CHAPTER 8

TECHNOLOGY SOVEREIGNTY OF THE EU: NEEDS, CONCEPTS, PITFALLS AND WAYS FORWARD

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Abstract

Technology sovereignty has become a major concern in science, technology and innovation policy debates in the last years. An intensive discussion has unfolded as to how countries and the EU should safeguard their abilities to produce and use the technologies needed, based on their own values and independent from unwanted foreign interference. The EU is lagging in a number of technologies, and is reliant on foreign input of knowledge, technological components and raw material. At the same time, it has been a long-held principle to work towards ever more openness, in particular for science, technology and innovation. Against this background, the chapter aims to shed some light on the specific challenges and opportunities related to technology sovereignty faced at EU level, delving into the conceptual underpinning of the concept and its link with open strategic autonomy and economic security, and current approaches adopted to determine the EU's sovereignty position. The chapter concludes with a number of considerations towards an effective and efficient technology sovereignty strategy at EU level.

1. Introduction

Technology sovereignty has become a major concern in science, technology and innovation (STI) policy debates in recent years. In small and big countries alike and, in particular, at European level, the idea has taken hold that responsible STI – and indeed industrial – policy needs to take into consideration how vulnerable systems are in terms of the ability to make available technologies regarded as critical. Of course, it has always been the duty of governments to ensure availability of core technologies, as technological innovation and capabilities are regarded as major determinants of economic competitiveness and welfare more generally. However, both the COVID-19 pandemic and, more importantly, a number of geopolitical developments in the last 10 years have triggered a new awareness and brought technology sovereignty to the top of policy agendas.

The COVID-19 reaction of Member States and the EU has shown two aspects. First, many countries were not able to secure all necessary medical equipment themselves and experienced shortages in times of acute crises. Second, as a reaction, in the first weeks of the acute crisis we saw a rather nationally orientated crisis reaction with limited flow of equipment and medical products across borders. Even if those developments were reversed quickly, they triggered a renewed awareness as to the vulnerability of support chains even within Europe (Darnis, 2020).

Furthermore, a few major geopolitical developments challenged the notion of international division of labour. First, the trust in the reliability of open exchange in the highly integrated world of the north-western hemisphere has been damaged. The Presidency of Donald Trump and his America First campaign have challenged the trans-Atlantic relationship. The potential for future disruptions may grow through strong political initiatives such as the Inflation Reduction Act, which may lead to the relocation of technological capabilities to the US, broadening the corridor of dependencies should a more protectionist administration return to power in 2024. In addition, Brexit has reminded us about the vulnerability of the internal market. Both developments have been particularly challenging, as these countries have been enormously reliable technological partners and are host to leading edge science in many fields. Second, and more important still, the relationship with China has been characterised by decreasing levels of trust and a development towards system competition and strategies of de-coupling or de-risking. As China is in the process of becoming a scientific superpower, and consequently a future technological superpower, and at the same time is still a major market for technology from western democracies, the question as to how the exchange of technologies with China will and should develop is at the top of geopolitical and STI agendas (Kroll and Frietsch, 2022). De-coupling and de-risking strategies, particularly with China, are now being intensively discussed and in parts implemented (Schüller and Schüler-Zhou, 2020; European Union Chamber of Commerce in China and Merics, 2020). Finally, the war in Ukraine and the conflict in the Middle East have put further pressure on the free exchange of technologies and scientific collaboration that had become the norm after the fall of the Berlin Wall. The global political debate around these conflicts has further demonstrated that the world is about to become a much more multipolar system, with a few strong, progressively self-confident actors (Münkler 2023). It is increasingly unclear what this global reorientation will mean for international technological cooperation and trade. We may find ourselves in a world of new

trade and cooperation walls around different geopolitical camps in the future. What we know already, though, is that the world has become more unpredictable, and that concerns over technology sovereignty are here to stay.

Against this background, an intensive debate has unfolded as to how countries and the EU should safeguard their abilities to produce and use the technologies needed, based on their own values and independent from unwanted foreign interference. This is, normatively and conceptually, different from the traditional discourse on technological competitiveness. The EU as a whole is lagging behind in a number of technologies and reliant on foreign input of knowledge, technological components or raw material. At the same time, it has been a long-held principle to work towards ever more openness, in particular for science, technology and innovation. It was the European Commission not long ago that focused its entire STI strategy on three dimensions of openness (Soete and Burgelman, 2023), stressing and embracing the value of international cooperation, division of labour and exchange. This new focus of STI policy on sovereignty, of course, produces a number of tensions with long-held principles of free exchange and collaboration in STI, international division of labour and international trade as major drivers of welfare. Governments increasingly face a need to navigate this tension between technology sovereignty and openness in STI carefully. In particular, for the EU and at EU level, the challenges are tangible. With its internal market and high level of techno-scientific integration, Europe holds, in principle, a strong position. The EU is characterised by immense complementarities in terms of technological competencies between its Members States, which can be mobilised to ensure leading-edge production of new technologies in many areas. Those developments now pose a series of challenges and pressing questions: What is the most effective strategy to safeguard technology sovereignty on the one hand, and to maximise the benefits from open exchange in STI on the other? What is the best way to navigate the different kinds of tensions between sovereignty and openness playing out in different dimensions of science, technology, innovation and the production of technologies? How should access to technologies from outside Europe and production of technologies within Europe be balanced? How can it be ensured that the question for technology sovereignty does not lead to a race to ever more protectionism and self-reliance? It is the aim of this chapter to shed some light on the specific technology sovereignty challenges of the EU and at EU level and on the conditions of the continent to face the challenges ahead, and on that basis to critically comment on current strategies at EU level.

