

**Technology Sovereignty
as an Emerging Frame for Innovation Policy –
Defining Rationales, Ends and Means**

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Contents

| | |
|---|-----------|
| Abstract..... | 1 |
| 1 Introduction..... | 2 |
| 2 Conceptualisation..... | 5 |
| 2.1 Basic definition and characteristics..... | 5 |
| 2.2 Prevalent risks of misconception | 7 |
| 2.3 Technology sovereignty as embedded agency vs. technology sovereignty as autarky..... | 10 |
| 3 Implications for innovation policy and its prevailing rationales | 14 |
| 3.1 Technological sovereignty and innovation policy | 14 |
| 3.2 Justifying technological sovereignty based on an economic welfare objective..... | 15 |
| 3.3 Justifying technological sovereignty based on a systems transformation objective..... | 17 |
| 4 Potential policy actions..... | 19 |
| 4.1 Developing strategic intelligence for technology sovereignty | 19 |
| 4.2 Policies to secure or gain technological sovereignty | 21 |
| 4.2.1 Traditional innovation policies for technological sovereignty | 21 |
| 4.2.2 Non traditional innovation policies for technological sovereignty | 22 |
| 5 Conclusion and outlook | 26 |
| References..... | 29 |

Abstract

In recent years, global technology-based competition has not only intensified, but become increasingly linked to a more comprehensive type of competition between different political and value systems. Against this background, the notion of technology sovereignty has gained prominence in national and international debates as an additional rationale for innovation policy, cutting across the established perspectives or paradigms of economic competitiveness and socio-technical transformation.

In this paper, we propose and justify a concise yet nuanced concept of technology sovereignty to contribute to and clarify this debate. We offer a balanced perspective of a nation's legitimate interest in ascertaining the availability of and access to technologies on the one hand, and the dangers posed by autarky and protectionism on the other hand, which are detrimental to global trade and eventually welfare. In contrast to much of the initial policy discourse, we derive our concept from economic and sociological theories. In particular, we argue that technology sovereignty should be conceived as state-level agency within the international system, i.e. as sovereignty *of* governmental action, rather than (territorial) sovereignty *over* something.

Against this background, we define technological sovereignty not as an end in itself, but as a means to achieve the central objectives of innovation policy - sustaining national competitiveness and building capacities for transformative policies. Based on this motivation, future policies will have to aim at establishing a stable, albeit dynamic, equilibrium between sovereignty and openness. To accomplish this, we propose three types of policies. First, new forms of strategic intelligence and foresight will be essential to understand the need for action to secure technology sovereignty and how to achieve it. Second, we propose to mobilise a set of traditional STI policies that have specific importance in the context of technology sovereignty, such as investing in research and the development of competences and high-level infrastructure as well as supporting entrepreneurial activities in emerging technologies, demand-side policies to establish technological lead markets, and international scientific and technological cooperation. Third, we propose a set of policies specifically targeted at securing technology sovereignty, such as international standardisation, strong regulatory frameworks, complementary competition, trade and investment policies and strengthening international institutions to safeguard rule-based trade and competition. We conclude by highlighting a number of challenges stemming from the political economy dynamics that are to be expected should technology sovereignty become a leading rationale for innovation policy.

1 Introduction

Although innovation policy is a long established field in both academic research and policy practice (Edler and Fagerberg 2017), it remains subject to constant external pressure from general politics and the intricacies of executive policy-making. New developments regularly result in novel political and societal claims vis-à-vis innovation policy and should be accompanied by sound conceptualisation in order to inform the debate. Such conceptualisation is needed to highlight the benefits and costs of responding to these new claims and to develop a rationale and a basis for their legitimacy as the foundation for new interventions in innovation policy. A good example of this is the recent development of transformative or mission-oriented innovation policies (Steward 2012, Weber and Rohracher 2012; Mazzucato 2018, Schot and Steinmuller 2018; Larrue 2021). This "third framing" by Schot and Steinmuller (2018) complements earlier rationales focused on boosting economic competitiveness by correcting market and system failures. Its main objective is to mobilise innovation policy in ways that more directly support socio-technical transformations, most notably, but not limited to, sustainability concerns.

In this paper, we turn the spotlight on technology sovereignty, taking up a very recent and dynamic debate now influencing the innovation policy discourse at European level and in a number of countries, which can be understood as spanning both competitiveness and transformation-oriented policies (BMBF 2021; March and Schieferdecker 2021; Aussilloux et al. 2020).

Quite legitimately, all nation states and supranational unions, whether leading or lagging, can assume that it is in the best interests of their constituency to work towards a self-determined position in a dynamically changing global environment. Accordingly, the case for technological sovereignty is usually made first with respect to specific technologies, which are deemed critical to the core functions of statehood including national defence and boosting the competitiveness of the domestic economy. In a European context, the concept has been invoked most often for modern communication technologies, 5G in particular, and has often focused on digital sovereignty.¹ More recently, however, its focus has also shifted to other fields, such as vaccine development or artificial intelligence.

The intensity with which this concept is now influencing innovation policy debates is in stark contrast to the lack of a serious conceptual underpinning as a basis for sound and

¹ For many examples, see speeches by the EU Commissioner Thierry Breton in July 2020 (Breton 2020b: https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_20_1362) focusing on microelectronics, and on September 11 2020, in which he talks of "technological war" and digital sovereignty (Breton 2020a: https://ec.europa.eu/commission/commissioners/2019-2024/breton/announcements/europe-keys-sovereignty_en).

explicit policy intervention rationale (March and Schieferdecker 2021). Given this background, our paper aims to conceptualise technology sovereignty based on the first outline discussed in Edler et al. (2020). In particular, we explore what technology sovereignty means for countries and governments, what its benefits and costs are, and how it interacts with the existing innovation policy rationales of economic competitiveness and transformation. This conceptual discussion also allows us to put forward governance and policy proposals which, we believe, will enable policy-makers to strike a balance between legitimate claims for access to critical technologies on the one hand and the benefits of international openness and the division of labour on the other.

In this paper, we claim that the rise of technology sovereignty results from the growing demand that states should preserve their ability to act strategically (see Mazzucato 2018, among many others) and autonomously in an era of intensifying global technology-based competition, which is increasingly motivated and fuelled by geo-political antagonisms as well as disagreements about core values (Joshi 2019; Ahn 2020). Over the years, fears of falling behind in the international race for technology superiority or of being relegated to unfavourable positions in global value chains have been at the forefront of European policy debates time and again. In the late 1960s, the "American Challenge" (Servan-Schreiber 1967) was regarded as threatening the competitiveness of Europe and, in the mid-1980s, Japan and its microelectronics and business process innovations were perceived as a last wake-up call for a sclerotic Europe (Contzen 1984; Duff 1986). The difference now, at least from a European perspective, is the threat of having lost the leading edge in critical technologies that dominate the new era of the platform economy while its competitors, notably China, are not only openly striving for technological leadership but also linking this ambition to a competition between different systems and values. Consequentially, they cannot be expected to compete within the existing international rules-based framework, but to question it and to game it for their own benefit (as the UK, Germany and the US did at different times during the 19th and 20th centuries). This is a socio-technological challenge of a new quality and explains why technology sovereignty has de facto become a horizontal dimension, not only for innovation policy, but for economic, foreign and security policy as well.

