological competencies that represent options today and are therefore more relevant for technological competitiveness can become fundamental for the fulfillment of social needs and sovereign tasks in the short term. Nevertheless, separating these rationales is useful – if not essential – to establish a convincing context for political justification.

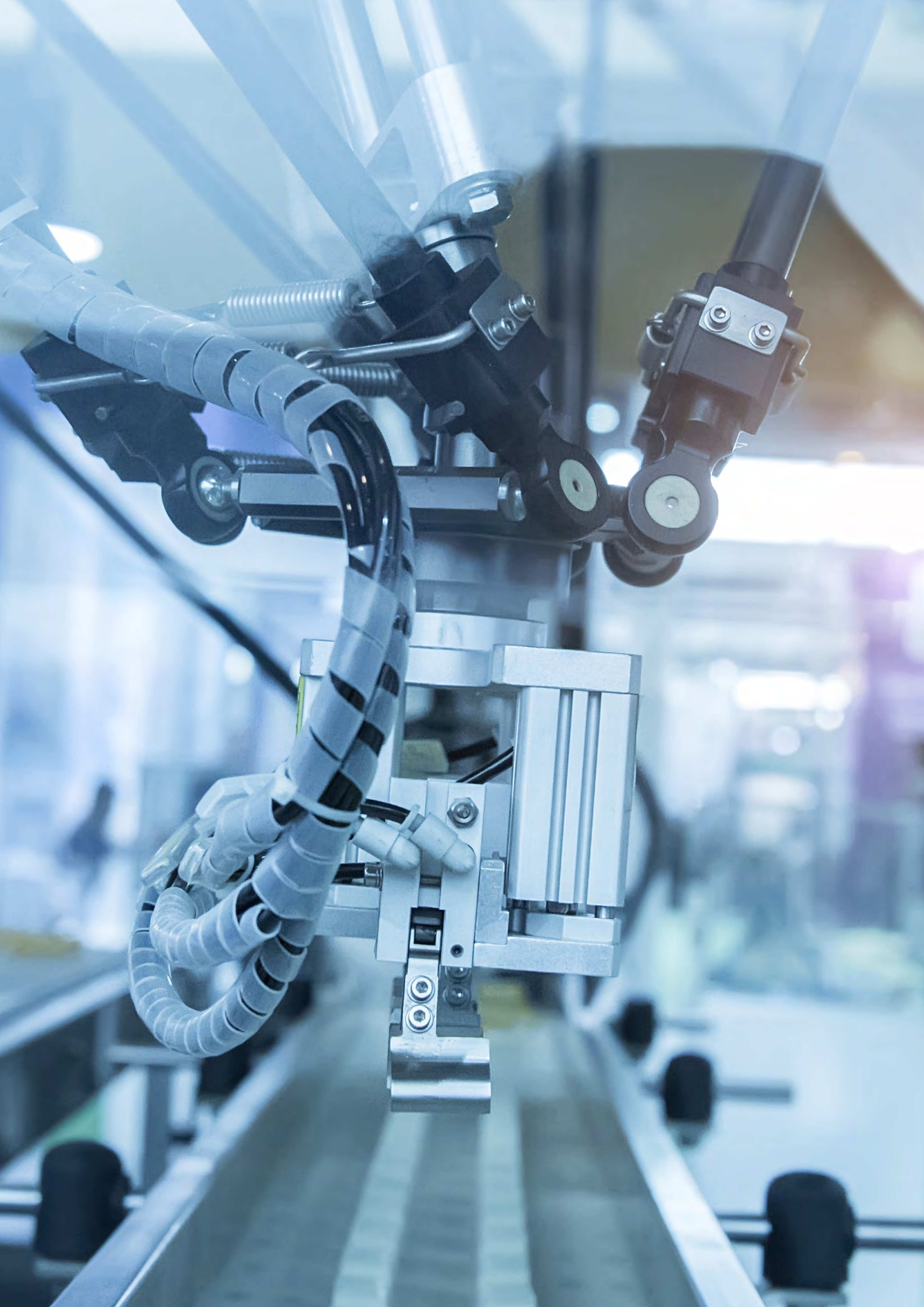
| | | Technology sovereignty | | |
|---|---|---|---|---|
| | | **Original sovereign tasks** | **Meeting needs of society** | **Economic competitiveness** |
| **Preserve and protect (static)** | Economic positioning and state functions | Defense, public security, administration | Public services, critical infrastructures, public healthcare (water supply, transport links, health system) | Creating jobs and value in existing industries (mechanical and automotive engineering) |
| | Being crisis-proof against | Military conflicts Terror attacks | Pandemics, climate-based crises, terror attacks | Euro crisis, structural breaks caused by transformation |
| **Dynamic development** | | informational self-determination, geopolitical positioning (5G debate and EU cloud) | System transformation (sustainable mobility/ logistics, energy transition) | Creation and renewal of paths, transform and develop new sectors (e-mobility, Industry 4.0) |