The chapter is structured as follows. The next section will summarise and qualify the conceptual underpinning of technology sovereignty. Its focus is on the discourse in Europe and the tensions of the concept with other current concepts such as the Open Strategic Autonomy and economic security, and the possible pitfalls of technology sovereignty approaches at EU level. Section three will then discuss the status quo, both in terms of the approaches suggested to actually determine the sovereignty position, and the actual empirical findings as to where Europe stands. Section four will discuss the specific conditions in Europe and at European level, both those that support and those that challenge a strong sovereignty policy. The final section will critically assess European strategies and suggest a number of core principles for a future policy approach that navigates the multiple tensions.

2. Conceptual underpinning and tensions at EU level

2.1 Taking technology sovereignty seriously

For a concept like technology sovereignty to be meaningful, there must be a clear distinctive added value. This added value needs to stem from a clear differentiation to earlier approaches, as well as to neighbouring concepts that are being discussed and put forward at European level. While a certain level of ambiguity around policy-relevant concepts can be highly functional, e.g. in terms of leaving space for idiosyncrasies and negotiations (Edler and James, 2015), there needs to be a sufficient level of joint understanding as to the additional opportunities and challenges of any new concept. Thus, if for technology sovereignty this conceptual additionality is not given at European level, the debate and implementation of technology sovereignty strategies might be ineffective, confusing or even counterproductive. Thus, we need to take a short look at the definition and at the delineation to earlier concepts, such as technological competitiveness and key enabling technologies (KETs), before technology sovereignty is discussed in the context of broader autonomy and security concerns at European level.

There is no single, widely shared definition of technology sovereignty across Europe. However, the definitions put forward in the European debate, in particular when European technology sovereignty is analysed, have at their core the ability – and competences – of a system to have reliable access to a technology it deems critical for its own system, without any structural, uncontrollable dependency from third countries (Di Girolamo et al., 2023; Kroll et al., 2023; Edler et al., 2020; Da Ponte et al., 2023; March and Schieferdecker, 2023). Where definitions and approaches differ is the extent to which the access to a technology now and in the future encompasses the need for actual production capabilities within the system. In some broader approaches, it is about the ability of the system to actually produce the technology itself, and in doing so gain economic benefit and independence, as well as retaining the opportunity to influence the future development of a technology (e.g. European Parliamentary Research Service, 2021; Archibugi and Mariella, 2021).[1]

Another, more narrow viewpoint is less focused on the production capabilities. In this perspective, there is a stronger acknowledgement of the division of labour globally and the effectiveness through taking advantage of comparative advantages in different systems. Here, the focus is much more on making sure that the system has access to the technologies and is not structurally dependent on other systems in ways that can barely be managed. In this perspective, it is of critical importance to identify redundancies and complementarities with international partners and establish trusted relationships with them (e.g. Edler et al., 2023; Kroll et al., 2023; Di Girolamo et al., 2023).

A further differentiation one needs to keep in mind is the focus on technology. It is important to understand that the concept of technology sovereignty focuses exclusively on technologies; it has to do with the access

1 The European Parliamentary Research services define European technological sovereignty as 'the ability for Europe to develop, provide, protect, and retain critical technologies required for the welfare of European citizens and prosperity of businesses, and the ability to act and decide independently in a globalised environment'. European Parliamentary Research Service, 2021, p. 3.

to and use of technologies. It is distinct from products, in which technologies are embedded, and it is far less broad than innovation or economic sovereignty (Beckert et al., 2021; Edler et al., 2023; Kroll et al., 2023) or even strategic autonomy (Rühlig, 2023). Innovation and economic sovereignty are broader and encompass the conditions with which a technology is mobilised for innovation and economic added value, thus considering broader ecosystems rather than the availability of or access to technological competencies and capacities as such.

In European debates, the various perspectives – the narrow one focusing exclusively on the technology and the broader one including the production and entire ecosystems required – are used in a rather unsystematic way. This, however, runs the risk that the *specific* challenges for technology sovereignty are not taken seriously enough, and analyses of technology sovereignty end up being traditional analyses of technological competitiveness (see for a discussion e.g. Crespi et al., (2021)).

A short look at the history of KETs shows the differences between technology sovereignty considerations and technological competitiveness approaches, which has a number of important implications. The strategies around KETs, starting in the late 2000s, have also been about choosing technologies that are critical across the board of sectors and determine the future competitiveness of Europe (European Commission, 2009, 2012, 2018; Herlitschka, 2023). The ambition was and is to be able to produce technologies that are regarded as dominating the high-tech competition of the future and, thus, to make sure Europe can realise the main value added for those technologies. The technology sovereignty debate has a different, broader claim. It is about enabling Europe to be agent of its own technological destiny and with it its own value and societal choices. Importantly, it is also functionally broader. It is geared towards access not only to ensure economic benefit and competitiveness, but also to ensure the state can deliver on its core functions and societies can accelerate the transformations they seek using the technologies needed, in line with the ethical standards defined in Europe. Consequently, a Commission working paper stresses the strategic value of technology sovereignty not so much as linked to competitiveness, but to the issue of safety and security, health and green transition (European Commission, 2021a). This is in line with a definition of Edler et al. (2020) who distinguish the functional dimensions in the three dimensions of economic welfare, main duties of the state and transformational aspirations of societies.

Of course, KETs and technology sovereignty agendas overlap, but there is a danger in mixing the two. In the current analyses concerning European technology sovereignty, what is very often measured and assessed is the European scientific and technological capabilities and competencies – or even leadership (Bauer and Erixon, 2020a) – as well as its trade patterns. Clearly, a system that is able to develop scientific knowledge feeding into new technologies and turn those into products can be regarded as sovereign when it comes to that technology. However, what is actually meant, and measured, here is a rather traditional concept of technological competitiveness or leadership. It would be, in theory, perfectly reasonable to assume that a system, let us say the EU, has full, reliable access to a critical technology which is produced in a number of reliable countries outside Europe that have a comparative advantage for that technology. If access is assured and if there are redundancies to ensure resilience, the system would not need to strive to produce that technology itself and still be sovereign in the use of that technology. For smaller

countries, which often lack certain capabilities altogether, this is the norm rather than the exception.[2] Within the EU, with its division of labour and high level of market integration and mutual trust, such a narrow understanding of technology sovereignty is perfectly reasonable. This aspect of reliable access to technology without one-sided dependency needs to be taken seriously if the concept of technology sovereignty is not just another label for technological competitiveness. Furthermore, what distinguishes technology sovereignty from technological competitiveness in the KETs agenda is the fact that one has to look at all the critical components of that technology, down to raw materials, and ensure access or develop alternative inputs or solutions altogether ((Airaghi et al., 1999; European Commission, 2021a; Edler et al., 2023; European Commission, 2023b). In the past, trusting in the free flow of inputs across borders, this dimension has often been neglected.