This development reveals a conceptual gap. Government actors have a legitimate interest to intervene with the aim of developing, gaining access to, or keeping control of technologies deemed critical for state functions, economic wellbeing and the welfare of their constituencies. At the same time, the potential downsides and limits of policy interventions seeking technology sovereignty must also be considered. Early attempts by European or national industrial policies to – at least implicitly – re-establish "national champions" focused strongly on the development of strategic autonomy (Jowett and Rothwell 1986). Earlier discourses around technology sovereignty included protectionist

tendencies or even tendencies towards advocating autarky (compare Krasner 2001; Kratochwil 2006). However, there are strong risks associated with returning indiscriminately to such earlier discourses. They are not able to address today's problems with sufficient precision. It is also very likely that generic arguments for technological sovereignty as an end in itself would open up a Pandora's box of innovation and industrial policies characterised by national egoism, an overemphasis of national competitiveness and the acceleration of an already ongoing erosion of international and supranational institutions at the expense of the international division of labour and collaboration.

Acknowledging the risk that a simplistic concept of technology sovereignty could pave the way towards protectionism, we develop a more nuanced concept, which explicitly rejects understanding technology sovereignty as national autarky or technological self-sufficiency (in line with March and Schieferdecker 2021). Instead, we propose that technology sovereignty should be understood as public agency in the domain of technology and innovation, i.e. the ability to act independently in the face of limiting institutional and economic structures and, in some cases, third parties' adversarial actions. We build on the theoretical framework of embedded agency (Thornton and Ocasio 2008; Thornton et al. 2015; Ocasio and Thornton 1999), which suggests that the actions of public agents are deliberate, while the degree of deliberation and the scope of actions available to them is limited by institutional structures they are embedded in (cf. Giddens 1977). Based on these theories, we conclude that the agency of states, or, more precisely, governments, should be considered in a systemic analysis of national innovation capacities (and their evolution) as well as current and future international interdependencies and that policies should be designed on this basis. We emphasize that what traditional innovation systems theory considers to be a framework (institutions and rules of the game) is in fact the result of conscious and often strategically targeted actions at government level.

In proposing this notion of government agency, we make the specific case that implementing successful innovation policies not only requires domestic resources and a conducive national institutional framework, but must also strategically and constructively deal with the opportunities and constraints resulting from global dependencies and interdependencies. Earlier innovation policy discourses – whether based on market and system failures or transformation rationales – have not focused on the question of international dependencies and interdependencies. Given the new quality of the debate on technology sovereignty, this is a serious omission. At the same time, actions based on considerations of technology sovereignty will necessarily interact with rationales and actions based on competitiveness and transformation. Only if the emerging policy debate around this issue is addressed and theoretically grounded, however, will innovation

scholars be in a position to inform policy on matters of international positioning and prevent the debate on technological sovereignty evolving into a destructive one dominated by short-term, retaliatory politics of protectionism or the plain protection of power.

This paper is structured as follows. We first present a basic definition and understanding of technology sovereignty. Then, we develop a deeper conceptual rationale to capture popular misconceptions and their risks, followed by honing the concept by mobilising the notion of embedded agency. Section 3 discusses the relationship of technology sovereignty with innovation policy, focusing on how technology sovereignty interacts with the two dominant rationales of competitiveness and transformation. We then suggest a number of governance and policy recommendations that are derived from and in line with the developed concept. A short final section highlights what we consider to be the main benefits of a conceptualisation of technology sovereignty that considers the balance between securing access and benefitting from open economies. Our framework allows policy interventions to be developed that further the two main existing rationales of innovation policy as well.

2 Conceptualisation

2.1 Basic definition and characteristics²

The basic definition we intend to deploy and further elaborate here is the following: We understand 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" (Edler et al. 2020).

As indicated above, this fundamental definition does not refer to the autonomy let alone the autarky of a state or a group of states. Instead, it stresses the notion of access to technology or relevant components that can be secured through domestic provision and through relationships with other economic regions that are reliable, i.e. structurally interdependent and politically trustworthy.

In this overall context, the concept of technology sovereignty must also be distinguished from broader concepts of innovation or economic sovereignty that may even more easily be conflated with protectionist arguments. While both constitute key rationales for the pursuit of technological sovereignty, they are by no means identical.

² The basic definition and its major building blocks are taken from Edler et al. (2020).

On a first level, innovation sovereignty can be delineated from technological sovereignty by highlighting that innovation requires much more than core technological competences, including the ability to pilot, further develop, commercialise and, eventually, access relevant markets (Edler et al. 2020). Economic sovereignty refers to an even broader concept that additionally includes a nation's unimpeded access to natural resources, investment capital, competences and logistics and its ability to safeguard economic competitiveness and wellbeing. Accordingly, technological sovereignty is only one relevant constituent of economic sovereignty.

While trade, defence, fiscal and monetary policy can be deployed as attempts to address or prevent imminent losses of economic sovereignty in the short run, they can develop limiting effects in the long run, if the nation deploying them does not invest in developing its own technological capacity as well. In other words, the efforts undertaken towards achieving technological sovereignty aim at building a technological basis that is essential for sustaining a country's economic sovereignty in the long run. While specific situations may require short-term measures to improve technological sovereignty from a static perspective (Edler et al. 2020), its core relevance results from dynamic considerations over time.

We argue that the key, and as such warranted, motivation for the debate on technological sovereignty is that various public actors have come to acknowledge that either government itself or the wider domestic economy have become too reliant on technologies designed, provided, and thus easily influenced or withheld by potential adversaries. Conceptually, this derives directly from established concepts of sovereignty in international law, which posits that all nation states should be able to govern their internal affairs without external interference (Hinsley 1986; James 1986). In this respect, the call for technology sovereignty reflects governments' concerns of losing the ability to act independently in the global technological system and/or of being relegated to unfavourable positions in global value chains. There are fears that national economic actors may lose their capacity for value creation and, in turn, governments may lose the ability to provide for their own populations with a view to generating public wealth and/or addressing relevant societal challenges at acceptable costs (e.g. Huotari et al. 2020; European Union 2020; Bauer and Erixon 2020).

The term technology sovereignty reflects a state's or a supranational union's ambition to retain and exercise control over global processes of technological development, aligned with and building on a broader notion of "sovereignty as autonomy", which has already been highlighted in the conceptual literature (Geenens 2017). More precisely, technological sovereignty relates to a state's or a supranational union's ambition to shape and direct (parts of) the global technological system – with the ultimate aim of ascertaining *future* economic wellbeing and the capacity to fulfil and further develop state functions

for the respective population. Accordingly, the concept of technological sovereignty put forward in this paper is an inherently dynamic concept, constantly evolving with the changing opportunities and demands for technologies and changes or potential changes in the international geo-political and techno-scientific environment.

Fundamentally, this concept has two main dimensions, to which the subsequent analysis relates. First, the need for the *ability to provide* certain technologies, which leads to a capacity-building argument intrinsic to innovation policy as well as to the call to not give away existing capacities unnecessarily for short-term economic reasons (March and Schieferdecker 2021). Second, the need for the *ability to source* without one-sided dependency, which leads to a broader discussion of trade, foreign investment, public guarantees and, at times, even defence policy.