Table 1: Typology of the dimensions of need for technology sovereignty

## Static, dynamic, and reactive technology sovereignty

Different goals for producing or preserving technology sovereignty can therefore be distinguished in addition to the above described differentiation of the rationales (see Table 1):

- *Preserving or protecting current technology sovereignty*, with the goal:
  - of obtaining an *advantageous position* in global innovation and value creation chains and *guaranteeing state sovereign functions and public services* based on existing competencies and resources,
  - of managing crises using own resources and thus ensuring that the European economic and innovation system is *crisis-proof* (resilient). This resilience and adaptability to foreseeable and unforeseen disruptions and crises is becoming increasingly important for European societies in view of developments that are perceived as dangerous. The risk of system failures is also becoming more and more relevant with the growing dependency on increasingly complex technical systems, for example, power supply or IT networks. In addition, natural catastrophes such as earthquakes, the increasing prevalence of floods and droughts due to climate change, pandemics, or protectionist and aggressive trade policy developments in the international political environment pose increasing threats to the economy and society.
- *Dynamic development of technology sovereignty*, with the goal of assuming an active, formative role in evolving processes and development pathways to proactively shape future developments.



# Criteria to determine the importance of technologies and access to them

## Importance and types of criteria

Empirically determining to what extent technology sovereignty exists for a specific state or federation of states and a specific technology (country-technology combination) requires the analysis of two interconnected questions:

**1) Within which system boundaries is technology sovereignty aspired to?**

**2) What are the factors influencing technology sovereignty and how are they expressed in a concrete case?**

Analyzing the system boundaries (question 1) is an important step to understanding whether a certain technology requires more detailed consideration and perhaps political measures to ensure technology sovereignty. It is necessary to define criteria to assess the technological, economic, legal, institutional, and political framework conditions. An in-depth analysis of the degree of technological sovereignty is only necessary for those technologies classified as critical after analyzing the system boundaries (question 2).

## Criteria for system boundaries

*Three different dimensions* can be distinguished in the discussion of system boundaries:

- the *spatial-political* dimension, i.e. the geographical and political frame of reference for technology sovereignty,
- the *functional* dimension of the analyzed services or goods for which technology sovereignty is to be aimed at in principle, and which we differentiated into sovereign tasks, social needs, and economic competitiveness in the first step above,
- the *time* dimension, which distinguishes short-term supply bottlenecks from structural dependencies.

Three additional sub-criteria are applied when determining the *spatial-political area* to which technology sovereignty should apply:

- The degree of political integration: As a rule, the more advanced this is, the more institutionalized coordination mechanisms are that aim at a free exchange of technologies.
- The degree of economic integration: The more advanced this is, for instance, with regard to value chains or corporate ownership/control, the less likely and even impossible it becomes to decouple individual political-geographical areas.
- Shared culture and value set: If, for example, an economic region shares the model of an open society or has social and political common ground such as a democratic state constitution with the separation of powers, the likelihood tends to be low that individual actors will deliberately use dependencies to reduce the technology sovereignty of other actors.

Whereas the temporal and functional dimensions should be analyzed and decided on a case by case basis, a general estimation can be made for the spatial-geographic dimension of Germany: its spatial-political integration within the EU is particularly strong. There are clear rules with the single market. In addition, there are numerous competencies regarding foreign trade issues at EU level. This degree of political integration makes politically induced disruptions to value chains and knowledge flows seem very unlikely. Mutual economic interdependencies and the European countries' common sociopolitical model also favor the "EU" political level. This is all the more valid since a national frame of reference for technology sovereignty would create its own necessity, as corresponding national efforts would undermine confidence in the interdependencies and mutual obligations within the EU. This would contribute to a dynamic of renationalization that cannot be in the interests of the technology sovereignty of the member states as a whole. However, such an approach could and should be adaptable to any changes in the level of interdependencies within the EU over time.

Starting from the EU as the region of analysis, the criticality of access to technologies outside the EU is assessed. This is indicated by the frequency and intensity of trade conflicts and violations of WTO rules by individual countries. Another indication is the existence of trade agreements, as these guarantee a certain degree of stability in economic and knowledge relations. Especially the existence of bilateral trade agreements with countries that have similar cultural, socio-political, or economic models (e.g. Canada or Japan) could result in otherwise essential technologies being classified as less problematic. Access here would be ensured with a certain degree of reliability.

We refer to the categories introduced in the chapter "Technology functions and rationales" for technology sovereignty aimed at supplying the following *functional areas*:

- technologies for maintaining the original *sovereign functions of a state,*
- ensuring *public services*,
- ensuring the *medium and long-term success of a national economy and its technological competitiveness*.

