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The EU's Quest for Digital Sovereignty: A Matter of Quantum Innovation?

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Abstract

The EU increasingly seeks to assert its digital sovereignty by boosting innovation and norm-setting in, among other, quantum technologies. This objective is generally reflected in numerous policy documents and crystallised in the Digital Decade Policy Programme, which sets specific targets to achieve it. The EU policy documents recognise a world-changing potential of quantum technologies whilst remaining vigilant due to their potential disruptive impact. This white paper maps the way the ambition of digital sovereignty is interwoven with the development of quantum technologies in the EU digital policy and legislation. It documents empirical work, identifying thirty policy and legal documents which were produced during the past five years and bind digital sovereignty and quantum technologies together. The aim of this white paper is to bring attention to and invite further examination of the complex interrelation between digital sovereignty and quantum innovation. In this way, the white paper wishes to spark a broader conversation on the feasibility and desirability of emerging and future tech governance approaches.

Keywords Digital sovereignty · European Union · Digital policy · Quantum technologies

1 Introduction

References to sovereignty in the digital realm, under different terms such as technological, data, or digital sovereignty or under the concept of strategic autonomy, feature prominently in EU policy statements and documents. For example, in her

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political agenda as a candidate for the European Commission Presidency, von der Leyen declared in 2019 that ‘it is not too late to achieve technological sovereignty in some critical technology areas’.¹ Since then, technological and digital sovereignty has become a core objective of EU policy. Amongst others, the Digital Decade Policy Programme sets out to ensure the EU’s digital sovereignty ‘in an open manner, in particular by secure and accessible digital and data infrastructures capable [...] supporting the competitiveness and sustainability of the Union’s industry and economy, in particular of SMEs, and the resilience of the Union’s value chain’.² This goal is also reflected in the 2023 European Declaration on Digital Rights and Principles for the Digital Decade, as a means towards achieving ‘a dynamic, resource efficient, and fair economy and society in the EU’.³ Whilst not the first to make use of this notion, following explicit claims or implicit strategies by, among others, China, Russia and the United States (Pohle & Thiel, 2020; Thumfart, 2022), the EU is unique in being a supranational entity claiming sovereignty.

Digital sovereignty is often considered the umbrella term used to convey a traditional understanding of (state) sovereignty as the assertion of autonomy and authority, in this case, over data, technologies and infrastructures (Broeders et al., 2023; Couture & Toupin, 2019; Pohle & Thiel, 2020). In its digital version, sovereignty transcends nation-state boundaries and remains a contested and highly contextual concept (Barrinha & Christou, 2022; Couture & Toupin, 2019; Gordon, 2023). In the EU setting, the supranational actor seeks to assert its authority in the digital domain by domestically investing in critical technologies, such as quantum technologies, and establishing EU values and a human-centric approach to tech governance as the global norm. For instance, von der Leyen, in her above-mentioned political agenda, continues by stating that ‘[t]o lead the way on next-generation hyperscalers, we will invest in blockchain, high-performance computing, quantum computing, algorithms and tools to allow data sharing and data usage. We will jointly define standards for this new generation of technologies that will become the global norm’.⁴ Furthermore, the Digital Decade Policy Programme sets several objectives alongside digital sovereignty, such as the promotion of a human-centred and fundamental-rights-based digital environment and the development of interoperable digital infrastructures.⁵ These objectives are to be achieved, among others, by bringing the EU to the cutting-edge of quantum capabilities by 2030.⁶

EU policy-makers recognise quantum technologies as ‘enablers for technological sovereignty, competitiveness at a global level and a successful digital transformation’ alongside super- and cloud computing.⁷ Therefore, they largely motivate investment in these technologies as a means to achieve the EU’s digital sovereignty. The European Declaration on Quantum Technologies, for example, stresses how ‘[i]n order to

¹ Ursula von der Leyen (2019), p. 13.

² Article 3(1)(c) Digital Decade Policy Programme.

³ Recital (6) Declaration on Digital Rights and Principles.

⁴ Ursula von der Leyen (2019).

⁵ Article 3 Digital Decade Policy Programme.

⁶ Article 4 Digital Decade Policy Programme. See also COM (2021)b).

⁷ Point 25 Council conclusions (2020).

strengthen the EU's position as a global actor in quantum technologies, it is essential to work together to accelerate excellence in quantum technologies and applications at European and national levels and raise awareness of their economic and societal potential, ensuring security and technological sovereignty.⁸ Quantum technologies are envisaged as 'strategic for the EU, given their foundational role in future digital ecosystems and far-reaching economic and social impact'.⁹ Due to their disruptive potential, however, they also 'raise issues of sovereignty that can change the reasoning about international collaborations' as well as cyber-security concerns.¹⁰

Similarly, quantum technologies comprise an umbrella term that denotes technologies that use quantum mechanics phenomena. While quantum mechanics have been studied for decades, recent technological advancements appear to bring the scientific world increasingly closer to controlling these phenomena into concrete applications (Hoofnagle & Garfinkel, 2022; Preskill, 2023; Purohit et al., 2024). In particular, quantum technologies typically encompass quantum computing, quantum sensing and quantum communications (Centre for Quantum & Society, 2023).¹¹ Very simplistically put, quantum computers should be able to perform certain calculations much faster and more efficiently than state-of-the-art computers; quantum mechanics render sensors more precise, detailed and robust in measuring properties such as time, gravity or magnetic fields; and solutions are being developed to secure networks and communications through quantum effects. Quantum technologies may improve existing methods or create entirely new possibilities, potentially revolutionising some sectors; as such, states and companies investing in them consider them highly promising. Yet, some of these applications, specifically quantum computing, remain a distant and uncertain future (Grumbling & Horowitz, 2019; Hoofnagle & Garfinkel, 2022; Preskill, 2023).