By combining these two dimensions, the concept of technological sovereignty proposed here remains an outward-oriented and cooperative one. It blends safeguarding certain abilities of a particular state or union and respecting the legitimate interest of other states or groups of states within the existing international division of labour and global value chains at the same time. Efforts to secure technological sovereignty can and should provide a means to safeguard and dynamically adjust a nation's ability to provide or access technology it defines as critical. Ideally, concerted efforts to build an "ability to provide" can help to avoid having to resort to more direct, and often less effective, means such as trade policy, broad-based subsidisation, government guarantees or the direct protection of power in areas of economic interest. In practice, however, tensions will remain. Giving priority to building abilities to provide over more defensive measures may have to be softened, as some of the latter measures may well be required, in particular, with respect to safeguarding and improving a nation's "ability to source" by securing access to a range of countries rather than just one.

Regardless of the means chosen, however, measures to retain and build technological sovereignty should – in their emphasis – be proactive, not reactive, strategically planned and forward-looking, not retaliatory and defensive. Their ambition should not be to force other nations into dependency situations, but to elevate a specific country's own agency by building capacities and encouraging activities in those arenas where the relevant future institutions of the global innovation system are negotiated and defined.

2.2 Prevalent risks of misconception

Although the overall objective of the technology sovereignty discourse thus rests on a legitimate basis, its wording and use in political debate implicitly convey an inward-looking, national, in Europe at best Europe-centric perspective. Hence, it is a concept at

constant risk of being appropriated by those who - often out of conviction - construe other countries or economic areas as threats rather than potential collaboration partners (March and Schieferdecker 2021).

Such an inward-looking view, however, is in stark contrast with the liberal discourses on international trade and techno-scientific collaboration that emerged, took hold and proved their effectiveness in the latter part of the 20th century. For good reasons, the prevalent conceptual blueprint to achieve a nation's ambition to ascertain wealth and public wellbeing has, for an extended period, been a liberal model of collaboration and rules-based economic competition (Porter 1990; Porges 1995; Barton et al. 2006). In particular since the fall of the iron curtain, the global institutional system has emphasized – if not international cooperation – at least the safeguarding of economic interests in free trade and has been accompanied by unprecedented technological advances, growth and welfare. In consequence, a growing number of trade agreements have been signed, tariffs reduced and intellectual property rights strengthened internationally (Barton et al. 2006), even if regular, implicit and explicit challenges to the overall system have remained common, providing clear evidence that a power dimension is still involved (Read and Perdakis 2005; McKinney 2009)

In parallel, standard economic theory encouraged the intensification of international collaboration and an ever more complex sharing of tasks in differentiated international innovation and production chains (Dicken 1994; Amin 2002; Gereffi et al. 2005). There are multiple accounts from both conceptual and empirical studies that collaboration in diverse areas ranging from science and technology, to production and trade creates positive-sum situations resulting from an optimisation of resource deployment according to nations' comparative and competitive advantages, at least if trade arrangements are free and fair (Persson 2010; Nomaler et al. 2013; Guerrero-Bote 2013; Rodrigues et al. 2016; European Commission 2016).

The countervailing suggestions for more sovereignty stem therefore less from concern that rules-based international trade and scientific exchange can no longer provide static gains. The concern is rather the dynamic international shifts in technological capacities in combination with geopolitical shifts and an increasingly obvious clash of value systems that are conjuring new challenges to the existing rules-based system. These limit the options remaining for an international, interdependent development of technologies. While small or developing countries traditionally have to position themselves in the global technology system and have a strong need of interdependent, reliable relationships, concern about the loss of technology sovereignty is now high on the agenda of all leading economic countries as well as the European Union.

The relatively stable institutional order of the 2000s and early 2010s has been increasingly called into question on two accounts. First, by new players, primarily China, who have come to openly promote diverging economic, social and political ideologies, and seek to either use or adapt the global institutional system to their purpose (McKinney 2014; Hearson and Prichard 2018; de Graaff et al. 2020, Hamilton and Ohlberg 2020). Second, by the fact that established players, primarily the US under the Trump administration, temporarily abandoned traditional commitments in foreign and economic politics, leaving the global community with damaged confidence in what used to be the main proponent and guarantor of the rule based order (Brewster 2018).

Under these changing framework conditions, international alliances long considered stable and institutions to safeguard economic interests long taken for granted proved more fragile than expected, eroding European policy-makers' established belief in multilateralism. At the same time, nationalist policy-making has been on the rise within Europe as well since the mid-2010s, not as a reaction, but in parallel to such efforts detected elsewhere. Against this background, there is a real and increasing risk that the concept of technology sovereignty takes on a nationalistic flavour, either unintentionally as a consequence of legitimate concerns over the need to safeguard the agency of states, or by design as a compliant tool of those seeking to dismantle free trade institutions, limit international collaboration and, more generally, reduce openness in international exchanges. Even deliberately multilateral versions of the technology sovereignty discourse can be twisted into discourses in which the acknowledgment of international collaboration is degraded into window dressing that both legitimises and conceals an inner core saturated by logics centred on protectionism. Indeed, some proposals put forward under the heading of technological sovereignty appear narrowly delineated from more conservative notions of independence, self-sufficiency or even autarky (e.g. Gorositz 2019). While, conceptually, an interpretation of technological sovereignty as technological autarky is a misconception (Edler et al. 2020; Grant 1983), this can be easily forgotten once the discourse crosses over into the political domain and becomes one of (inter)national security policy or traditional industrial policy, hijacked by considerations of political economy.

To avoid such misappropriation and to reap the benefits associated with a multilateral notion of technology sovereignty in practice, the concept needs a strong theoretical basis, which has so far been lacking. In the following section, we therefore propose a conceptual foundation for a multilateral version of the technology sovereignty discourse that is grounded in the fundamental concept of sovereignty as agency (Giddens 1977) rather than sovereignty as autarky.

2.3 Technology sovereignty as embedded agency vs. technology sovereignty as autarky

While theoretical models of international trade tend to highlight the overall benefits of such trade, these are unevenly distributed among the trading partners. In particular, countries specializing in the value-intensive, high-tech parts of global value chains, robustly take a larger share of the returns associated with globally dispersed production and trade (Crook and Combs 2007). This explains why countries typically seek to upgrade their technological bases in order to be able to specialise in the high-value activities in global value chains (Janger et al. 2017; Acharya 2017; Wu 2018). Constructing or maintaining technological bases requires mastery and control of key technologies. This is why (legally) sovereign nations subjected to global technology competition are increasingly concerned with actions to control the technologies considered relevant, either by developing them domestically or obtaining secured and stable access to them (Edler et al. 2020; BMBF 2021; Aussilloux et al. 2020).

Against this background, we identify three weaknesses in liberal theories of global competition that interrelate and mutually reinforce each other and which require us to rethink our positioning on the present cooperative paradigm in international relations in science and technology. Overall, liberal theories of global competition display three main shortcomings of relevance for our argument. First, the focus on static optimisation, ignoring the dynamic dimensions of risk. Any international division of labour increases the vulnerability of supply lines, in which countries' ability to act can become unduly exposed to external shocks whether of natural or political origin (Dicken et al. 2001; Dicken 2007; Levy 2008; Coe et al. 2008). Second, the concept of optimisation in a stable system is built on a conservative notion of production and innovation (Romer 1990). This underestimates the ease with which technological advances can enable other emerging countries to leapfrog into new technological paradigms and challenge incumbents (Brezis 1993). Third, the assumption that emerging nations will play by the rules. These will, in contrast, seek to build and exploit dependencies and change the established terms of collaboration to their benefit. Challenges to established configurations of power and influence (and respective reactions) are therefore to be expected (Wu 2018; Hearson and Prichard 2018; Nicholas 2016), including those stemming from competing value systems.