*Criteria along the time dimension* are needed to distinguish short-term supply and delivery bottlenecks from those related to structural technology sovereignty. For example, in the context of the corona crisis, short-term delivery problems for certain goods like face masks or toilet paper were also addressed as dependency problems. We believe a demarcation is needed here. In terms of our concept, technology sovereignty refers to at least a medium time horizon (e.g. six months to ten years). Shorter-term dependencies can be counteracted, e.g. by improved stock-keeping. In a very long-term perspective, numerous new technological competencies can be developed; on the other hand, there is the risk of medium-term dependencies becoming locked in if path dependencies exist, which can then only be addressed by accepting extremely high conversion costs.

## Criteria to determine the degree of technology sovereignty

For the *criteria to determine the degree of technology sovereignty*, a distinction must be made between various sub-criteria that influence technology sovereignty in different ways:

- Technology sovereignty is high if the technology is produced within a country's own political-geographical domain, or the ability to produce it exists.
- In cases where technologies are not produced in a country's own political-geographical domain, but can be obtained without restriction from outside it, factors should be considered that increase the risk of access to the technologies being limited or refused. Corresponding factors are required that describe these supply risks.
- Supply risks are reduced if technological alternatives (substitutes) are available. These also have a disciplinary effect on the exertion of market power by a supply concentration. The existence of mutual dependencies has a similar effect.

## Ability to produce the technology in the home country

If a technology is already produced in the home country, it can usually be assumed that it will also be available locally in the future. However, even in this case, the condition must be satisfied that the required components remain available and that access to critical input factors continues to be given. This makes it clear that assessing technology sovereignty may not be limited to the final product alone, but must consider the entire associated value chain.

A high degree of technology sovereignty exists even if initially only the abilities to start production in the short to medium term are available. The ability to produce a certain technology presupposes knowledge and access to other critical input factors.

Technological know-how can be mapped using, e.g. technology-specific patent indicators that show technological performance (see Infobox). However, this also requires the existence of economic actors who can apply this knowledge. Ultimately, any assessment of ability also necessitates assessing the performance of the corresponding technological innovation system.

## Criteria for supply risks for technologies obtained from abroad

For cases in which the relevant technologies are only available outside the analyzed geographical-political area, factors must be considered that increase the risk that the technology can no longer be accessed for economic, political, or other reasons (e.g. climate events, political instability, pandemics).

This risk of access restrictions increases with increasing supplier concentration, because this raises their market power on the one hand, and reduces the scope for switching to other supplier countries should access be restricted. To estimate the risk of losing access to resources and technologies, it is important to regularly analyze indicators such as, e.g. the Herfindahl Hirschman index, which can be used to measure this kind of supplier concentration.

In addition to supply concentration, the reliability of the supplier countries also plays an important role. Important factors here include political and social stability, compliance with legal regulations, and the absence of corruption. For example, the EU assesses countries supplying critical raw materials with the help of the World Governance Indicator and the underlying database of the World Bank.[6] The degree of mutual dependency must also be examined. Mutual dependency exists to the extent to which a supplier is itself dependent on the country it refuses to supply. This reduces the risk of one-sided, deliberate supply restrictions. Trade statistics on the flow of goods, an analysis of the compliance of individual countries with WTO regulations or the Economic Complexity Index[7] on production capacities can provide important information here.

## Existence of possible substitutes

Supply risks are reduced and technology sovereignty increases if technological alternatives (substitutes) to the analyzed technology are available or foreseeable.

Technological feasibility is one criterion for the existence of a substitution alternative. In this context, the first thing is to assess whether there are any relevant approaches in the home country in the medium term. Patent analyses and periodical, systematic expert surveys can provide indications of this. This includes assessing whether the relevant possibilities make economic sense. Finally, it is essential that substitutes are also potentially available or must be created within the home country. Ultimately, this means that the above listed criteria must then also be applied to the substitution options.

## Criteria to assess technology sovereignty

Overall, it becomes clear that several criteria need to be combined to assess the degree of technology sovereignty. These include quantitative indicators and evaluations based on qualitative estimates. The assessment generally follows a continuum of a stronger or weaker degree of technology sovereignty rather than a simple yes-no decision. At the same time, the different sub-aspects make it clear that assessments may change over time. In this respect, technology sovereignty is not a static construct, but a dynamic one. The fact that the granularity of analysis and the indicators used to implement the criteria can vary is shown by the discussion of two different example applications (see page 25 ff.).

## Summary of several important methods for analyzing technology sovereignty

Analyzing to what degree technology sovereignty exists requires a mix of methods. Quantitative indicators based on technology-specific search algorithms aid these kinds of analyses. They should be supported by systematic expert surveys to provide context and validation so that the specificity of each individual technology can be considered.

**Own competencies and resources**

- *Patent analyses* and derived indicators such as patent shares and specialization map the extent of a state's or a federation of states' own technology competencies.
- *Bibliometric analyses* and derived indicators such as publication shares and specialization provide information about the scientific resources and competencies of a state or a federation of states.
- *Analyses of the contribution of individual countries to global or – leading – national standards*, possibly in the context of their own patent portfolio, enable an estimation of the autonomy of a state or a federation of states in shaping future technology development.
- *Analyses of technology- and resource-specific production statistics* enable the identification of the regional availability of relevant resources and production capacities.
- *Analyses of technology-specific export shares* provide information about the international competitiveness of the production of a state or a federation of states.