What follows from that with regard to the conceptualisation of technology sovereignty? Three requirements need to be established. First, as with KETs, there need to be clear criteria against which one assesses what technologies are seen as critical and through what processes the decisions are taken. The criteria for the choice are broader and more complicated than in the traditional approach. In extension of the traditional technological competitiveness approach of the past, technology sovereignty also needs to be more explicitly concerned with the secure provision of current and future technologies to meet critical societal challenges (crises and transformations), as well as for delivering the core duties of the state, such as internal and external security or health provision. In this approach, even if a technology would not deliver on economic welfare, it may still be critical for societal and political reasons and, thus, subject to sovereignty policies. In this approach, the logic of the market economy alone cannot deliver.

A second requirement is the analysis of the capabilities of Europe to produce this technology *or* to secure access to it. Again, in extension to the traditional technological competitiveness approach, analyses now need to take into account how, for example through international cooperation and open trade with trusted partners, access can be assured, both to technologies and to inputs into technologies (Di Girolamo et al., 2023). In this analysis, even in a technology in which Europe is highly competitive it may not be sovereign if critical components are not provided within Europe, putting their provision from abroad in danger.

Finally, even if a technology could be sourced from abroad on a reliable basis, Europe would not be sovereign if the features of those technologies were not in line with its value system. This aspect has been much less prominent in the traditional competitiveness discourse around KETs. Technology sovereignty not only means that Europe has access and can use a technology, it also means it can be used according to the basic values and norms of the continent. Thus, when analysing the partners that provide technologies, Europe cannot develop on its own; the in-built values of those technologies need to be part of the analysis, and thus part of a technology sovereignty strategy.

Having established a few major core requirements for a meaningful use of a technology sovereignty approach, we can now discuss its relationship to important neighbouring concepts, not only to clarify the differences, but also to understand how the various concepts can reinforce each other.

2 For a similar line of argumentation see Kroll et al. (2023), who put the concept of technology sovereignty into the context of Open Strategic Autonomy and economic security. See below for a further discussion of this approach..

2.2 Technology sovereignty, openness and open strategic autonomy

It is a conceptual challenge that the concept of technology sovereignty is embedded in long-standing efforts of the European Commission to 'open up'. The rather defensive, inward-looking character of technology sovereignty appears to contradict the three dimensions of openness (innovation, science, world) as declared by Commissioner Moedas (European Commission, 2016; Soete and Burgelman, 2023). As a consequence of the developments discussed above, the openness discourse has flattened in recent years. One strategy through which Europe increasingly seeks to reconcile this openness and its advantages with the basic idea of asserting more sovereignty is the concept of Open Strategic Autonomy. This concept emerged after the financial crisis of 2008. It was first formally mentioned at European level in a Council declaration in 2013, but has broadened in recent years through the external shocks of Brexit, the irritations with the Trump Administration and the Russian war in Ukraine. As a result, it still is somewhat ambiguous (Damen, 2022). It refers to 'the capacity of the EU to act autonomously – that is, without being dependent on other countries – in strategically important policy areas' (Ibid.). Here, 'open' refers to the need and willingness of Europe to engage in multilateral cooperation wherever possible and appropriate (Amaral-Garcia et al., 2023, p.1). In fact, in a core document of the European Commission, the focus was very much on openness, claiming that European leadership and open cooperation would best serve its global interests (European Commission, 2021b; see also European Commission, 2023b; Cagnin et al., 2021).

It is thus a conceptual and a policy challenge to define the appropriate levels of and strategies for openness in a quest for technology sovereignty. Given the European economic and geopolitical position, openness can be seen as a means to achieve strategic autonomy (Bardt et al., 2022, p.48). Through openness, international cooperation and engagement, Europe not only benefits via trade, division of labour and international complementarities, but also influences international rules, regulations and standards, and increases its negotiation power (Franke and Torreblanca, 2021).[3] This means, there is, in principle, a virtuous circle of openness on the one hand, and economic as well as political power and autonomy on the other. The stronger the EU is technologically and economically, the more powerful it is in international negotiations and trade relations; and the more open it is to those international cooperations and relations, the more economically powerful and autonomous it can become.

It is against this basic idea of open strategic autonomy that one has to conceptualise technology sovereignty and define sovereignty strategies. One needs to consider that any related activities that limit openness, justified as they may be for all kinds of reasons discussed in this chapter, will have repercussions on this potential virtuous circle. How the added internal strengths envisaged through technology sovereignty strategies that rely on European capabilities influence the potential welfare and power losses produced by reduced international engagement and exposure is hard to predict. However, this welfare calculation

3 Franke and Torreblanca Klicken oder tippen Sie hier, um Text einzugeben.go one step further and stress that the technological power of Europe is a determinant of its geopolitical power in general. Technology sovereignty is thus a direct indispensable basis for a strong geopolitical role of the Union.

needs to be taken into consideration in an overall assessment of the benefit of a risk-reducing technology sovereignty strategy.