The consequence is that the premise of stable global rules-based systems, exchange patterns and technological paradigms and hierarchies is untenable. Historically, as well as today, rules, exchange relationships and technological hierarchies have always been subject to dynamic change driven by the evolving interests of leading nations and changing global norms, e.g. concerning sustainability (Barton et al. 2006; Skogstad 2015; Krapohl et al. 2020),

Despite this background, one does not arrive at the conclusion that mainstream liberal economic theory is wrong in promoting openness and exchange. However, some of its premises are simplistic. A more differentiated approach is required during periods of dynamic technological change and challenges to the global institutional system, particularly if they co-occur with the prevalence of competing value and economic systems. In that sense, our proposed approach to technological sovereignty is not an antithesis to the paradigm of openness and collaboration, much rather an attempt to qualify this under dynamic framework conditions.

Theoretically, we conceptualise technology sovereignty from an embedded agency perspective (Thornton and Ocasio 2008) of globalised technological competition. Embedded agency has evolved from the more general debate on whether the surrounding socio-institutional structures are determinant in shaping an individual's behaviour, or whether the individuals are endowed with agency, i.e. the ability to act freely and in a self-motivated manner (Giddens 1977). Since the 1980s, this discussion has increasingly evolved into a synthetic discourse, which posits that, while structures shape agency, agency as such does exist and enables actors to influence future structures (Giddens 1984).

Embedded agency is thus a concept describing the interplay of individual action and institutional structures, where structures are 1) both enablers and limiters of action and 2) emergent from past collective action (Battilana and D'Aunno 2009). This sociological agency view has clear links to technology policy and sovereignty. For example, a state seeking to specialise its economy within a relevant technology needs a certain level of autonomy – or technology sovereignty – on the one hand, which enables a certain level of control or mastery of that technology. On the other hand, within a framework of technology competition, its sovereignty will constantly be challenged by competing nations and by strong individual firms that increasingly dominate important areas of economic activity and societal development by applying global internet-based platform business models. These challenges limit its level of technological sovereignty. In consequence, while a country may remain legally sovereign, this sovereignty is limited, because it is embedded within structures of globalised economic and technological interdependencies. This becomes a threat to the country if those interdependencies turn into one-sided structural dependencies.

However, the concept of embedded agency not only helps to clarify the boundaries of agency in international structures, it also highlights the global structure and the interplay of state action. Any action taken to preserve technology sovereignty will affect the (international) structure and thus shape the global system. For example, if a country withdraws from international investments and re-shores technology production, this will cause oth-

ers to react and will create new value chains and trade patterns, which in turn will influence agency in the future. On the other hand, if a country invests in the development of international standards, it can enhance its own influence on market structures and consequently its own agency.

Conceptualising technology sovereignty from the perspective of embedded agency raises two questions: First, how can a state devise STI policies to best serve the needs and demands of its population under the current structures? Second, how can a state devise STI policies to ensure the largest possible influence on future structures? These questions are obviously open-ended and do not prescribe a specific way of action. Instead, they welcome the integration of insights into effective innovation policies from different theoretical backgrounds and logics, including market failure theories, socio-technical transformations, international relations and trade politics, to name but a few. In particular, the agency perspective does not preclude that international cooperation in science, the creation of strategic multinational technology alliances or the free flow of knowledge within certain economic areas are the best way to achieve the STI-related goals or technology sovereignty in a specific setting.

Arguments in favour of technology sovereignty motivated in this way therefore differ markedly from those suggesting the need for autarky or self-sufficiency as a legitimate goal in itself - rather than one deriving from the legitimate aim to safeguard the fulfilment of particular needs and demands of a population. We therefore claim that the autarky view, when suggesting an intrinsic value of becoming independent from other nations, confuses the means and ends of STI policy. This is the essence of Grant's (1983: 239) much earlier definition, which is in line with our own definition provided above, and defines technological sovereignty as the retention of agency "to select, to generate or acquire and to apply, build upon and exploit commercially technology needed for industrial innovation [which must] be distinguished from technological self-sufficiency" as a perceived end in itself.

Critiques may be tempted to flag this openness of the agency view as a weakness, because it does not directly prescribe much in terms of STI policy. This, however, would be misguided, because the agency perspective provides a very clear interface to the various systems of innovation literatures, which allows us to derive clear propositions of which policies appear most advisable and which not. This interface becomes clear with respect to the methodological apparatus of embedded agency theory, which consists of two building blocks. The first is "actors", which, when combined with the notion of technology sovereignty, emphasises the role of governments and supranational organisations besides that of large companies and research organisations. The second is that of the organisational field, which can be understood as a (constantly changing) playing ground

defining the rules of the game. As we highlighted above, in the context of technology sovereignty, the generic game that is played by the actors is technological competition in relation to a specific technology or a set of mutually dependent technologies.

In this context, it is worth noting the parallels between an organisational field on the one hand and an innovation system on the other. The innovation systems literature (Nelson 1994, Edquist 1997, 2010, among many others) often uses constructs very close to the organisational field literature, albeit with a different wording and a less pronounced emphasis on the role of state action. Of particular usefulness for our definition of technology sovereignty is the concept of a (global) technological system of innovation. The technology systems literature (Carlsson and Stankiewicz 1991) has a very compatible focus, in particular as some more recent variants take a broader perspective on technological systems delineated by functional challenges (Bergek et al. 2015; Markard 2020).

However, the concept of the technological innovation system is more limited than an organisational field in the sense that it predicates a techno-centric view, which is a reasonable framework for STI discourses focusing on technological innovation. However, STI discourses relating to transformative change and thereby involving changes in social habits and practices, policies, and even societal values in addition to changes in technology (Geels and Schot 2010; Coenen et al. 2012) are not easily captured within an innovation system framework alone. More specifically, we argue that, so far, the role of governments as agents has been underrated in the innovation systems approach, which becomes particularly problematic when, as is the case with technological sovereignty, international relations and government level exchanges play a major role. In a situation of dynamic changes in the global system, the traditional view of institutions as providing a largely stable, national-level framework cannot suffice. Instead, institutions should be seen as the result of a constant succession of conscious, and in part, strategic government actions - thus placing government centre stage as a key actor on both the national and the international scene of establishing and renegotiating rules-based systems. In sum, thinking along organisational fields rather than technological ones is helpful, as it broadens the view to include elements that are critical for the consideration of technology sovereignty, but not normally included in the technology systems approach.

In the next sections, we explain what the loss or lack of technological sovereignty means for innovation policy in general and what policy-makers need to do to address it. We then explain how, specifically, the agency perspective of technological sovereignty contributes to the currently predominant discourses on innovation systems inspired by the logics of economic competitiveness on the one hand and transformative discourses on the other hand.