**Dependence and access to competencies and resources**

- *Analyses of international standards, patent pools and Open Source repositories* provide information about internationally available technologies that can be used.
- *Analyses of trade balances grouped and analyzed by technology* provide information about the dependence of a state or a federation of states on technology-specific imports (resources and components), and their distribution.
- *Complexity indices* make it possible to estimate the dependence of relevant geographical areas on specific technologies and how these technologies are integrated into local or regional innovation and value chains.
- *Analyses, e.g. of WTO compliance*, enable a concrete assessment of the reliability of potential partner nations in specific issues.
- *Analyses of the World Bank's World Governance Index, various corruption indices and indices on the form of governance* make it possible to assess the basic reliability of potential partner nations.

Finally, the results of the individual analyses must be carefully weighed against each other in order to arrive at an overall assessment.

Infobox: Analytical tools for assessing technology sovereignty

# Strategies for dealing with challenges related to technology sovereignty

The above remarks show the numerous perspectives and differentiations that must be applied to determine the degree of technology sovereignty and to draw up counter strategies. These conceptual considerations lead to a series of potential strategic measures suitable for countering the challenges of technology sovereignty.

## Analytical capability to determine the need for technology sovereignty

Analytical capabilities in the system form the basis for addressing the question of which technologies are critical and how to secure access to them. Methodological and analytical competencies must be available in order to be able to process the main dimensions with regard to technology sovereignty in a technology-specific manner and with the necessary granularity. Sufficient competencies and databases are required to perform the following three-dimensional analysis:

- ◇ determine the criticality of technologies,
- ◇ develop a clear picture of which fundamental economic and social functions this technology helps to fulfill and how it does so,
- ◇ ensure access and provide own competencies.

### Possible strategic approaches

The following strategic approaches can be derived from the three determining factors of technology sovereignty:

- ◇ For a country to maintain its own ability to produce the relevant technologies and products in a dynamically developing environment, it is first necessary to generate technology-specific knowledge using the classic instruments of research and innovation policy. This requires a critical mass of knowledge carriers – persons possessing the relevant knowledge – which is only formed by actually teaching the corresponding content at universities (e.g. the gap in professorships in battery technology).
- ◇ In addition, public procurement can provide strategic impulses so that ultimately production capacities for technologies and the corresponding products can be created or ensured.
- ◇ However, the potential portfolio of technologies is much too large for the majority of national economies to provide the necessary research capacities in all the fields relevant for technology sovereignty. Further, these technologies or products often require access to certain raw materials. Therefore, a division of labor is necessary, not only in the European context, but in an international one, which can be initiated, for example, through long-term research cooperation. In such cooperation, bilateral, but above all multilateral research is conducted with partners who have the relevant complementary competencies in technologies identified as critical, which ensures joint access to these technologies and avoids one-sided dependencies.

- The development of open standards (potentially combined with patent pools) supported by many international companies, but also by Open Source software and hardware, can be regarded as a special form of access. These prevent a proprietary monopolization of technologies and therefore dependencies. These standards also reduce dependencies on single suppliers within complex value chains and therefore also reduce risks (e.g. standards in the automotive industry increase competition among suppliers).

- If this is combined with public procurement, it allows access a larger number of suppliers of the relevant technologies. This enhances competition which prevents the dominating companies exerting market power and ensures sustainable competition.

- In the long term, in addition to supporting research and demand-oriented strategies such as public procurement, it makes sense to design the regulatory framework in a way that gives domestic or European industries the right conditions and incentives to develop the corresponding research and therefore also production capacities in fields prospectively at risk of technology dependencies. This includes an appropriately designed competition policy, which includes the acquisition of European companies by non-European concerns.

- If technology sovereignty is limited or no longer present due to already existing dependencies on individual suppliers, attempts can be made over the long term to build up a country's own research competencies in order to develop substitutes. However, this is often not possible, even in the long term, due to resource restrictions. Furthermore, such dependencies usually affect not just one country's economy but the majority of national economies. This is why joint solutions are an option here, coordinated by the European Union, but also by larger international consortia.

- Finally, in addition to the single European market, free world trade with its strong incentives for competition remains an important boundary condition to ensure technology sovereignty. Compliance with agreed multilateral regulations should be ensured by strengthening key international organizations such as the WTO.

## Increasing the resilience of the EU

The EU should increase its investments in the resilience of its economic and social systems so that these can recover rapidly from shocks and disruptions, and adapt quickly to changing contexts. This is an important cornerstone of any consideration of future-proof technology sovereignty. The EU states already have the right prerequisites for this because their economies are strongly oriented towards open competition. In addition, their societies are influenced by subsidiarity and, above all, are organized democratically. This means the EU's adaptability is fed by a diverse pool of common economic, political, scientific, and civil society features.