The aim of this white paper is twofold; first, it seeks to inform scholars of this complex relationship between digital sovereignty and quantum technologies in the making. While digital sovereignty is often analysed conceptually, this white paper examines the EU's approach to achieving sovereignty in the digital realm by focusing concretely on one of the technological sectors considered by the EU as key enabling, that is quantum technologies. To that end, the white paper documents how the EU's ambition to ascertain its digital sovereignty and strategic autonomy is interwoven in diverse policy documents with investing in and developing quantum applications. To obtain a more comprehensive overview of the policy discourse, the literature review was complemented by empirical research of relevant EU policy and legal documents. On a secondary level, the white paper wishes to invite scholars and policy-makers to challenge the foundations underlying the future and role the EU envisages for itself as a digitally sovereign global actor by means of quantum innovation. In that regard, the white paper closely and concretely examines how the EU plans to achieve this ambition and raises critical questions on the feasibility and desirability of these plans.

⁸ European Declaration on Quantum Technologies (2023) To date, all Member States but Ireland have signed the Declaration.

⁹ COM (2023), p. 13.

¹⁰ European Quantum Flagship (2020), p. 91; JOIN (2022), p. 13.

¹¹ See also [Quantum Flagship](#), [Quantum Technologies in a nutshell](#).

The white paper is structured as follows: Sect. 2 introduces the policy landscape before delving into specific aspects thereof, namely the most prominent regulatory framework, the funding, and the relevant concerns. Section 3 provides a high-level assessment of this policy discourse and respective challenges before concluding in Sect. 4 with open questions for further research.

2 The Policy Discourse

2.1 Introductory Remarks

The white paper relies on an empirical study of EU policy papers documenting the linkages between the concept of digital sovereignty and the interest in quantum technologies. In particular, I performed two advanced searches on the official repository of EU documents, EUR-Lex; first, I used the keywords “digital sovereignty” and “quantum”, which yielded 82 results. Second, I searched with the keywords “technological sovereignty” and “quantum”, yielding 129 results. The two searches included some overlapping references. Then, a selection of 28 documents was made based on how closely digital/technological sovereignty and quantum were presented, textually and thematically, that is, in such a way that one affects or relates to the other. Documents where references to the two were coincidental or no relation between the two could be established were excluded. Two additional documents complemented this selection; they derive from the European Quantum Flagship, which comprises a European research project funding scheme; as such, these documents are considered indirectly linked to and, therefore, part of EU policy. The list of selected documents was created in March 2024 and is attached to this white paper in the Annex.

Before delving into this specific aspect of digital sovereignty, it is worth noting how this term and idea was heavily promoted as an agenda priority by EU Member States, especially France and Germany. Discussions on this concept were recorded as early as 2006, with private sector actors and economy-oriented policy-makers as its main advocates.¹² That was when French tech experts wrote an essay on ‘souveraineté numérique’ (Benhamou & Sorbier, 2006) before the term made it to the French government as well as the political agenda of several German ministers around the 2010s. Partially a response to the Snowden revelations of global mass surveillance and driven by incentives to regulate economic activity online and protect digital critical infrastructures, digital sovereignty started to get promoted as a crucial aim for the economy and security of not only individual Member States but also at the EU level.¹³ Meanwhile, academia and industry, emphatically from Germany and France next to other countries, campaigned for the unique potential of quantum technologies for ‘a more sustainable, more productive, more entrepreneurial and more secure European Union’.¹⁴ Although not calling it as such, the promise behind developing quantum technologies alludes to digital sovereignty attributes. Eventually, the year

¹²For a detailed account of the historical development and use of this term, see (Thumfart, 2022).

¹³Ibid.

¹⁴Quantum Manifesto: A New Era of Technology (May 2016).

after von der Leyen, a German national herself, set her political agenda, marked a proliferation of policy documents proclaiming the significance of investing in critical tech areas such as quantum technology to ‘increase’ and even ‘ensure’ technological sovereignty.¹⁵ Thereafter, the terms technological and digital sovereignty became widespread and their link to quantum tech innovation had been explicitly established.