It is, therefore, important to further differentiate the meaning of openness. As a recent ESIR report (European Commission, 2023b) has noted, openness has a different meaning for science, for economic competitiveness, for fighting global challenges and for securing Europe's security (Ibid., p.6-7). Therefore, the role of technology sovereignty in relation to those dimensions as outlined in the ESIR report needs to be looked at separately – and this leads to particular challenges for Europe. It will remain of great importance to secure scientific collaboration. Scientific knowledge production is now characterised by a highly differentiated global division of labour. Restrictions here, as a consequence of consideration of technology sovereignty or economic security (see below), will inevitably reduce the productivity of the science system to the detriment of everyone. Of course, this price would have to be paid in areas in which scientific knowledge production has direct security implications (dual use) or is used by others in ways not compatible with Europe's value system. But the balance needs to be struck very carefully and on a case-by-case basis to not undermine the knowledge base for the transformative progress sought. The same holds true in areas of obvious contributions to tackle global challenges together. Reduction in scientific cooperation will reduce effectiveness and speed in tackling these challenges. Furthermore, as stressed above, Europe's economic model relies heavily on the openness of trade, and any restriction on trade because of technology sovereignty concerns will reduce the effectiveness of international trade, one way or another.

A further tension in the relationship between technology sovereignty and open strategic autonomy arises from the breadth of the open strategic autonomy concept. A recent JRC background paper to the CONCORDI conference 2023 signifies the conceptual, methodological and political challenge of technology sovereignty (Amaral-Garcia et al., 2023). Here, technology sovereignty is conceptualised as an *essential* element for Open Strategic Autonomy (OSA) as well as the twin transition. However, OSA itself is defined as a strategy that not only supports twin transitions, but also does so while supporting regional and societal cohesion. In a positive reading, one can hope to leverage 'the unique strengths and capabilities of different regions' to create 'synergistic ecosystem that drives growth and innovation' (Amaral-Garcia et al., 2023, p.24). This of course is another way of stressing the complementarities within Europe to broaden its technology sovereignty. Notwithstanding the normative value of regional and social cohesion, as well as the added value of complementary assets across different regions, this framing of 'not leaving anyone behind' adds yet another layer of complexity to the design and effectiveness of technology sovereignty policies in Europe – and may actually dilute strategic efforts.

2.3 Technology sovereignty and European economic security

More recently, the European Commission and the High Representative for Foreign Affairs have further developed the relationship of technology with concerns for open strategic autonomy by developing a European strategy for economic security, for which they define technology sovereignty as indispensable (European Commission, 2023a). This draft puts further stress on the relationship between sovereignty and autonomy on the one hand, and openness on the other. The economic security strategy concept is far reaching.

It strives to ensure Europe's independent economic development by enhancing its technological and production capabilities. It is thus an extension of the broad technology sovereignty definition outlined above. Moreover, this is to be done on the basis of identifying and reducing various kinds of risks, while keeping in mind 'the inherent tensions that exist between bolstering our economic security, and ensuring that the European Union continues to benefit from an open economy' (Ibid., p.2). The list of strategic risks is comprehensive and goes far beyond dual use and ethical considerations. It includes risks concerning supply chains, physical and cyber infrastructure, technological leakage (in relation to those technologies that are critical for economic security), as well as weaponization in terms of economic dependencies or coercion. Furthermore, the concept, at least implicitly, divides the international partners into those that share 'our concerns and interests on economic security' (Ibid.) and those that do not. For technology sovereignty this would mean that the concerns against which technology sovereignty needs to be defined have broadened, and with it the claim as to what technologies are 'critical' (Ibid., pp.9 and 14) and for which sovereignty must be secured strategically. Any technology sovereignty strategy would be even less selective on that basis. It also means that the openness to develop technology together, to exchange through technology trade or technological collaboration, may be further reduced, for example through tighter export controls and more security consideration for outward investments.

2.4 Potential pitfalls of technology sovereignty approaches

Any conceptual consideration of technology sovereignty must take into account the potential downsides of this approach. To start with, technology sovereignty policy interferes in market dynamics for reasons beyond traditional market and system failure, as it inserts a number of additional drivers for state interference and radiates a defensive spirit of closing down. This may severely reduce the overall efficiency of the national economy for two reasons. First, it may distort markets, as the responsibility of securing the conditions for production of technologies shifts away from businesses and towards the state, potentially overburdening governance capacities of the state and advantaging lobbying efforts over market performance. Second, the idea of technology sovereignty most certainly reduces the international division of labour and trade with interim products and technologies. As the competition around selected technologies intensifies and openness reduces, the global market may even split up in separated areas of technological influence, with diverging standards and norms and reduced interoperability and complementarities across the emerging blocks.

A convergence of technological efforts across countries may also be seen, with potentially counterproductive effects on diversity and variety. Historically, countries have had the tendency to converge to a narrow set of technologies in their strategies for key enabling or critical technologies. As Lee et al. (2023) have shown, the recent national debates and strategies for technology sovereignty build upon strategies on KETs or 'critical' technologies that all advanced countries and the EU have had for decades. A longitudinal analysis of eight countries (US, Japan, Germany, UK, Australia, Canada, France, South Korea) and the EU (Ibid., 2023) finds astonishing similarities of lists of technologies across the comparative countries. In the more recent, intensified debate on technology sovereignty

this pattern is very likely to be continued. This then may intensify the competition across the selected technologies, which may lead to an acceleration of technology development. However, this convergence runs the risk of a reduced variety in the global production and application of technologies in those areas that are not in the immediate focus of technology sovereignty policies. In addition, it may further increase the sense of urgency and vulnerability and foster reactions of closing down nationally, thus contributing to a vicious circle. This, in turn, would confirm the major criticism by Soete and Burgelman (2023), according to which technology sovereignty is a severe threat to and limitation of the three dimensional openness of Commissioner Moedas.