Fostering a broad basis of competencies and capacities in critical technology fields is an important element in lowering the EU's vulnerability to potential disruptions and shocks – especially in times of increasing global uncertainty. In the sense of a systemic approach to resilience, technological key capabilities should be promoted, innovation networks formed as well as experimental learning encouraged, for example, in the context of regulatory sandboxes.

## Examples of determining and ensuring technology sovereignty

How can we analyze whether technology sovereignty exists in concrete terms and what measures can be taken to ensure it? The following two case studies illustrate what such an analysis should look like.

## Example 1: 5G technologies

**System boundaries for technology sovereignty**
The geographical and political frame of reference for 5G technologies is defined by the European area, based on the joint European decision for GSM in the early 1990s. It is therefore necessary to consider technology sovereignty for 5G within the context of a highly integrated system in political and economic terms. 5G is very important for both private sector and public sector functions; its economic and societal integration and environmental interdependence are high. When considering the shared European culture and set of values, which attach great importance to the free exchange of information, 5G technologies are very important as a necessary communication infrastructure. 5G technologies are therefore highly relevant for public services, safeguarding sovereign tasks and ensuring economic success in almost every industrial sector. Finally, the time dimension must be considered when analyzing 5G technologies. Providing the associated functions in the European area in the short term and long-term resilience are both essential conditions for the technology sovereignty of 5G.

**Degree of technology sovereignty**
The analysis must begin by determining whether the European area has the capability to supply these technologies, or at least the knowledge required for technology development. Patent applications are suitable indicators for identifying technology competence (see Infobox on page 20). A current analysis, conducted with the support of Fraunhofer ISI,[8] shows that the patents for 5G technologies are indeed strongly influenced by Chinese companies, but that European enterprises also feature among the internationally most active technology developers. At present, Chinese companies, especially Huawei and ZTE, account for 33 percent of total 5G patents worldwide, South Korean enterprises for 27 percent, European companies for 17 percent, and US-American companies for 14 percent.

Nokia and Ericsson are two of the internationally leading manufacturers of 5G network components from Europe. Compared to 4G technologies, both companies have increased their patent shares in 5G technologies (Nokia by 2.39, Ericsson by 1.14 percentage points).[9] In addition, small and medium-sized enterprises that do not receive much attention, such as Adva Optical Networking from Germany, continue to be active as 5G network equipment providers.[10] Intensive efforts are being made in Europe to expand the knowledge base for 5G. The European Graphene Flagship[11] is one example of this. Optoelectronic components are being developed here that enable the extremely high switching speeds needed for 5G.[12]

In principle, therefore, there are at least two important elements for achieving technology sovereignty in EU countries: the technological production base with internationally leading technology companies, and a dynamic knowledge base. It cannot be stated in principle, therefore, that a one-sided dependency exists on technologies and know-how developed in China.

**What is the supply risk?**
The discussion usually focuses on Huawei as the world market leader for 5G components. As already pointed out, however, there are at least several potential suppliers in Europe, who are among the world's leading 5G suppliers. But other global regions also offer possibilities, especially South Korea and the US. With 13 percent and 11 percent of all 5G patents, Samsung, and LG Electronics (South Korea) are among the top five companies worldwide. Samsung is ranked second[13] after Huawei (15 percent). Major companies in the US include Qualcomm (6 percent patent share) and Intel (4 percent); CISCO is also expected to become a major player in future.[14] A differentiated view of the supply risk is therefore required.

In the short term and also from a cost perspective, Huawei is the most important 5G supplier. However, alternatives already exist in Europe with Ericsson and Nokia. This is also shown by the example of the British Vodafone concern, which announced at the beginning of 2020 that it would swap Huawei hardware for Nokia components in security-relevant areas of its 5G network.[15] However, Vodafone expects additional costs of around 200 million euros and a possible delay of two to five years for the switch. Furthermore, both South Korea and the US reduce the supply risk with several potential suppliers. Both regions are ranked higher in the World Governance Index than China; the US is ahead of South Korea (but somewhat behind Germany).[16] At the same time, the EU has struck a trade deal with South Korea, which has a positive effect on assessing its reliability as a supplier country.

**Are there possible substitutes?**

Intensive work on technological alternatives for individual components of 5G technologies is already ongoing within the EU. This concerns the required materials and switching elements in particular.[17] Europe is one of the leading innovation regions in the field of materials. Optimized materials can, among other things, help to improve the energy efficiency of 5G technologies and thus address an important technological challenge. Ericsson and Nokia are part of the relevant research networks, especially the Graphene Flagship, and therefore have direct access to these globally leading technology developments in contrast to competing 5G suppliers from China, South Korea, and the US.

**Overall, the analysis shows:**

◇ Focusing the discussion about technology sovereignty for 5G on the role of Huawei and the dependency on China is too narrow.

◇ In fact, applying the criteria to determine technology sovereignty reveals that several aspects already speak for technology sovereignty for 5G in the European area, or that at least the potentials for this already exist.