More specifically, since 2020, there has been a steady production of policy documents conditioning the EU’s capacity ‘to make its own choices, based on its own values, respecting its own rules’¹⁶ and ‘to protect itself’¹⁷ on the development of ‘key enabling’, ‘critical’, ‘strategic’ or ‘next generation’ technologies.¹⁸ Those include, for example, artificial intelligence, semiconductors, robotics, and quantum technologies on which this white paper is focused.¹⁹ Most documents are generated by the European Commission, with few deriving from the European Parliament and other EU bodies or agencies. They primarily set out strategies for (cyber-) security, (cyber-) defence, industry, space, and data.²⁰ Of the references to quantum technologies, the most prominent are those to quantum computing; a few of these documents consider quantum communication, including encryption, key distribution and cryptography, and only one – seemingly exceptionally – mentions quantum sensing.²¹

2.2 The Digital Decade

The Digital Decade Policy Programme crystallised several general objectives for the digital transformation of the EU’s economy and society during 2020–2030, including digital sovereignty ‘in an open manner’, the promotion of a ‘human-centred, fundamental-rights-based [...] digital environment’, and the development of digital infrastructures such as high-performance, edge, cloud and quantum computing.²² Additionally, four targets are set with regard to digital infrastructures: they relate to gigabit coverage, semiconductors, edge nodes and quantum computing.²³ As regards the latter, the EU should have its first computer with quantum acceleration by 2025, ‘paving the way for the Union to be at the cutting edge of quantum capabilities by 2030.’²⁴

Leading up to the drafting and adoption of the Digital Decade Policy Programme, Member States had already expressed their positive desire for an EU-wide digital

¹⁵ See, for example, European Commission (2020).

¹⁶ *Ibid.*

¹⁷ European Council (2020).

¹⁸ See i.a. *ibid.*; European Commission (2020); COM (2020b); JOIN (2022); European External Action Service (2022).

¹⁹ European Parliamentary Research Service (2021).

²⁰ COM (2020a); COM (2020b); COM (2021a); JOIN (2020); JOIN (2023); European External Action Service (2022).

²¹ The latter can be found in a European Parliament study on the EU’s technological sovereignty. European Parliamentary Research Service (2021).

²² Article 3 Digital Decade Policy Programme.

²³ Article 4 Digital Decade Policy Programme.

²⁴ Article 4(2)(d) Digital Decade Policy Programme.

strategy carrying these characteristics. First, the Council of the EU explicitly recognised the importance of quantum technologies for technological sovereignty in June 2020.²⁵ Four months later, the European Council invited the European Commission to present a Comprehensive Digital Compass with concrete digital ambitions for 2030.²⁶ In its invitation, the European Council stated that ‘to be digitally sovereign, the EU must build a truly digital single market, reinforce its ability to define its own rules, to make autonomous technological choices, and to develop and deploy strategic digital capacities and infrastructure.’ It also pointed out the need for the EU to ‘leverage its tools and regulatory powers to help shape global rules and standards.’ In this process, it is vital to ‘safeguard our values, fundamental rights and security, and be socially balanced.’ Therefore, the EU ‘will remain open to all companies complying with European rules and standards.’ Furthermore, fostering quantum computing and enhancing cybersecurity, especially through quantum encryption, were explicitly put forth by the European Council as objectives to be advanced through EU funds.²⁷ This invitation was consequently backed by the Estonian, Finnish, Danish and German Prime Ministers, calling for the EU to take immediate actions to become digitally sovereign, including a reference to quantum computing.²⁸

Following these initiatives by Member States, the Digital Decade Policy Programme was proposed by the European Commission in 2021 and adopted in its final form in 2022.²⁹ It is a policy action seeking to ensure the conditions necessary for the competitiveness of the EU’s industry.³⁰ Although this legal basis cannot result in any harmonisation laws, it can give rise to policies of innovation, research and technological development. Most important in this context are the documents produced a year later to assess the state of the Digital Decade Policy Programme and the EU’s progress towards meeting the set digital targets.³¹ These targets are examined as part of four cardinal points: digital infrastructures, digital skills, digitisation of business and digitisation of public services. Although quantum primarily concerns the first, mentions of quantum computing are also made in relation to cybersecurity in all fields and investment in digital education and skills.³²

2.3 Other Policy and Legislative Documents

Next to the pool of primarily policy documents, two more pieces of legislation discuss quantum tech in terms of sovereignty besides the Digital Decade Policy Programme. First and foremost, the EU Chips Act is equally concerned with enhancing digital sovereignty by reducing dependencies and equipping the EU with the semiconductor technology capacities needed for research, development, and manufac-

²⁵ Point 25 Council of the European Union (2020).

²⁶ European Council (2020), point 6.

²⁷ *Ibid.*, points 7–8.

²⁸ ERR News (2021).

²⁹ COM (2021b); Digital Decade Policy Programme.

³⁰ Article 173 Treaty on the functioning of the European Union.

³¹ COM (2023); SWD (2023a-c).

³² European Quantum Flagship (2020); European Parliamentary Research Service (2021); COM (2023).

turing.³³ Among other things, the Chips Act seeks to accelerate the development of quantum chips specifically. Broadly speaking, this initiative is meant to support the quantum ecosystem by enabling start-ups, scale-ups and SMEs to access venture capital and grow their business. In particular, the EU Chips Act draws attention to actions ‘including on design libraries for quantum chips, pilot lines for building quantum chips and facilities for testing and validating quantum chips produced by the pilot lines’.³⁴ It, therefore, consists of an essential piece of legislation promoting the development of quantum technology for digital sovereignty.