Another downside of the technology sovereignty momentum may arise from the poor conceptualisation or the ambiguous discourse around it. In the past, as Lee et al. (2023) show, the selection and support of KETs were based on economic growth and competitiveness, while only a few countries had systematic linkages to societal benefits and broader innovation goals in the past. Thus, traditionally, the debates on what technologies and sectors to foster were closely linked to considerations of industrial policy, sectoral strengths and priorities in each country. If technology sovereignty is applied according to its broader, functional concept of criticality, the debate on what is to be supported is by definition broader. In combination with the ambiguous discourse on technology sovereignty and the broadening of claims due to open strategic autonomy and economic security, this may invite broad and fierce lobbying for subsidies and preferential conditions across a range of industrial sectors and, indeed, research organisations.

All these potential downsides of technology sovereignty debates need to be taken on board, not only as footnotes in strategies, but as criteria against which any technology sovereignty strategy is being implemented.

3. State of play: measuring European technology sovereignty

Any empirical analysis of technology sovereignty must start with the question: which technologies are critical, and why? This has two elements, which are often confused. First, which technology is indispensable for core activities in the system and/or core duties of the European Member States or the European Union as such; and how are choices made? Second, how competitive and vulnerable is a country or Europe in terms of providing for this technology and its development in the future? While various contributions have different methodological and sometimes conceptual approaches, those two questions are, one way or another, part of any meaningful analysis of technology sovereignty at national or European level.

In this regard, a range of powerful new conceptual and methodological advances are being developed, which enable going beyond the concepts of technological competitiveness or leadership and to be true to very idea of technology sovereignty. In particular, very sophisticated approaches have been developed to define sovereignty positions of technologies at national and European level, and first steps are being made in order to understand the existing and potential partnering approaches to broaden resilience for technology sovereignty.

In one of the more sophisticated approaches, Di Girolamo et al. (2023) analyse the position of Europe in terms of 'complex technologies'. Rather than applying an ex-ante functional framework for the choice of technologies to be analysed, the authors define the level of complexity of the technologies. Knowledge complexity is used as a tool to assess a country's knowledge base that 'encompasses both value and quality of innovation outputs' (Ibid., p.7). A high knowledge complexity index (KCI) means that the technologies produced are hard to replicate by others. Second, they use the concept of technology relatedness, meaning the level of capacity a country (or Europe, or a firm) has to absorb a technology from elsewhere based on the prior level of related knowledge held by the country, Europe, firm, etc. (Ibid.). The study finds that Europe has lost ground versus other major economies in the last 30 years, and has a weak position in those technologies that have a high knowledge intensity, in particular computer technologies, digital communication optics and semiconductors, while it is relatively strong in technologies with a lower complexity and in technologies relating to the green transition.

Di Girolamo et al. (2023) also show that Europe has a structural disadvantage to close the knowledge gaps with other innovators, pointing to the risk of remaining dependent on partners to drive its own transformation. This can severely limit Europe's technology sovereignty, as, for example, digital technologies (where the US and China are clearly leading and have structural advantages) are critical for energy transition efforts (Ibid., p 17). This analysis thus shows that it is not (only) the economic welfare argument that is of concern, but also the broader argument of losing the independent agency to use the best available technology for the transformations needed.

A second effort on the European level worth noting is Kroll et al. (2023). Similar to Di Girolamo et al. (2023), this study also introduces conceptual and methodological innovations based on technology sovereignty logics. It introduces the distinction between autonomy at the technological level (the

'innovation' domain) and the ecosystems level (the economic domain), trying to approach this delicate relationship in two steps. They first distinguish between autonomy as the freedom from external reliance and sovereignty as being independent from external partners. The former is a measure of international division of labour, while the latter is a measure of the trust that this openness holds. They then distinguish between innovation autonomy as a measure of reliance on external partners for the production of knowledge, and economic autonomy as the measure of reliance on getting components or technologies from abroad. The higher the reliance, the lower the autonomy. This approach is a helpful one to navigate the relationship between technology sovereignty and economic autonomy. For a comprehensive strategy that seeks to ensure economic autonomy, one would have to differentiate between the autonomy with which Europe can create knowledge (innovation autonomy) and the autonomy with which it can source and develop technological products (economic autonomy), analysing the sovereignty risk in each of the domains separately. Such an analysis supports strategic decisions as to the need for specific technology sovereignty policies for any given economic domain. Only if a domain is heavily relying on a technology for which both the autonomy is low and dependency is high would a technology sovereignty policy be needed. At the same time, if sovereignty in the core technologies of an economic domain is not sufficient, further conditions beyond technology production must be met. Importantly, their approach also allows differentiating different kinds of dependencies, and incorporating a risk analysis for trade partner countries.

A further recent approach to analyse technology sovereignty at European level focuses on one specific technology, 5G mobile communication, without offering a general, broadly applicable selection framework for that choice. Da Ponte et al. (2023) develop a technology sovereignty index (TCI), focusing on assets and competencies (human capital, science and technology efforts, innovation capacities, capitalisation of research and development), conditioners (external and outsourced resources) and technology sovereignty drivers (resilience in terms of human capital, production, logistics and raw material dependencies). They operationalise the index through a broad range of indicators and demonstrate that those indicators can be meaningfully filled with available data. In terms of material results, the sovereignty index is much lower than that of China and the US, by and large confirming the previous two studies. The methodological and conceptual added value is the differentiation into a set of indicators, which allows a pressure point analysis and setting policy priorities. Furthermore, this approach can be used to show heterogeneity across European countries, as the data in principle is available on a country level.

Recently, Reiss et al. (2023) performed the first[4] comprehensive technology sovereignty analysis for a specific economic sector, i.e. the pharmaceutical sector. They conceptualised technology sovereignty following the definition of Edler et al. (2023). Their added value, though, is the fact that they analysed both the level of competitiveness in a selected technology and the level of international integration and dependency, and measured international integration in three dimensions: knowledge, technology and trade. In their approach, a high level of international integration is a prerequisite to benefit from knowledge and technologies that is generated abroad (co-publications and co-patents), as well as mutual interdependence in trade (Reiß et al., 2023). However, integration is only a positive asset if the country shows a strong position in terms of technological competitiveness, in which case integration ensures mutual benefits and dependencies. A high level of integration

4 As of December 2023, and to the knowledge of this author.

combined with poor domestic technological performance and competences, however, is associated with a high level of dependency. Equally, if a country is highly competitive, but poorly integrated, this position may not be future-proof as it risks falling behind future international developments and thus becoming vulnerable in the years to come.