3 Implications for innovation policy and its prevailing rationales

3.1 Technological sovereignty and innovation policy

As stated above, technology sovereignty has already become an issue of major concern for innovation policy-makers, but it requires clearer conceptual framing and grounding. As we argued above, it should be conceived of as a means to achieve existing innovation policy objectives more effectively, rather than as an end in itself. To further illuminate the issue, it is useful to describe in more conceptual detail why the loss or absence of technology sovereignty can be detrimental to policy-makers in their pursuit of innovation policy objectives. However, we begin by examining under which framework conditions governmental action can be justified at all.

Conceptually, technological sovereignty emphasises the build-up of capacities and the safeguarding of technological access (March and Schieferdecker 2021; Edler et al. 2020). These become particularly pressing when a state's own capacities and relationships with other countries become insufficient to ensure access to technologies deemed critical to successfully perform the public tasks for which government has been granted a mandate. Therefore, innovation policy guided by technology sovereignty considerations aims to focus on selected, strategically identified domains. Likewise, potentially disruptive policies beyond the traditional domain of innovation policy (trade, investment or security policy) should be deployed carefully and with moderation. In fact, new measures only appear justified in response to the evident structural failure of past innovation policies, substantial changes in the global technological system or domestic societal preferences, or the need to respond to a lack of systemic resilience and redundancy in the face of crises like Covid-19.

Given the benefits of open, interdependent systems in providing static efficiency gains, state intervention is thus justified only in those cases where states or groups of states experience or expect a loss of agency with a view to fulfilling core governmental tasks that is grounded in the lack of access to critical technologies. It is not per se a suitable measure, and certainly not a panacea, to improve nations' or supranational unions' positioning in global technological competition.

Against this background, public policy inspired by technological sovereignty will have the greatest justification and develop the highest leverage the earlier a concrete challenge with respect to a particular domain of government agency is identified, i.e. when there is still time to focus public activities on constructive, capacity-building activities intrinsic to the innovation process (rather than having to forfeit known benefits by limiting free trade or global investment). In order to ensure the success of innovation policies focusing on creating or restoring agency, two main issues need to be addressed.

First, it is essential to clearly specify the technologies, or, more precisely, the element of the innovation and value chain in which greater sovereignty is required. Since numerous studies document the extent to which the generation of technological innovations is characterised by an international division of labour, the idea of relocating entire innovation chains to a single country, or to a well-integrated multinational economic area (such as the EU), must appear very questionable at best. Thus, it is critical that there are clear criteria to define those technologies, for which a state or a group of states takes action to increase sovereignty.

Second, in order to identify such technologies, it is essential to determine precisely in which functional context the respective technology is considered critical, as this will define how, why, on which timeline and with what degree of urgency it will have to be addressed. Here, we can distinguish three major functions at the systems level for which a state or a group of states need to have sufficient agency in terms of critical technologies: First, technologies to provide central functions of the state (defence, security); second, technologies to support long-term economic competitiveness; and third, technologies to support the pursuit of societal preferences in the context of directed socio-technical transformation.

The following sections outline the relevance of technology sovereignty for the second and third dimensions in particular, as questions of technology sovereignty have always been prominent to ensure agency for exclusive state functions such as defence. The reason for disregarding the context of defence-related issues is that this touches upon the provision of non-excludable and non-rivalrous public goods, which are not supplied by the market and have therefore always been the domain of the state.

3.2 Justifying technological sovereignty based on an economic welfare objective

As outlined in the introduction, a nation's ability to enable its firms to compete freely and successfully in the global technological system is essential to ensure sufficient high-level value added and to provide for its population in the long run. As discussed above, there is a long tradition of economic thinking that state intervention to support the competitiveness and innovativeness of its systems is essential in the context of market and system failures. The subsequent paragraphs outline how this need to ascertain the competitiveness of firms and the long-term agency of states adds another rationale for state intervention to achieve and maintain technology sovereignty.

While international competition itself is driven by companies, not states, these companies' ability to compete depends on a number of central factors, from which a rationale

for state intervention in the pursuit of securing international competitiveness can be derived. More precisely, companies' ability to compete freely and unimpeded depends on at least five main fundamentals that are at least partially within the domain of government (Edquist 1997; Kuhlmann and Arnold 2001). First, the availability of talent, which, in turn, depends on the availability of excellent basic and higher education in key fields. This may be organised privately, but in most countries it is de facto at least partially under state control. Second, it depends on knowledge, even those technologies developed in and transferred from the research sector, which is counted a public domain because of the associated knowledge externalities. Third, on functioning value chains, where the state's task is keep these open and reliable by setting appropriate institutional frameworks (e.g. trade agreements). Fourth, on suitable, modern infrastructure, in particular in the digital domain, which should be set up from public sources at least to a certain degree, as companies will underinvest due to free-rider incentives. Fifth, and finally, it depends on and is shaped by regulation and standardisation, which fall either directly under the remit of the state (regulation) or can be monitored, encouraged and incentivised by government agencies (standardisation).

Further, short-termed economic rationales of the owners and shareholders of companies may lead to selling off critical competences to foreign competitors, even if this is not in the interest of the wider economy, and may limit technology sovereignty.

Nevertheless, the core activities in international competition are performed by the companies themselves and not the state. Technology development, sales, trade, business and – importantly – the financing of these activities remain largely outside the remit of public authorities. Despite the above-mentioned exceptions, this fundamental paradigm is not questioned by legitimising state action in pursuit of national competitiveness.

In contrast, public efforts to retain or regain technological sovereignty can be motivated by the need to enable, safeguard and, if need be, defend the robust foundations as well as a favourable and equitable framework of global competition. Fundamentally, this can be derived from three central rationales for state functions, which do not deviate substantially from mainstream economic theory. First, from the ambition to ascertain the foundations on which future competitiveness rests, in particular in the area of basic and strategic, mission-oriented research, where public good characteristics are most obvious (e.g. Stiglitz 1999; Williams 2016, Griffioen et al. 2021). Second, from the ambition to ascertain the physical and institutional infrastructure on which international competition depends (Gruber 2019; OECD 2020; Greenstein 2020). Third, from the ambition to safeguard and, if need be, defend a level playing field for global competition by acknowledg-

ing, and, where inevitable, defensively and deliberately countering other nations' prevalent use of non-market means like large-scale subsidisation or protectionist trade policies (Nicolas 2016; Weinhardt and ten Brink 2019; de Graaff et al. 2020).

Technology sovereignty as an additional rationale calls for securing access to the knowledge relevant for competitiveness as a public good, even with the trade-off of allowing other countries access to this knowledge base. Furthermore, access to increasingly global physical infrastructures has to be assured for the respective country's companies, again, potentially in exchange for allowing foreign countries access to that country's own infrastructures. This argument also holds for access to institutions, e.g. patent courts in Europe for Chinese companies. Finally, violation of the rules of global competition by single countries might not only challenge the short-term competitiveness of domestic companies, but also the longer-term technological sovereignty of the country at large. This would require government to undertake counter strategies that are more comprehensive and focused on the longer term than the short-termed policies of securing its country's own competitiveness.

Overall, state action to achieve technological sovereignty can therefore be legitimised from a competitiveness perspective, albeit in a limited manner. At least in welfare states, governments have the clear mandate to ensure future prosperity for their electorate. Without technological sovereignty, however, such prosperity cannot be achieved and sustained. Accordingly, governments not only have the right, but are mandated to safeguard and improve their nation's international standing and agency. Without a suitable foundation and reliable framework, which only the government can provide, economic actors will not be able to ensure national welfare in the long run.