In terms of legislation, a 2023 Proposal for a Regulation on solidarity and capacities for cybersecurity discusses technological sovereignty in that area and puts forth measures for stimulating co-investment between the EU and Member States in, among other things, quantum facilities.³⁵ In relation to quantum computing specifically, its promise for digital sovereignty has also been tied to the future of artificial intelligence by the preparatory work for the EU’s Artificial Intelligence Act (AI Act).³⁶ Therein, it is again expressed how quantum computing comprises an invaluable opportunity for Europe’s technological sovereignty, which can be grasped thanks to Europe’s academic strength and industry’s strong position in the field.³⁷ Without referring to scientific or other sources, the document asserts that quantum computers will ‘generate exponential increases in processing capacity’, thereby ‘allowing for the development of new AI applications across sectors.’³⁸ The AI Act itself, however, makes no mention of either digital sovereignty or quantum computing.³⁹

2.4 Funding

The 2023 report on the state of the Digital Decade praises Europe’s ranking ‘only behind China in public investment in quantum,’ with nearly EUR 7 billion combined; at the same time, the need for more coordinated efforts and private sector investment is also stressed.⁴⁰ In that regard, it is worth noting how the estimation of the total amount of combined EU and Member State funds of EUR 7 billion comes from a report by McKinsey, the US multinational consulting firm, rather than the EU’s own resources. To put this amount into perspective, one can compare it with other EU targets. When it comes to gigabit and wireless high-speed networks, the EU is investing less than its key trading partners, with EUR 23 billion in grants available

³³ Recital (2), Article (4)(2)(c) and Annex I Part V Chips Act.

³⁴ Recital (17), Article 5(c) and Annex I Part III Chips Act.

³⁵ Article 1(2) and Annex Proposal for a Regulation of the European Parliament and of the Council laying down measures to strengthen solidarity and capacities in the Union to detect, prepare for and respond to cybersecurity threats and incidents.

³⁶ European Commission (2020); SWD (2021).

³⁷ European Commission (2020), p. 4.

³⁸ Ibid.

³⁹ Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act).

⁴⁰ COM (2023), p. 13, with reference to (Masiowski et al., 2022).

for 2021–2027 in comparison to, for instance, USD 90 billion (about EUR 85 billion) foreseen in only one of the many US funding schemes.⁴¹ Similarly, the foreseen budget for semiconductors is EUR 21 billion of combined public and private investment approved under EU state aid rules.⁴² Against that background, the EU funding of quantum innovation can be considered as being still in an early stage.

Part of the quantum tech funding is reserved for the European Quantum Flagship, which comprises a large-scale research and innovation initiative with a budget of EUR 1 billion to fund projects over ten years.⁴³ Another initiative mentioned in this context is developing and deploying a European Quantum Communication Infrastructure (EuroQCI) ‘to secure the EU’s public communication assets, in particular its critical infrastructure and encryption systems, against cyber threats’, thereby boosting the European quantum ecosystem more broadly.⁴⁴

Several documents accompany the 2023 report on the state of the Digital Decade to provide further details.⁴⁵ Among other things, they explain the EU’s position vis-à-vis other countries.⁴⁶ To start with, a dedicated heading discusses digital partnerships with ‘like-minded countries’, including the US, India, and Japan, in general, and in relation to quantum technologies. Focusing on the quantum technology industry, the projected market size in the US is USD 106 billion in 2040. Whereas Big Tech companies, namely IBM, Google, Intel, and Amazon, dominate the US quantum field, the EU relies primarily on research organisations and start-ups.⁴⁷ For instance, 49% of the target contributions to research and innovation on quantum derives from the EU research funding schemes Horizon 2020 (H2020) and Horizon Europe.

Horizon Europe refers explicitly to quantum technologies as an area of intervention towards ‘reinforcing capacities and securing Europe’s sovereignty in key enabling technologies’.⁴⁸ H2020 and Horizon Europe finance the above-mentioned Quantum Flagship,⁴⁹ while Horizon Europe is also set to fund research and innovation activities under the Chips Act.⁵⁰ Two more EU funding schemes are essential in this context: the Digital Europe Programme (DEP) and the European Defence Fund (EDF), which are both similarly linked to digital sovereignty and quantum technologies. In particular, the DEP, the relevance of which had already been highlighted in prior policy documents,⁵¹ will bankroll capacity building activities under the Chips Act.⁵²

⁴¹ COM (2023), p. 8.

⁴² *Ibid.*, p. 12.

⁴³ European Commission, Press Release (2018).

⁴⁴ SWD (2023a).

⁴⁵ SWD (2023a-c).

⁴⁶ SWD (2023a).

⁴⁷ SWD (2023a).

⁴⁸ Annex I(2)(d) Regulation (EU) 2021/695.

⁴⁹ European Commission, Press Release: Quantum Technologies Flagship kicks off with first 20 projects.