◇ This differentiated view of technology sovereignty for 5G puts the discussion for the development of suitable strategies for dealing with technology sovereignty on a wider footing.

**What are the possible strategies for dealing with technology sovereignty?**

With regard to 5G in Europe, our analysis reveals that technology sovereignty has multiple layers, can be described analytically from different perspectives, and which issues should be subject to closer examination. This results in a more comprehensive picture that can stimulate the discussion of further strategic options for dealing with technology sovereignty.

In the short term, it makes sense to expand supply relationships with the European 5G suppliers, and explore setting up further supply relationships with leading companies from South Korea and the US in order to reduce the overall concentration in supply chains.

Developing a European innovation eco-system would be one way to provide reliable and configurable 5G technologies within the EU in the medium term. This means that the individual competencies, potentials, and technologies that already exist today, together with the required framework conditions such as European standardization, would have to be combined into an overall system. This would be supported by different stakeholders from industry, research, politics, and society, who perform different functions in the systems. Key actors at company level would be the network equipment suppliers Ericsson and Nokia. They could form the crystallization points of this innovation network. Close relations and dependencies within this network would simultaneously make it more robust.

## Example 2: Industry 4.0 and robotics

**System boundaries for technology sovereignty**

The EU forms the geographical and political frame of reference for Industry 4.0 and robotics, since these technology fields represent key unique selling points of leading European countries in a global comparison. However, since not all European countries have the relevant competencies, discussions here also always have a national component. Some member states have only low competencies in this field, and the density of industrial robots in Europe as a whole is below that of China.[18] Still, there are relevant competencies within the scope of European institutions and thus at the core of Europe's innovation and industry policy.

In addition, it can be stated that the contribution of technology sovereignty to prosperity and value creation in Industry 4.0 and robotics is mainly realized in the context of global markets. Although Germany was the country with the third highest density of industrial robots after Singapore and South Korea in 2018, the German market is only about one sixth the size of the Chinese one and approximately half the size of the Japanese market. With Germany, Denmark, Italy, France, Austria, Sweden, the Netherlands, Luxembourg and Finland, numerous member states are net exporters of robotics, whose technological design capability can be implemented globally, especially compared to countries that (still) have to import complete robots or their core components to a large extent, and source these partially from Europe, and partially from suppliers outside Europe.[19]

**Degree of technology sovereignty**

Almost without exception, Europe's major industrial nations have a significantly above-average technology sovereignty in this field, which can be documented along various analytical dimensions – from patents through to exports. Nevertheless, there is still a considerable dependence on non-European producers with regard to key intermediate inputs in the field of microelectronics. However, since both the final product and the direct upstream components are still designed and manufactured in Europe, the main objective of the innovation and industry policy debates in this context is the question of how to preserve or use existing competencies.

The success of many European nations in the field of advanced manufacturing and especially robotics is based on systemically combining strengths in mechanical and plant engineering with software and hardware for integrated systems. Europe's key challenges and its major contributions to solutions are currently in managing complex industrial application scenarios while guaranteeing the security of networked systems. In terms of IT, various European companies are developing successful reference architectures and making major contributions to global standardization and thus to achieving interoperability.

**What is the supply risk?**

There is a supply risk in particular with regard to key hardware components required in the production of Industry 4.0 and robotic devices. The corresponding chips and microelectronic elements are not only no longer manufactured in Europe, but are also only partially designed here. As a result, Europe is already clearly dependent today on external supply chains for major components and partially also on specific manufacturing skills. For example, there are only two relevant production sites for microchips left in Europe, so that a multitude of basic components now have to be imported, mainly from Asian countries.

In the medium term, as the technology evolves, it is conceivable that larger shares of value creation will shift to software or hardware components that have not been produced in Europe for some time, which could lead to increased dependency on a few large technology companies in the United States or Asia. Although there is not (yet) any isolated dependency on individual non-European states or companies at present, greater concentration is conceivable in the future.

**Are there possible substitutes?**

Technologies from the field of robotics represent a pivotal component of modern manufacturing systems and cannot be substituted by other technologies from a systemic perspective.

However, European companies have already positioned themselves in specific, higher-value areas of robotics (complex application scenarios, guaranteeing security), where they are confident and profitable actors thanks to the strength of their existing competencies. To a certain extent, therefore, it should be possible to resubstitute simpler, currently imported technologies with corresponding European products should such a switch be required for geopolitical reasons.

**Overall, the analysis shows:**

- The economic advantage of existing technology sovereignty is usually only (fully) realizable in a global context; it would be a drawback if development perspectives were restricted to certain markets; interoperability remains a major goal.

- An already existing dependency in the field of major components could become more significant in future if these components (microelectronics) themselves become more relevant; stronger and more one-sided dependencies are possible.

- If core competencies are drained, e.g. due to company acquisitions, there is a danger that key unique selling points will be lost to those demanding specifically European competencies.

- Ongoing technology development means that even leading companies with high integration competence face the challenge of learning new skills in fields that will become more important.