It is precisely this strategic, capacity-oriented perspective at the core of this rationale, which is important. While protectionism and short-termed interventions into the economic process may help specific firms ephemerally, they do not automatically build lasting national capacities. Accordingly, they cannot be readily justified based on the above argument, unless they are a direct response to other countries' already existing or evidently planned interventions of a similar nature.

3.3 Justifying technological sovereignty based on a systems transformation objective

As stated above, a rather recent, but increasingly important rationale for innovation policy is the contribution it can make to the transformations needed to tackle major societal challenges. This has become most obvious in the Covid-19 crisis, where the quick mobilisation of innovations through collective efforts has become an imperative. However,

transformative policies are now defined in all kinds of societal areas, most notably – but not limited to – concerns around climate change and sustainability. While the generation of innovations, more precisely technological innovations, will not be sufficient for the transformations needed, many societally desirable transformations will not happen without the generation and diffusion of technological innovations. The argument for this rationale is a long standing one, and different policy intervention rationales have been developed as a result. Most notably, the rather technocratic mission-oriented innovation policy approach suggested by Mazzucato and the EU Commission postulates that the state can define concrete goals that can be achieved by targeted innovation policy interventions supported by complementary policies as needed (Mazzucato 2014, 2018; Kuitinen et al. 2018). A second variant, transformative innovation policy, postulates that the state can support transformations that are emergent and typically follow a bottom-up rationale. State interventions here strengthen inherent dynamics to replace incumbent socio-technical regimes with those that are more akin to desired societal outcomes (Schot and Steinmueller 2018, Molas-Gallert et al. 2020). These rather idealistic extreme variants of innovation policy supporting transformation have since been complemented by a whole range of different approaches and types (Larrue 2021, Wanzenböck et al. 2020; Janssen et al. 2020).

Despite their differences, all these conceptual approaches and their empirical applications have three things in common: First, the legitimacy of the state rests on its ability to mobilise innovation for transformation, to achieve the desired change, rather than on input additionality or improving how the innovation system works (Edler and Fagerberg 2017; Boon and Edler 2018). Second, the state needs to ensure that investments in technological innovation are directed towards achieving societally desirable goals. Third, many of the societal challenges tackled are shared by other countries and are in themselves transnational in nature and thus benefit from international learning and cooperation.

System transformation as a leading rationale is a challenge on all accounts, and even more imperative to secure technology sovereignty. If the pursuit of major political goals depends on the availability and roll out of very specific technologies, failing to develop these technologies nationally (or at EU level), to secure access to them or to provide substitute technologies directly undermines the legitimacy of the state. Further, any development triggered by technology sovereignty considerations that would - as a reaction - undermine international cooperation and learning will also reduce the ability of a country or groups of countries to tackle the shared challenge of system transformation. The loss of economic welfare as described above would be accompanied by a loss of societal welfare that is linked much more directly to the failure of the state to deliver.

At the same time, this top down approach of technology sovereignty orchestrated by public policy can be complemented by bottom-up dynamics in transformation processes. Transformative innovation policy is characterised by a much more conscious and stronger societal discourse about the desired direction of change and the means to achieve it. This bottom-up element of transformative innovation policy can help to define technology needs more explicitly than in traditional policy approaches. Anticipatory discourses (Schot and Steinmueller 2018) also support the search for alternative solutions and experimentation, and this collective exercise can be one way to manage situations of poor access to important technologies.

4 Potential policy actions

In the previous section, we outlined how technology sovereignty cuts across the established competition/welfare rationale on the one hand and the transformational rationale on the other hand as a precondition for these two primary rationales to be successfully achieved. This raises the question whether any specific policy recommendation can be motivated based on the notion of technology sovereignty which goes beyond the mandate of the other two rationales. Understanding technology sovereignty as safeguarding agency can, in cases where the positive build-up of technology sovereignty will not be sufficient, motivate measures in the field of competition, trade or investment policies that would otherwise be considered “off limits”. From a technological sovereignty perspective, however, these may be used – with moderation – to avoid structural dependencies.

In the following, we explain why and how the acknowledgement of technological sovereignty as an important precondition justifies and suggests a number of interventions beyond those usually mandated by the established rationales of innovation policy.

4.1 Developing strategic intelligence for technology sovereignty

Innovation policy that considers technology sovereignty as a means rather than an end requires the state to make careful assessments of which technologies are actually critical and which threats to their provision or access to them actually exist (Edler et al. 2020).

While strategic intelligence is also required for other policy paradigms such as mission orientation, such assessments are usually limited to identifying relevant fields of action. They do not, however, require an overarching assessment of a country's position regarding technological competitiveness and power relations in international value chains. The assessment of technology sovereignty is no easy task and puts higher demands on a

state's strategic intelligence capabilities – arguably much higher than result from any other innovation policy rationale adopted so far.

The analytical or strategic intelligence capabilities of a country or a multinational economic area (such as the EU) are not only relevant for a functioning innovation system (e.g. Hekkert et al. 2007), but also form the basis for deciding which technologies are critical and how to secure access to them. Methodological and analytical competencies must be available in order to be able to investigate the main dimensions with regard to technology sovereignty in a technology-specific manner and with the necessary level of granularity.

Several main aspects have to be diligently considered in detail before any political efforts towards increasing technological sovereignty can be initiated. First, whether and why a technology is currently critical or will become critical in future, including the functional context in which it is critical (economic competitiveness, meeting key societal needs, contributing to sovereign tasks), i.e. why state intervention is motivated. Second, how and to what extent access to this technology is or could soon be threatened; including a differentiated risk assessment of current sourcing patterns and strategies. Third, within which spatial-political system boundaries should technology sovereignty be achieved and a definition of what is needed to achieve it in this specific area. Fourth, which competencies and resources the country in question already (or still) possesses, which ones it is confident of developing in the short to medium-term, and which will have to be sourced from third parties for the foreseeable future, be it for commercial, environmental or other reasons (cf. Edler et al. 2020).

The strategic intelligence requirements are not only analytical, i.e. mobilising bibliometric, technometrics techniques and economic analyses. They are also discursive, i.e. it is critical to establish foresight processes³ that outline possible future trajectories of societal demands and technological developments that can be used to underpin any decisions about criticality and technology sovereignty.

³ See, for example, the scenarios based on the consultation of various stakeholders related to the future of the 5G supply chain in the EU in Dinges et al. (2021).

4.2 Policies to secure or gain technological sovereignty

4.2.1 Traditional innovation policies for technological sovereignty

The following policy actions can be considered to secure or regain technology sovereignty in a specific domain. The compatibility of the technology sovereignty approach on the one hand with the established competitiveness and transformation rationales suggests that the policies mandated by them will also be relevant from the technology sovereignty perspective. Since technological capabilities form the foundation of all technological sovereignty, they are restated here, even if their justification does not require the adoption of a technological sovereignty perspective. We do so in order to convey that the overall balance or focus of policy intervention would only be influenced very moderately should a technological sovereignty perspective be adopted in the manner proposed in this paper. Regardless of whether complementary measures are required, we highlight the following four areas as the core fields of intervention in innovation policy.