⁵⁰ Article 4(3) Chips Act.

⁵¹ Tambiama Madiega – EPRS (2020); European Quantum Flagship (2020).

⁵² Article 4(3) Chips Act.

The EDF is a more targeted funding scheme in the field of (cyber) defence and is put forth as a tool to maintain a military advantage and reduce strategic dependencies.⁵³

Still, according to the Commission reports, joint investment in the form of multi-country projects and resources for start-ups and scale-ups is critical given the current unavailability of the required financing.⁵⁴ The measures suggested to bridge the investment gap are to address the supply chain risks, including the position of the EU quantum ecosystem in international value chains, set up a federated quantum infrastructure, and participate in international cooperation on quantum initiatives.⁵⁵ Additionally, several Member States ‘are also using their national Recovery and Resilience Facility plans to invest in quantum, where the overall value of planned investments between now and the end of 2026 is estimated to be of at least EUR 1 billion.’⁵⁶

Indeed, two pending proposals for a Council Implementing Decision on the approval of the assessment of the recovery and resilience plan concern Germany and France and equally directly link national and European digital sovereignty to quantum technologies. Most notably, the plan for Germany concerns investment in terms of supporting research, development and innovation on critical technologies, such as quantum communications, ‘to strengthen German and European digital and technological sovereignty’.⁵⁷ Similarly, the French recovery and resilience plan seeks to improve strategic autonomy and technological sovereignty through horizontal investments in, among others, developing a digital market in the quantum sector.⁵⁸ Besides, Germany’s leadership in investments in semiconductors, cloud and quantum is explicitly recognised as contributing ‘greatly to Europe’s technological sovereignty.’⁵⁹ More recently, a European Declaration on Quantum Technologies has been signed by, to date, no less than twenty-three Member States.⁶⁰ Therein, the Member States recognise how essential it is to collaborate in order to ‘accelerate excellence in quantum technologies and applications,’ which should, in turn, ‘ensure security and technological sovereignty’.⁶¹

However, as aforementioned, the EU itself points to external sources to quantify the funding for quantum technologies. Therefore, obtaining a comprehensive and up-to-date image of the public and private amounts invested by Member States and the EU individually and in combination to develop quantum technologies and applications currently and in the future is particularly challenging given the scarcity of available trustworthy sources.

⁵³ JOIN (2022); JOIN (2023); European External Action Service (2022).

⁵⁴ SWD (2023b).

⁵⁵ COM (2023).

⁵⁶ SWD (2023b).

⁵⁷ Proposal for a Council Implementing Decision (Germany).

⁵⁸ Proposal for a Council Implementing Decision (France).

⁵⁹ SWD (2023c).

⁶⁰ European Declaration on Quantum Technologies.

⁶¹ *Ibid.*

2.5 Concerns Around Quantum

It is worth noting that some concerns have been raised with respect to quantum technologies in these policy documents. Namely, the EU is apparently lagging behind the US and China in quantum patents, intellectual property rights in the quantum world being a ‘real matter of autonomy and “sovereignty” for Europe and European companies.’⁶² A couple of those documents also perceive the shortage of qualified professionals in the field of quantum technologies as potentially undermining the EU’s competitiveness and technological sovereignty.⁶³ The move from research to industry and market is presented as critical, albeit costly, without, however, getting into the details of budgetary requirements for such a move. A European Parliament study on key enabling technologies for digital sovereignty foresees that a quantum advantage, that is, reaching the point where quantum computers can solve problems that traditional computers cannot, is ‘well within the realm of possibility in the next few years’.⁶⁴ Yet, such an advantage is also perceived as coming with the intrinsic challenge of making ‘Quantum AI algorithms explainable.’⁶⁵ Finally, the same study speaks of science espionage as an overlooked gap in EU policy that should be further investigated and addressed through defensive policies such as foreign investment screening and export controls.⁶⁶

Broadly speaking, as mentioned in the introduction, policy-makers consider quantum technologies also to pose a threat to sovereignty, be it digital or analogue, due to their disruptive potential.⁶⁷ More specifically, the threat partly derives from the risk of cyberattacks through quantum computing breaking public key encryption. Although this potential application of quantum computing may be a matter of the far – far – future, if realised, it could even result in the decryption of data generated and stored now in the present. As such, it comprises a national security concern for governments and, according to many, the main driver behind investment in the field of quantum computing (Hoofnagle & Garfinkel, 2022; Van Daalen, 2024).

3 EU Policy and the Future

3.1 Defining Digital Sovereignty

Albeit proclaimed as a crucial objective, digital sovereignty is mainly left undefined throughout most of the policy documents. Exceptionally, two definitions have been put forth by the European Parliament and the European Commission. In a 2021 study by the former, technological sovereignty was defined ‘as the ability for Europe to

⁶² European Quantum Flagship (2024), p. 214–215.

⁶³ Ibid, p. 22, 33. Also noted by Tambiama Madiaga – EPRS (2020), p. 2.

⁶⁴ European Parliamentary Research Service (2021), p. 15.

⁶⁵ Ibid.

⁶⁶ Ibid, p. 51.