- A crucial point in this context is to consider to what extent technology sovereignty must be regained in important complementary areas such as cloud and data infrastructures.

**What are the possible strategies for dealing with technology sovereignty?**
Substantial investments in retaining and updating current and future key competencies in the field of Industry 4.0 and robotics can be observed in many European countries. Increasingly, other countries that want to overcome their current dependency on imports are also making efforts to master these skills (and will do so in the medium term). Government support here often takes place nationally and at European level through the Research Framework Programmes and initiatives for "Advanced industrial technologies". These include the targeted funding of technological developments on the one hand, but also preventing the strategic acquisition of existing expertise by non-European companies or nations on the other hand. In addition, funding (research) cluster initiatives and other alliances is intended to increase cooperation between science and industry and therefore the efficiency and speed of technology transfer – and by using test beds – to not forfeit technological leadership in complex application contexts. Finally, individual member states and numerous European institutions are supporting the participation in international standards. This is intended to ensure that existing competencies and those still to be developed can be productively integrated into the global value networks of the future, and to guarantee the highest possible interoperability for European system solutions. There are additional activities to create new basic data infrastructures such as GAIA-X, in which European solutions can be integrated securely, efficiently and without being directly dependent on external providers, where this is necessary to guarantee data security.

A multi-level strategy is therefore suitable for the future:

- Anticipate technology developments and develop the associated required capacities,

- strengthen and update existing key competencies,

- create a systemic framework (cloud and data infrastructure), within which specifically European competencies can be further developed,

- avoid that key competencies that set European companies apart from international competitors are drained through external acquisitions,

- deliberately spread the supply risk in upstream areas where it does not make sense to develop own competencies.

# Conclusions

Global prosperity is built on an international division of labor in terms of industries and technologies, globally-oriented open trade policies, and science networks that span national borders.

At the same time, there is an understandable need for countries to preserve or to create a politically autonomous scope of action with the lowest possible structural dependency on competitors with regard to critical technologies, in order to keep their own economies competitive in the long term and to be able to meet society's essential needs. The calls for technology sovereignty, which are becoming louder and louder, intensified by the current crises and geopolitical shifts, are therefore in conflict with a globally networked economy as a guarantor of prosperity, especially for Europe and Germany.

Against this background, our concept provides added value through its differentiated view of technology sovereignty and concrete proposals for its analysis. This differentiation is based on the current and future criticality of technologies, the motivation for technology sovereignty, and the basis for producing it, i.e. essentially the access to current and potential resources and competencies (see Figure 2). The interplay of these dimensions can determine the current and desirable degree of technology sovereignty in a specific situation and, where required, strategies can be developed to preserve or produce it.

Comprehensive analytical system capacities are required to decide which technologies are critical or will be in future, what the key factors are that make technology sovereignty in our defined sense possible, and what measures should be taken at which level to achieve this. At the same time, this must also consider the system conditions that determine how technologies are transformed into functioning innovations on markets, such as production capacities, infrastructures, or demand-side conditions. Finally, it requires strategic creativity and foresight to avoid throwing out the baby of Germany's and the EU's internationally oriented competitiveness with the bathwater of technology sovereignty. For Germany, given the extent of economic and political interdependence and the added value this provides through specialization gains and political stability, the frame of reference for technology sovereignty is definitely the EU. A renationalization reflex in the face of striving for technology sovereignty would not only be inefficient, but even counterproductive in the long run, as it would trigger a spiral of protectionism. A system that differentiates the challenge posed by technology sovereignty, analyzes and processes this in a forward-looking manner, will not only be more adaptable in future, and therefore more competitive, but also more resilient to external shocks.