Competences and research: To maintain their ability to produce relevant technologies and products in a dynamic environment, countries have to generate technology-specific knowledge using the classic instruments of research and innovation policy, as promoted recently by the German Federal Ministry of Research, for example, under the heading of "ability, not autarky" (March and Schieferdecker 2021). Beyond investments in R&D, this requires a critical mass of knowledge carriers which can only be formed by teaching the corresponding content at universities. The ongoing discussion on the gap in professorships in battery technology or Open Source in Europe is one example of this (Blind et al. 2021).

International cooperation: Since the potential portfolio of technologies is much too large for the majority of national economies to provide the necessary research and production capacities in all the fields relevant for their technology sovereignty themselves, it is necessary to establish long-term collaborations, in particular in those areas where technological sovereignty is missing. These technologies or products often require access to specific raw materials. Therefore, a division of labour 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 addition, international scientific and technological cooperation is essential to build up structural interdependencies and mutual trust internationally, thereby reducing the risk of one-sided dependencies in the long run.

Entrepreneurial activities: Since the competencies and capacities of the private sector guarantee future technological sovereignty, it is important to not only strengthen already

well-established companies or incumbents, which tend to exploit their competitiveness based on already existing technologies and products, but also to support start-ups in emerging technologies that are likely to assure technological sovereignty in the future.

Demand-side innovation policies: Targeted public procurement can help to create early markets or lead markets (Beise 2004) for innovations that may become relevant for many other countries, and thus to establish global technological leadership and eventually a good negotiating position to safeguard technology sovereignty in certain technological domains. In addition, it makes sense in the long term to design the regulatory framework in a way that provides domestic or European industries favourable conditions and incentives to perform the corresponding research and therefore also to establish production capacities in fields prospectively at risk of technology dependencies.

Infrastructure: In a dynamically changing environment, all enterprises depend on an up-to-date infrastructure, in particular in the digital domain, which they can rely on in their research, development and production activities. Typically, at least the fundamentals of such infrastructures have to be provided by the public sector.

4.2.2 Non traditional innovation policies for technological sovereignty

In addition to these fundamental, traditional policy approaches, which should continue to form the foundation of all future research and innovation policy (March and Schieferdecker 2021), technology sovereignty may also justify further policy action, which does not necessarily follow directly from transformational or welfare rationales as such, but only becomes relevant if recourse is made to the need to safeguard government agency in innovation policy. This section discusses the role of regulatory frameworks, competition/trade/investment policies and setting up/strengthening international institutions including international standards.

Regulatory frameworks: The national regulatory framework can be shaped to improve the functioning of innovation system, but also to foster the transformation of the system, e.g. to address the challenges of climate change. However, national regulations can also address dimensions which are relevant for technological sovereignty. In addition to the institutional regulations related to intellectual property rights that incentivize investment in research and development, regulations also address challenges related to public goods or negative externalities. For example, the EU toolbox to mitigate cybersecurity

risks gives the Member States guidelines on how to regulate national procurement practices of 5G mobile telecommunication technologies.⁴ Here, the objective is to assure the integrity of national physical infrastructure, an important element for the functioning of the state and therefore also for technological sovereignty.

Competition/trade/investment policies: In addition to shaping the regulatory framework conditions in an innovation-friendly way, some specific competition, trade and investment policy measures can be aimed at securing technology sovereignty. According to the OECD (2015)⁵, competition policy addresses the abuse of dominance and monopolisation, cartels and anti-competitive agreements, mergers, liberalisation and competition interventions in regulated sectors and general pro-competitive policy reforms. All these policy areas have links to technological sovereignty, albeit to different degrees. If competition policy instruments successfully address the topics listed above, they make a general contribution to a state's technological sovereignty, because this is served by the long-term survival of a sufficient number of companies in a competitive environment.

Developing industrial capacity in selected areas: State support to develop industrial capacity in areas that are seen as critical and in which technological sovereignty as defined in this paper is under threat is a further option. This can take place in the form of targeted pooled public support as in the European IPCEI initiatives⁶ or in the form of (partly) state-owned companies such as Airbus in the past (Archibugi and Mariella 2021). Measures such as "national champion" policies should be contemplated primarily at a supranational level, such as those coordinated by the European Commission, as these may otherwise pose risks to competition on the national market and can trigger counter measures that threaten transnational dependencies.

However, nationally-focused competition policy might be insufficient to secure a state's technological sovereignty. Therefore, this has to be embedded in the broader context of trade (see for example the proposal of the European Commission DG Trade 2021) and investment policies. Among the various dimensions of trade policy listed by the OECD

4 <https://digital-strategy.ec.europa.eu/en/library/cybersecurity-5g-networks-eu-toolbox-risk-mitigating-measures>

5 OECD (2015), *Policy Framework for Investment, 2015 Edition*, OECD Publishing, Paris. Online: <https://doi.org/10.1787/9789264208667-en>, Chapter 4; <https://www.oecd.org/competition/assessment-toolkit.htm>

6 IPCEI: Important Project of Common European Interest is a form of public subsidy to develop pooled technological and production capabilities and infrastructure in areas defined as critical by the European Union [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014XC0620\(01\)](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014XC0620(01))

(2015)⁷, international trade agreements are the most effective approach to secure technological sovereignty. Here, governments' activities related to market-expanding international trade agreements and through the implementation of their WTO commitments can consider technological sovereignty as well, e.g. by explicitly addressing areas of insufficient sovereignty in such agreements via clauses guaranteeing access to specific technologies or goods. Investment policy is complementary to trade policy. Among the dimensions of investment policy listed by the OECD (2015)⁸, intellectual property rights and the non-discriminatory treatment of national and international investors, in particular, but also international co-operation are relevant for securing technological sovereignty. A basic requirement is the implementation of laws and regulations for the protection of intellectual property rights and effective enforcement mechanisms. In 1995, therefore, the WTO launched the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Here, the question arises whether the treatment of domestic and foreign firms following the principle of non-discrimination should be reconsidered in the context of technological sovereignty.⁹ Finally, the collaboration of national investment policy authorities with their counterparts in other economies to expand international treaties on the promotion and protection of investment could also consider the dimension of technological sovereignty, e.g. by focusing on reciprocal investments in areas relevant for the respective countries' technological sovereignty, or by preventing the selling off of critical technological capacity to foreign companies or states. Monitoring the acquisition of European companies by non-European multinationals according to Regulation (EU) 2019/452 is a specific example of a measure addressing both competition and trade policy. In addition, dumping practices by non-EU vendors can be prevented within the framework of Regulation (EU) 2016/1036 on protection against dumped imports from non-EU countries. Counter measures could involve the WTO based on its Anti-Dumping Agreement¹⁰, but could also involve setting up funds to subsidise national companies harmed by the dumping practices of foreign competitors.

Strengthening international institutions: 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 organisations such as the WTO.