⁶⁷ Point 8 European Council (2020); European Quantum Flagship (2020), p. 91; JOIN (2022), p. 13; COM (2023), p.10; SWD (2023a), p. 41; Article 4(1) Chips Act.

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.’⁶⁸ The implementation report for the state of the Digital Decade, dated in 2023, considers digital sovereignty as referring to ‘our ability to act independently in the digital world and therefore it constitutes a crucial means to safeguard our values.’⁶⁹ As such, it covers the following elements: ‘the resilience of the Union’s digital supply chains’; ‘[t]he ability to innovate and develop digital technologies, services and infrastructures’; ‘[t]he capacity to develop secure, sovereign and accessible digital infrastructures’; ‘[a] strong manufacturing digital sector’; regulation supporting ‘the competitiveness and sustainability of the Union’s industry and economy’; and ‘broad access to global markets’.⁷⁰ In this way, the EU’s ambition for digital sovereignty seems all-encompassing and largely aligned with traditional understandings of sovereignty that centre around territorial boundaries and a state’s ability to provide for its citizens and economy.

The picture becomes more concrete with the addition of the benefits expected by the investment into quantum technologies. In particular, quantum technologies are critical ‘for the future economic development and digital self-determination of societies’,⁷¹ can ‘deliver the [necessary] breakthrough in productivity’ and enhance ‘the competitiveness of the European industry and society’.⁷² Quantum technologies can even define ‘the winners of tomorrow.’⁷³ In fact, quantum computers are expected to be ‘fully programmable and accessible from everywhere in Europe while being highly energy efficient and [...] able to solve in hours what is currently solved in hundreds of days, if not years.’⁷⁴ The foreseen possible applications include health, increased security of communications and data transfers, better monitoring of resources through sensors, and optimisation solutions for business and the environment.⁷⁵ For example, ‘[t]he use of quantum technologies will make it possible to solve societal problems that are considered simply insoluble today, whether in the development of entirely new medicines, the optimization of traffic flows or financial strategies, the development of new materials that are still unimaginable today or the use of unbreakable secure communication.’⁷⁶ In other words, quantum technologies are meant to revolutionise the world we know now.

3.2 Achieving Digital Sovereignty and (Quantum) Innovation

To harness the capabilities of quantum technologies and prepare the economy and society for their disruptive impact, scholars have advocated for a deeper engagement

⁶⁸ European Parliamentary Research Service (2021), p. 3–4.

⁶⁹ SWD (2023a), p. 31–32.

⁷⁰ Ibid.

⁷¹ European Quantum Flagship (2020), p. 6.

⁷² Tambiama Madiaga – EPRS (2020); European Parliamentary Research Service (2021).

⁷³ COM (2020a), p. 3.

⁷⁴ COM (2021b), p. 8.

⁷⁵ Ibid.

⁷⁶ European Quantum Flagship (2020), p. 6.

with the ethical, legal, social and policy implications of quantum technologies in the context of broader technology governance frameworks (Perrier, 2022; Hoofnagle & Garfinkel, 2022, Chap. 9; Kop, 2023; Gercek & Seskir, 2024). The EU digital policy can be seen as moving towards that direction.

On the one hand, the examined EU documents seem to meet certain policy standards; they ‘prioritize public funding schemes for beneficial social objectives, linked to sustainable development goals’, look to enhance international cooperation and take into account the security concerns raised by quantum technologies (Kop, 2023, p. 13). The EU policy documents, and especially the Digital Decade Policy Programme that lays down concretely how digital sovereignty is to be achieved through, among others, investment in quantum technologies, consider the multiple aspects that are crucial for enabling the development and commercialisation of quantum technologies. In particular, the range of EU policy documents is diverse and pays close attention to the need for a public/private sector approach bringing together industrial, educational and research policies (Hoofnagle & Garfinkel, 2022, pp. 376–379).

The policy approach is also, to an extent, targeting strategic dependencies which are critical for the development of key enabling technologies, through, for example, the EU Chips Act and the 2023 Commission Recommendation regarding risk assessments on four critical technology areas.⁷⁷ The former seeks to primarily tackle deficiencies and dependencies in the semiconductor supply chain, which is crucial for asserting technological sovereignty (Mans et al., 2023a, b). The funding and investment opportunities presented above are looking broadly at building capacity, reducing dependencies and enhancing EU competitiveness in quantum and other critical technologies. Moreover, the Commission Recommendation identifies advanced semiconductor, artificial intelligence, quantum and bio- technologies as presenting the most sensitive and immediate risks related to technology security and technology leakage. Because of that, the Recommendation promotes collective risk assessments in collaboration between Member States and the Commission. Such collective efforts can help enhance the multi-country project efforts brought forward by EU policy to bridge the investment gap, as discussed above. Moreover, the inclusion of quantum technologies alongside the other, more ready-to-use technologies could point to the seriousness with which European leadership is taking the quantum horizon.