A recent analysis of the US Critical Technology Assessment Network is worth noting here as it highlights both the sense of the US' self-reliance when it comes to technology sovereignty, as well as a specific methodological approach (National Network for Critical Technology Assessment, 2023). The authors indicate why a range of technologies are critical and need specific support, not so much to prevent dependencies, but to ensure future technological leadership. Both the sense of self-reliance and the understanding of technology sovereignty are based on the understanding that the US has, in principle, the basic critical assets to actually deliver sovereignty across a broad range of technologies with their own domestic competencies. Based on expert views and AI-supported database analyses, the report determines the relative importance of a technology for the economy and for tackling selected challenges (the need analysis), and domestic as well as international capabilities and competences. This multi-perspective analysis covers all relevant department and agencies of the government.

This network also highlights the challenges of a time-critical assessment of international production capabilities and the change in relative competitiveness. They advance methodologies, but not so much in analyses of dependencies, rather in the sense of competitor analyses and analysis of US capabilities.

They also apply a rather crude but effective selection process when it comes to technologies: in consultation with the interagency working group they identify and annually review and update a list of not more than 5 US societal, national and geostrategic challenges that may be addressed by technology. They then pick not more than 10 key technology focus areas and evaluate the relationship between US societal, national and geostrategic challenges and the key technology focus areas (National Network for Critical Technology Assessment, 2023, p.1).

As for the selection of technologies, the European Aerospace and Defence Industry Association suggests a stepwise filtering approach, whereby only those technologies that are absolutely essential for making a specific defence and security function are seen as critical and deserving a sovereignty policy (AeroSpace and Defence Industries Association of Europe, 2020). Importantly, they include the underlying value chains and seek to understand the 'appropriate level and form of European control over the value chain'. On that basis, they identify gaps and dependencies that 'may undermine our sovereignty'. The detailed and deep consideration of value chains, as well as the understanding of 'control' needed over the value chain, are critical elements that exceed many existing approaches. Given the absolute criticality of specific technologies in terms of military performativity, this in-depth value chain analysis appears to be a feature more generally of the defence sector (see also Gholz, 2023): '*However, to achieve an appropriate level of technological sovereignty in strategic sectors, Europe should avoid dependencies that would enable a non-European actor to unilaterally impose constraints on European technologies, or to hinder European suppliers from mastering and executing all of the key steps of the technology development and industrial cycle*' (AeroSpace and Defence Industries Association of Europe, 2020).

4. European assets and liabilities for a technology sovereignty strategy

Within the EU and at European level there are a number of specific conditions which could result in a relative advantage of the region vis-à-vis other countries and partners globally. At the same time, a EU-level concept has to deal with a variety of challenges stemming from its heterogeneity, both in terms of socioeconomic levels of performance and different national profiles, as to the selection of technologies and potential partners to secure technology sovereignty. As, by definition, technology sovereignty policy means to make choices that are more consequential than traditional innovation and technology policy, different national profiles might pose even more challenges than those currently experienced.

4.1 Favourable conditions for active technology sovereignty policy

What are the EU's structural assets that may give it an advantage over competitors and partners globally? Firstly, the awareness regarding the importance for systematic considerations as to technology sovereignty is now considerably high; all political actors at the Commission and in the Council have understood the criticality of the issue. Against the background of the pandemic and geopolitical frictions, technology sovereignty strategies at European level and within Europe are high on the political agenda. Furthermore, in comparison to the initiatives regarding the key enabling technologies of the past, there are now more stakeholders involved: it is not only specific industrial sectors or scientific organisations lobbying for more support for their key technologies. Now it is a debate that is functionally broader, where stakeholders involved in all kinds of important sectoral policies, including defence and security, and transformational policies have a stake. This can and should broaden and enhance the awareness for the importance of investment in sufficient assets and capabilities. The support for science and technology policy as a basis for self-defined developments across Europe appears to fall in line with a change of Zeitgeist in Europe more generally. As Schmitz and Seidl (2023) have shown empirically, what they call the 'neo-liberal consensus' within Europe as to open trade and removing trade barriers is under pressure through 'socially oriented politisation' and through 'geopoliticisation', despite a considerable and persistent share of free trade advocates. Instead, the Open Strategic Autonomy discourse has gained momentum: the free trade and competitiveness focus has shifted towards endorsing active trade policies, recognising systems competition and defence considerations[5], as well as transformation.

Secondly, Europe already benefits from the internal market. This is a considerable strength already, albeit with much room for improvement. As for technology sovereignty, two aspects stand out. One is complementarities across Member States, which can be pooled and thus secure a broader coverage of technologies to be provided within Europe (Schmitz and Seidl, 2023). The new world order will mean

5 The survey by the authors was made before the second Russian aggression in Ukraine in 2022, thus the importance of defence considerations across Europe has most likely further increased..

not only to trade with trusted partners, but to develop integrated technology sovereignty strategies with partners outside Europe with complementary assets. This strategic option is in-built in the fabric of Europe. To be sure, European countries are also competitors. But when it comes to resilient and reliable value chains to secure future technologies, the balance between competition and cooperation within Europe is unique. In particular, as technology sovereignty is more than just the front end of a scientific and technological development, the integrated internal market is a core asset, even if, as argued below, it has serious room for improvement.

Thirdly, there is a further positive effect of the internal market. As the Commission itself has stressed in the context of its broader approach for economic security, a strong internal market enhances the position of Europe when it comes to opening up international supply chains and influencing international trade and production. (European Commission, 2023a; see also Bardt et al., 2022). What has been labelled the 'Brussels Effect' in the past, the normative effect of the export power of Europe on global markets may also play to the advantage of Europe. However, the very merit of the internal market is not fulfilled as yet, which leads us to the specific challenges and dysfunctionalities for the EU when it comes to technology sovereignty.