7 OECD (2015), *Policy Framework for Investment, 2015 Edition*, OECD Publishing, Paris, <https://doi.org/10.1787/9789264208667-en>; Chapter 3; <https://www.oecd.org/investment/toolkit/policyareas/tradepolicy.htm>

8 OECD (2015), *Policy Framework for Investment, 2015 Edition*, OECD Publishing, Paris, <https://doi.org/10.1787/9789264208667-en>

9 See the current debate about waiving patent rights on Covid-19 vaccines.

10 See WTO (2018).

Complementary to the WTO as a governance structure for global trade, bi- or multilateral trade and investment agreements are appropriate ways to reciprocally secure countries' technological sovereignty. In addition to the existing institutions responsible for assuring free trade and global competition, the establishment of new institutions could be also considered. These would be complementary to the already mentioned international standards, on a more generic level. One recent example is the ORAN Alliance, created by several global active mobile network operators in 2018 as an attempt to increase their independence of the dominant vendors of 5G technology (see Dinges et al. 2021 for its analysis and possible future scenarios).

Standardisation: Although standardisation is occasionally understood as promoting functioning innovation systems and being relevant for system transformations, it plays an even greater role in securing technological sovereignty, because international standards can also be considered international institutions. The development of open standards according to the six principles of the WTO¹¹, of which openness, transparency and impartiality are the most important for technology sovereignty, (potentially combined with patent pools) supported by many international companies and research organisations, can assure access to technologies that are relevant for the broad majority of countries. The openness of standards can be promoted even more by integrating elements of Open Source software (Blind et al. 2019) and now hardware (Blind et al. 2021). These open standards prevent a proprietary monopolisation of technologies, which challenges countries' technological sovereignty if these are owned by only a few foreign companies. Consequently, open standards reduce dependencies on single suppliers within complex value chains and therefore also lower the risk of supplier failure. Overall, open international standards developed according to the WTO principles are effective instruments to assure technological sovereignty. If national stakeholders, in particular companies, but also research organisations actively contributed to these, this would increase the integration of nationally developed technologies into international standards (as revealed for the United States and China by Blind and von Laer 2021), reduce the implementation cost for domestic companies and thereby foster not only their international competitiveness, but also technological sovereignty.

In line with our discussion of agency and structuration, this section has demonstrated that many of the state actions designed to strengthen technological sovereignty will inevitably link back to the global structure. This is especially true for more defensive actions in terms of trade and investment policies, which could trigger adverse reactions from other countries and blocs, but it also holds for standardisation policies, where the positive

¹¹ https://www.wto.org/english/tratop_e/tbt_e/principles_standards_tbt_e.htm

effects could be a global market in line with the standards developed in a particular country. Understanding these feedback loops, both intended and unintended ones, is a major requirement for any balanced technology sovereignty policy.

5 Conclusion and outlook

Sovereignty discourses have proven powerful and ubiquitous, despite the fact that many authors have predicted their demise due to the increasing relevance of international integration and global institutions (Werner and de Wilde 2001). In particular during times of crises and disruptions, i.e. when a nation's ability to maintain status-quo processes is at stake, a renewed ambition to control existing dependencies may come to the fore (Krasner 1999; Werner and de Wilde 2001). Therefore, it should not come as a surprise that technology sovereignty as a specific variant of sovereignty discourses has once again become fashionable after a turbulent decade influenced by the financial and economic crisis, increasing protectionism in the USA and China, and the Covid-19 pandemic. Against this background, we maintain that sovereignty discourses function as a self-legitimising, protective mechanism of states faced by challenges originating from their external environment (Kratochwil 2006).

In this context, we have argued that technology sovereignty will become an additional, horizontal rationale for innovation policy, supported by trade, investment and competition policies as needed. Increasingly fierce technology-based global competition means that a limited number of countries or economic blocs are fighting for dominance of the pervasive key enabling technologies of the future. In contrast to earlier post-World-War competition, this is now linked to serious rivalry between different political and value systems, and is thus assuming a new quality. If this central premise is correct, it is essential that technology sovereignty policies are conceived as supporting the ambition to retain agency in the innovation domain, based on a conceptual widening around the notions of risk and vulnerability, and not as a move towards across-the-board independence, let alone autarky.

Our technology sovereignty concept is therefore built on four central premises:

- First, it is a reaction to a changing world order, in which the preferable system of free trade and collaboration has come under attack and therefore no longer provides a reliable basis under all circumstances,
- Second, it is a dynamic concept, focused on building competences and capacities through innovation policy and seeking to maintain, wherever possible, stable international technological interdependencies,

- Third, it highlights the need to not forfeit competences and stability for the sake of short-term profit maximisation without acknowledging the long-term need for agency in critical technologies,
- Fourth, it retains the option to react by activating competition, trade or investment policy instruments as needed, but only as last resort, possibly coordinated with other countries in the wider context of trade agreements, and with a view to retracting those measures as soon as possible to avoid a vicious circle of protectionism.

Applying this enlightened concept of technology sovereignty through state intervention faces a number of challenges that are worth highlighting in conclusion. To begin with, any technology sovereignty policy is prone to contestation between different economic and societal actors. Inevitably, policies aimed at achieving technology sovereignty will force tough choices between strong material interests in society and the economy. In this context, some may be tempted to adopt sovereignty as a normative ideal, with obvious risks. Such a rationale would tilt the entire discourse towards inward-focused protectionist tendencies and autarky, setting in motion a vicious circle internationally, despite the overwhelming body of evidence on the overall superiority of rules-based systems and international openness in science and technology.

A further concern is the internal race for state support of specific technologies under the conditions of asymmetric information. Even if state actors follow sophisticated analytical and methodological steps as outlined here and in Edler et al. (2020), it is still likely that the information advantage of industrial actors in terms of understanding the technology and its international position will induce opportunistic rent-seeking. This problem is exacerbated if the technologies deemed critical for socio-technical transitions multiply and many aspects of the process are normatively charged. Any multiplication of the technologies deemed critical that is not warranted by objective analysis would be an undesirable outcome of the technology sovereignty discourse. The static and dynamic welfare losses could be substantial if preferential treatment is associated with market dominance and the power to mobilise public support rather than the analytical, objective determination of criticality.

In order to limit the risk of welfare losses, it is imperative that the state maintains a sufficient level of independence of actors with vested interests and that it reduces asymmetric information by establishing suitable and capable bodies and/or building capacity in existing ones. This implies – as outlined above – that the state strengthens investments in the ability of the system to understand future needs and technologies and its own tech-

nological expertise by upgrading strategy departments, and supporting them with independent expertise, potentially even institutionalised in advisory bodies that have no vested interests in the assessed technologies.

The innovation policy of the future will have to be developed in the triangle of transformation policies, competitiveness policies and technology sovereignty considerations. The movement towards mission- and transformation-oriented policies has already complicated innovation policy, but technology sovereignty considerations add to this complexity in terms of the analytical requirements, the political negotiations needed, and the instrumentation of policy itself. Innovation policy, defined as the positive development of competences, capacities, systemic conditions and international scientific cooperation, will be complemented by trade, investment and competition policies to a greater degree than in the past, so that it can react more swiftly to the policies of other countries or blocs. Innovation policy therefore faces two challenges: the need for more systemic long-term thinking to secure future technology sovereignty, and more comprehensive short-term reaction, if necessary via other policies, which complicates the coordination and consequently governance of the rather independent policies. As we have tried to argue throughout, this new balanced innovation policy must avoid throwing out the baby of international welfare gains through free trade and division of labour with the bathwater of short-sighted technology sovereignty policies driven by domestic interest groups. This is what the concept of agency and structuration tells us. Any action at home to retain or regain agency will inevitably influence international structures. Understanding this structuration may be one of the major requirements of intelligent technology sovereignty policy in years to come.

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