On the other hand, the interdependency between the digital sovereignty of a union of states such as the EU and the development of future – or even futuristic and speculative – technologies can also raise several questions. Challenges may relate to the conceptualisation and implementation of digital sovereignty by the EU. What it means for a supranational entity to be sovereign can be called into question given its lack of statehood, the potentially conflicting national sovereignties, and the scope of its powers. While certain Member States have shown great support and even pressure towards the crystallisation of digital sovereignty as an EU ambition for the decade 2020–2030, its foundations are ambiguous. In times of political turmoil following the 2024 European elections, the ubiquity and unitedness of European values that digital sovereignty is firmly attached to might equally prove questionable. Even more so, in

⁷⁷ Commission Recommendation of 3.10.2023 on critical technology areas for the EU’s economic security for further risk assessment with Member States, C(2023) 6689 final.

the European quantum ecosystem, different values may be promoted or prioritised by different stakeholders, while they also run the risk of being narrowly framed through the market or economic security lens (Purohit et al., 2024; Shelley-Egan & Vermaas, 2024).

Furthermore, there are inherent tensions between sovereignty and the digital as well as the means employed by digital sovereignty and strategic autonomy discourse and the purported ends of innovation. Digitisation poses unique, well-known challenges to territoriality, on which sovereignty claims are traditionally based. Besides the borderless nature of the internet and data, the infrastructure and (raw) materials on which the development and deployment of technologies rely are commonly spread across the globe. What is the relationship then between digital sovereignty and strategic autonomy on the one part and innovation on the other? Are the policies deriving from the former appropriate to achieve the latter? Even more so, how can digital sovereignty be achieved ‘in an open manner’ in accordance with the Digital Decade Policy Programme; what implications does that entail for developing and deploying quantum technologies in a globalised world, taking into account the current insufficiency of the required financing and resources? As explained above, the EU’s proposed measures to bridge the investment gap include addressing the supply chain risks and participating in international cooperation on, among others, quantum initiatives.⁷⁸ In concrete terms, however, this often translates to stricter measures such as export controls and foreign direct investment screenings. These measures are often considered exclusionary rather than ‘open’ (i.a. Broeders et al., 2023; Shelley-Egan & Vermaas, 2024).

The challenges behind such closed policies that are linked to tech sovereignty ambitions more broadly, and the European Commission’s approach to quantum innovation governance, in particular, are often discussed in terms of technological protectionism (Shelley-Egan & Vermaas, 2024; Lee et al., 2024).⁷⁹ The risk is posed that these measures might actually go against the goal of innovation promoted by digital sovereignty or even be unrealistic in light of the existing material dependencies. Semiconductors and quantum technologies, particularly, are thought to exist in global innovation networks that are too complexly connected for one country or union of countries alone to develop in isolation (Lee et al., 2024). Especially for quantum technologies that are still largely in the research and development phase, shrouded by uncertainty regarding, among others, the components, devices and equipment for the physical implementation of different types of qubit systems (Nguyen, 2025 forthcoming), closed policies risk path dependencies and stifling innovation (Lee et al., 2024).

Another crucial element to consider is that the claims regarding the revolutionary impact of future quantum technology applications are not supported by concrete scientific or other evidence in the examined policy documents. Of course, scientific advancements in quantum tech are real, as is their promise to an extent; however,

⁷⁸COM (2023).

⁷⁹Technological protectionism refers to the adoption of specific measures restricting international knowledge exchanges to promote the development of domestic research and manufacturing capabilities. It is, therefore, linked to the notion of digital sovereignty (Shelley-Egan & Vermaas, 2024).

how real they are is not substantiated in these policy documents themselves. It is up to the reader to figure out if they wish. This lack of a fact- and science-based discussion of quantum capabilities and the appropriate mechanisms for controlling them could undermine the reliability of and trust in EU policy. Trust-building requires a clear framing of the risks and benefits associated with quantum technologies as well as public dialogue and consensus-building processes that include a variety of stakeholders beyond those directly involved in the development and deployment of the technologies (Purohit et al., 2024). Without properly demonstrating and justifying such unconditional faith in the forthcoming revolutionary consequences brought by quantum technologies, policy-makers might fall short of building the required trust and public consensus.

The lack of concrete evidence or even scenarios about the impact of quantum technologies is even more surprising when seen in contraposition to the other three technology areas identified by the aforementioned Commission Recommendation.⁸⁰ Whereas advanced semiconductors, artificial intelligence and biotechnologies undoubtedly have a major transformative potential for digital sovereignty, economy and society at large, the Commission Recommendation acknowledges how ‘[t]he full impact of quantum technologies that are being/will be developed cannot yet be fully qualified’. Such an admission begs the question of why quantum is included in those technology areas where heightened attention should be placed.

Finally, among the quantum technologies, quantum sensing has the potential for both beneficial and dangerous uses and is considered the most mature of quantum technologies, with some sensors already in the market (Hoofnagle & Garfinkel, 2022). Yet, quantum sensing remains largely ignored in these documents. Instead, most emphasis is placed on quantum computers, which are not expected to reach a game-changing status in the imminent future, according to the state of the art (Purohit et al., 2024). This choice raises questions regarding the prioritization of quantum computing investments by EU policy-makers.