4.2 Specific challenges

While the internal market is one of the greatest assets for the EU in the global technology competition, it is still far from complete in order to deliver all the advantages it could in terms of technology sovereignty.[6] The internal market still suffers a great deal from fragmentation when it comes to specific regulations (Da Ponte et al., 2023). For example, the scaling of digital business models is much more complicated in Europe compared to the huge internal market of the US or China. If new technologies are being exploited much quicker and more profitable in other areas, the competencies and capacities to develop those technologies will also concentrate in those markets. Thus technology sovereignty will suffer in specific sectors, as will technologies that rely on data and the exploitation of data in large markets, with the potential spillover to other neighbouring sectors and business models. Furthermore, there is still considerable market concentration of business activities across Europe, producing a range of internal dependencies (European Commission, 2021a, pp. 28-29).

This is particularly true given the changes in Europe's relative weight. The 'Brussels effect' and the power of the European technology export markets will diminish. The relative share of Europe will reduce from its current 15% of global GDP in 2022 to 9% in 2050.[7] The regulatory and lead market advantages in some markets will potentially become smaller and will need more elaborate and proactive strategic efforts, particularly in terms of participation in international standardisation and norm activities. This may very well turn into a vicious circle of less relative weight economically, and less regulatory and lead market power.

A further challenge for a European approach to technology sovereignty is the need for EU-wide legitimacy in the face of persistent heterogeneity in terms of levels of economic

6 See Herlitschka (2023) for the example of the semi-conductor industry..

7 See https://www.statista.com/statistics/253512/share-of-the-eu-in-the-inflation-adjusted-global-gross-domestic-product/ and https://www.pwc.com/gx/en/research-insights/economy/the-world-in-2050.html

and technological performance, technological and industrial profiles, and international trade relations. A shared polity like the EU, under conditions of multi-dimensional heterogeneity, needs a technology sovereignty strategy that is very explicit, transparent and regarded as legitimate throughout. As Chrétien and Drouard (2022) point out, the EU has been delegated sovereignty from Member States, but is itself not sovereign. As with any major strategic approach, technology sovereignty also needs to find sufficient support in Member States. However, a consensus on the very nature of and need for technology sovereignty has yet to develop (Ibid.). Heterogeneity exists in the Member States in terms of their positions and ambitions as regards technology sovereignty, in terms of their international exposure and dependence, and in terms of their perception of the need to emancipate Europe from the US. Furthermore, explicit and consequent technology sovereignty strategies involve, by definition, a stronger role for the Member State to define and select critical technologies for which specific measures to secure sovereignty are to be developed. While, as stated above, there are indications of a shift towards a more proactive Member State again, the understanding of the basic role of the Member State (and in particular the basic direction of Member State action) differs enormously across European Member States, increasingly so given the right-wing shift in a number of countries.

Thus, tough choices need to be well justified and posteriorities explained (Crespi et al., 2021). This has further practical and political reasons: the complexity in terms of technological capabilities and gaps across Europe is strong, and the European-wide discourse on choices and instruments highly complex. In addition, and maybe more importantly, there are two political problems. First, technology choices have to do with power and economic gains and, as with any policy with distributive effects, will lead to political controversy between constituencies, stakeholder groups and countries. A second point has to do with the level at which tough choices are made and are being accepted. This in fact resembles an argument made by neo-realist and neo-conservative scholars (Lieven, 2020) who concede that only a strong legitimacy based on national identity and elections could successfully implement transformative policies that ask for a change of behaviour. As an analogy, we could expect that the preferential treatment of a selected number of technologies, supporting certain sectors more than others, could be easier to accept at national level. If Europe turns much more interventionist than it used to be in terms of technological and sectoral choices, this issue of heterogeneity, of winners and losers across the EU, will become more relevant. Thus, at EU level the choices for technologies and related technology sovereignty strategies need to be made in light of different positions, and of the overall importance of a technology for the Union as such. That is why the focus cannot only be on competitiveness issues, but also on issues of value-based duties of the Member State and societal preferences in terms of directionality and in-built values. In addition, any strategic intelligence to support decisions on technology sovereignty must be sound and transparent, and political choices well communicated.

Against this background, the EU's technology sovereignty approach meets different ideational contexts and policy traditions in the 27 Member States. There is still no evidence that the meaning of technology sovereignty and related policies, let alone the depth of related intervention, is commonplace across the EU institutions and EU Member States (European Parliamentary Research Service, 2021). In fact, Bauer and Erixon (2020b) show the basic differences in the German and French approaches and concede various further country positions in their paper. A survey done in eight European countries in

2021 (Friedrich-Ebert-Stiftung and Fondation Jean Jaurès, 2021) reveals the diversity of attitude when it comes to sovereignty in Europe, and the relative meaning of European vs national sovereignty. In general, the share of the population associating sovereignty as positive is much smaller in the Mediterranean countries (including France) than in Germany, Sweden or Romania. There is a clear north-south divide, with considerably more people in the south associating power and nationalism rather than independence with sovereignty. As for European sovereignty, while the majority of all countries surveyed supports a strengthening of European sovereignty, the population in France, Italy, Spain and Sweden is divided and far more sceptical than in Germany or eastern or central European countries. Furthermore, there are obvious material differences in terms of the fears based on the loss of technology sovereignty. For example, new AI-based production technologies influence the core industry of a country like Germany, and thus there is a strong feeling in the country that the domestic system must be able to generate those new technologies to determine its direction. In other countries, the access to those technologies may be seen as sufficient. Finally, there are indications of a notable difference between small and larger Member States when it comes to aligning with European approaches (MIT Sloan Management Review). For example, while in Austria the discussions on technology sovereignty strategy take the EU approach as a starting point (Austrian Council for Research and Technology Development, 2021), the German Futures Strategy, limited as it still is in terms of an explicit technology sovereignty strategy, does not appear, as of December 2023, to develop a coordinated approach.