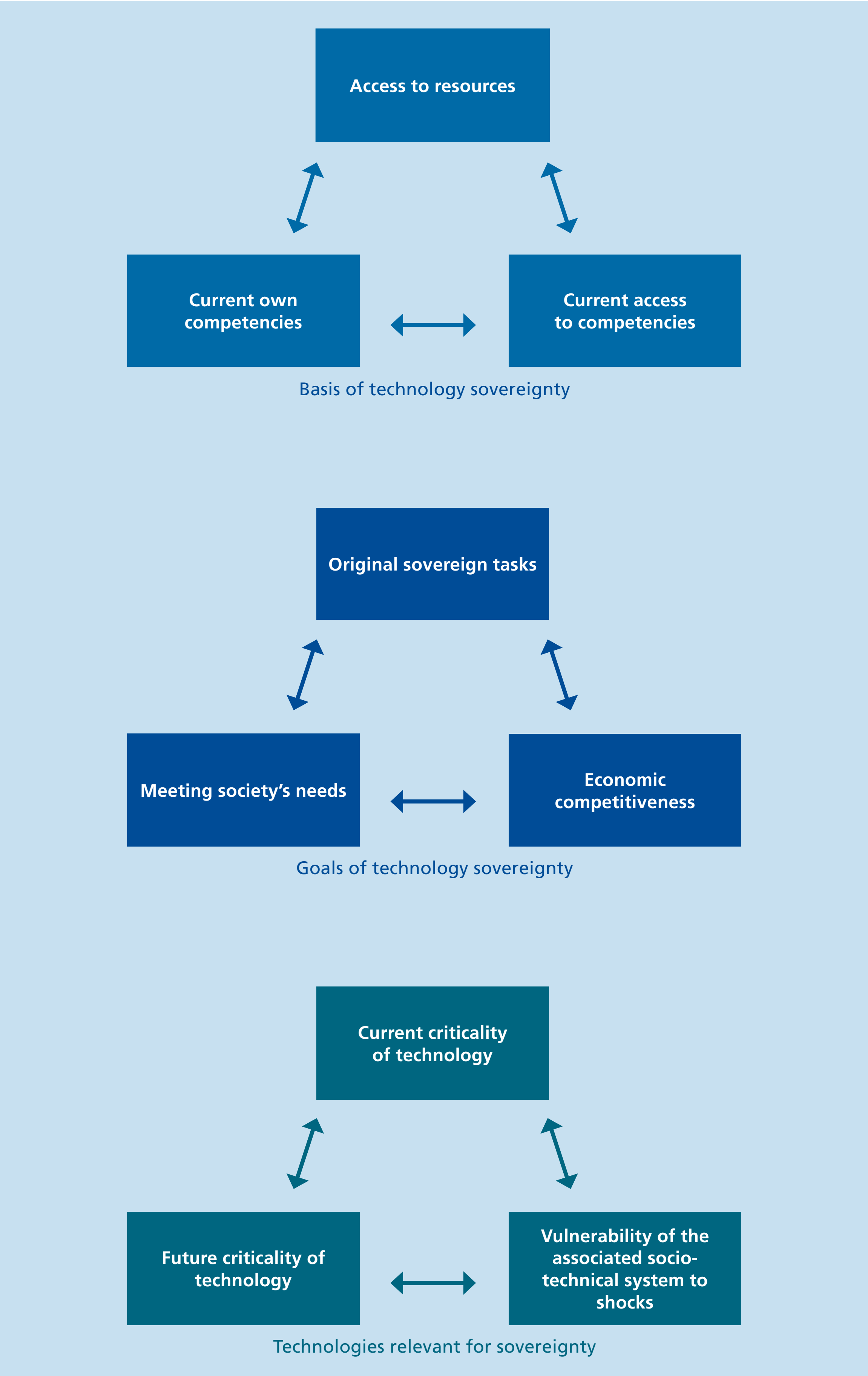



Figure 2: Dimensions used to determine technology sovereignty

# Endnotes

1 See, for example, the call made by the Commissioner for the Internal Market, Thierry Breton, for "strategic autonomy" as part of Europe's industrial strategy (https://ec.europa.eu/commission/presscorner/detail/en/IP_20_416 , 10.03.2020), the Joint Statement of the European Council, April 21 2020: Road to Recovery; Brussels; and European Parliament P9_TA(2020)0054. European Parliament resolution of 17 April 2020 on EU coordinated action to combat the COVID-19 pandemic and its consequences (2020/2616(RSP).

2 See BMWi (2020): Made in Germany. Industriestrategie 2030; https://www.bmwi.de/Redaktion/DE/Dossier/industriestrategie-2030.html, and the justification for founding the Cyber Agency in Germany (see the report by the Commission of Experts for Research and Innovation 2020, p. 143), press release by ZVEI on 19.02.2020 (https://www.zvei.org/presse-medien/pressebereich/technologische-souveraenitaet-fuer-europa-sichern/ ) or the "Technological Sovereignty" Position Paper by the German Association for Electrical, Electronic & Information Technologies VDE (2020): Technologische Souveränität. Vorschlag einer Methodik und Handlungsbedarf, Frankfurt am Main.

3 In the context of the corona crisis, the focus is on companies researching vaccines, such as CureVac in Tübingen or BioNTech in Mainz. Historically, the discussion about (technology) sovereignty mainly revolved around the security of food supply.

4 see BMBF 2020, https://www.wirtschaftsdienst.eu/inhalt/jahr/2020/heft/13/beitrag/digitale-innovationen-und-technologie-souveraenitaet.html

5 ibid.

6 http://info.worldbank.org/governance/wgi/

7 https://oec.world/en/rankings/country/eci/

8 https://www.iplytics.com/de/report-de/5g-patentstudie-2020/

9 ibid.

10 https://www.capital.de/wirtschaft-politik/5g-ausbau-diese-firmen-machen-huawei-konkurrenz

11 https://graphene-flagship.eu/ultra-fast-graphene-photonics,https://graphene-flagship.eu/project/spearhead/Pages/5G.aspx

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16 https://info.worldbank.org/governance/wgi/Home/Reports

17 https://graphene-flagship.eu/project/spearhead/Pages/5G.aspx

18 IFR World Robotics Report 2019

19 http://www.worldstopexports.com/top-industrial-robots-exporters/

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