In short, diversity, a seed for complementary assets and creativity in Europe, can turn into uncertainty and ambiguity as to what actually is to be expected from technology sovereignty policies (Schmitz and Seidl, 2023). Moreover, even if the necessity of joint forces for technology sovereignty in Europe is acknowledged, and even if the instruments are recognised and available, there are voices from the industry that (based on experiences on KETs) doubt the readiness and willingness of Member States to combine forces in order to do so meaningfully (Herlischka, 2023). The quality with which national and European-level approaches align when it comes to technology sovereignty will remain the critical issue for years to come.

5. Conclusions

In Europe, across a range of political areas, from economic policy to security policy, there is a high resolve to strengthen Europe's ability to act more independently. In this context, technology sovereignty has become a top priority, framed to be critical for a number of European goals in times of geo-political upheaval, not as an end in itself, but rather as a mean to enable Europe to control its technological destiny, encompassing not just economic benefits but also fulfilling state duties and societal transformation goals. However, the resolve to be technologically sovereign is not yet met by a clear strategic understanding as to how this should come about.

As argued in this report, any concrete strategy to develop technology sovereignty must have a clear understanding of what this concept entails, how it differs from older approaches, from neighboring, complementary ones, and to what end it is applied. Achieving technology sovereignty in the EU requires a nuanced strategy that goes beyond traditional competitiveness considerations or the focus on individual key enabling technologies. It is about ensuring the EU has reliable and independent access to critical technologies and its components, including raw materials, balancing the need for being able to master the production of certain technology within Europe on the one hand with the benefits - and risks - of the global division of labor on the other hand. Technology sovereignty thus carries with it a defensive, at times even aggressive, connotation. Any system striving for more self-reliance risks reducing its openness and cooperation with other systems. Consequently, greater sovereignty risks leading to increased isolation from those outside the circle of trust, thereby creating a downward spiral of protectionism, where each step towards self-sufficiency further limits engagement with the broader global community. For a continent like Europe, interdependent with other parts of the world, this risk needs to be managed carefully.

Therefore, rather than simply seeing technology sovereignty activities as reactive and defensive - or as precautionary at best -, it should be understood as functional for Europe's global standing (Ringhof and Torreblanca 2022). Technology sovereignty in this perspective does not only mean being sovereign, but being a technological leader, creating technologies that are globally indispensable, shaping and benefiting from early markets in order to strengthen the European position. This would be a consequence of a particular strength, the European internal market - which indeed is "much more than a market" (Letta 2024) - and could result in an extension of the "Brussels Effect", whereby Europe could proactively influence global technological norms and standards, in line with European values and priorities, and in partnership with technologically strong value partners.

However, a technology sovereignty approach defined at EU level, in conjunction with open strategic autonomy and economic security, would still face the material challenge to define which technology to choose and how to support it. Even if the basic concept of technology sovereignty finds enough support in the political space, the implementation of a strategy tailored towards European level considerations and technological positions remains a huge challenge.

In this regard, the EU faces hurdles also due to the incompleteness of its internal market and regulatory fragmentation. The heterogeneity across Member States in terms of economic, technological, and industrial capabilities - alongside different international

exposures and ambitions for technology sovereignty- complicates consensus-building. This diversity, while a source of creativity, can lead to uncertainty regarding the direction and expectations from technology sovereignty initiatives.

There are a range of operational and strategic steps to be taken. First, Europe needs an appropriate strategic intelligence to underpin a robust technology sovereignty strategy. Here, Europe is making commendable efforts, including not only traditional metrics like patents, trade, and publications, but also embracing a mix of indicators and qualitative assessments that consider value chain complexities, thereby going beyond the inner core of technological development. In this respect, one can only support the demand of a recent ESIR report to set up a sophisticated technology monitoring and more awareness when it comes to dependencies of raw materials and how they can be mitigated (European Commission, 2023b; p. 11-12). Second, STI policies will need to be increasingly strategic, with a focus on complex technologies and its components. This includes the need to form explicit international partnerships aimed at collaborative technology sovereignty. It also includes embedding in a holistic, coordinated policy approach, with strategic STI policies coordinated with trade policies, industrial as well as foreign policy (European Parliamentary Research Service 2021)

However, even if those two conditions were met, there is still a profound dilemma at EU level. Given the size and capacities of individual European countries and the advantages of the internal market, technology strategies are only meaningful and promising at EU level. At the same time, as technology sovereignty policies are about strategic choice, priorities and posteriorities, the interventionist policies needed are contested and need a high level of legitimacy. This, unfortunately, is a particular challenge for the time being at EU level. If governments strive for sovereignty, they need a high level of legitimacy to implement all measures needed, which may privilege one group over the other. If that legitimacy is limited, sovereignty policies will be under pressure. At the same time, if sovereignty policies are proclaimed, but fail to deliver, the repercussions for the legitimacy of the EU may be immense. In this respect, it remains questionable at best to link technology sovereignty, as was recently done, with consideration of cohesion. If technology sovereignty as a policy approach is stretched to respond to the sovereignty imperative *and* cohesion consideration at the same time, chances are high that it fails to deliver on one of the two accounts, or maybe even on both accounts. This would inevitably limit the credibility and legitimacy of technology sovereignty approaches. Cohesion goals, important as they are, should thus be pursued through other means.

While skepticism remains regarding the readiness and willingness of Member States to harness their strengths collectively towards European technology sovereignty, there is no alternative to do so. The path forward requires navigating these complexities and the legitimacy challenge with strategic intelligence, transparent decision-making, and effective communication to align diverse Member State interests with the broader EU technology sovereignty agenda. And surely, established European instruments to support technology development, chiefly the European Framework Programme, will have to play a major part in this critical journey Europe is undertaking.

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