4 Concluding Remarks and Open Questions

The EU has produced at least 30 documents during the past 3,5 years highlighting the interdependency between achieving digital sovereignty and developing quantum technologies,⁸¹ while at least EUR 7 billion of EU money has been publicly announced as being attached to realising this aim. Among others, the deriving EU policies concern strategies for the civil, defence and space industries, as well as cyber defence and security. Most significantly, the Digital Decade Policy Programme adopted in 2022 defines digital sovereignty as one of the core EU objectives and, to that end, sets specific targets regarding quantum computing. This interrelation is supported by regulatory frameworks concerning the direction of funding towards the development of quantum technologies, mainly through academia as well as start-ups

⁸⁰ Commission Recommendation of 3.10.2023 on critical technology areas for the EU’s economic security for further risk assessment with Member States, C(2023) 6689 final.

⁸¹ That being a minimum selection of documents from the EU repository, see Sect. 2.1.

and scale-ups. Yet, quantum technologies are also feared as a threat to sovereignty due to their disruptive potential.

Besides the EU, attaching the pursuit of sovereignty in the digital domain to capabilities acquired through the development and deployment of quantum technologies can also be observed at a global scale (Hussin, 2024; Kumar & Das, 2024; Wilkinson et al., 2023). It, therefore, demands further attention. This white paper raised several concerns relating to this policy and governance approach, particularly relating to the questionable alignment between digital sovereignty, the scientific reality of quantum technologies and the pursued economic and societal goals.

In light of these complexities, what future the EU envisages through this complementarity and to what extent this future is realisable and desirable for those affected by it should be further questioned and explored. More specifically, researchers and policy-makers are invited to consider, first, how the EU can actualise its digital sovereignty aspirations, taking into account its supranational nature and the various normative and value-laden challenges underlying the concept of sovereignty as such. The second and related issue concerns the compatibility between digital sovereignty, innovation, and societal welfare. The examined EU policy documents present an interdependence between them: accordingly, digital sovereignty not only depends on but also is a means for innovation in critical technologies, including quantum. At the same time, EU values and economic and societal prosperity underpin digital sovereignty. Does one follow from the other, however? In other words, is digital sovereignty the way to (quantum) innovation and is (quantum) innovation the way to economic and societal welfare? In prioritising quantum technologies as a technology area that is critical for digital sovereignty, particular emphasis should also be placed on how to clearly substantiate the quantum revolution for those potentially affected by it, such as the EU citizens as well as those impacted by digital sovereignty measures such as export controls. What are the odds for its materialisation and the possible realistic scenarios to get there, in light of the current uncertain nature of quantum innovation?

Annex: List of Documents

Chips Act, Regulation (EU) 2023/1781 of the European Parliament and of the Council of 13 September 2023 establishing a framework of measures for strengthening Europe's semiconductor ecosystem and amending Regulation (EU) 2021/694 (Chips Act), OJ L 229, 18.9.2023, p. 1–53.

COM (2020a), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A European strategy for data, 19.2.2020, COM/2020/66 final.

COM (2020b), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A New Industrial Strategy for Europe, 10.3.2020, COM/2020/102 final.

COM (2021a), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee

- of the Regions, Action Plan on synergies between civil, defence and space industries, 22.2.2021, COM/2021/70 final.
- COM (2021b), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 2030 Digital Compass: the European way for the Digital Decade, 9.3.2021, COM(2021) 118 final.
- COM (2023), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Report on the state of the Digital Decade 2023, 27.9.2023, COM/2023/570 final.
- Council of the European Union (2020), Council conclusions on shaping Europe's digital future, OJ C 202/1, 16.6.2020, p. 1–12.
- Council Regulation (EU) 2021/1173 of 13 July 2021 on establishing the European High Performance Computing Joint Undertaking and repealing Regulation (EU) 2018/1488, OJ L 256, 19.7.2021, p. 3–51.
- Digital Decade Policy Programme, Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme 2030 (Digital Decade Policy Programme), OJ L 323, 19.12.2022, p. 4–26.
- Declaration on Digital Rights and Principles, European Parliament, Council and European Commission, European Declaration on Digital Rights and Principles for the Digital Decade 2023/C 23/01, OJ C 23, 23.1.2023, p. 1–7.
- European Commission (2020), White paper on Artificial Intelligence – A European approach to excellence and trust, 19.2.2020, COM(2020) 65 final.
- European Council (2020), Special meeting of the European Council (1 and 2 October 2020) – Conclusions, 2 October 2020, EUCO 13/20, CO EUR 10, CONCL 6.
- European External Action Service (2022), A strategic compass for Security and Defence: For a European Union that protects its citizens, values and interests and contributes to international peace and security, March 2022.
- European Parliamentary Research Service (2021), Key enabling technologies for Europe's technological sovereignty, Study Panel for the Future of Science and Technology, Scientific Foresight Unit (STOA), PE 697.184, December 2021.
- European Quantum Flagship (2020), Strategic research agenda, February 2020.
- European Quantum Flagship (2024), Strategic Research and Industry Agenda, February 2024.
- JOIN (2020), European Commission, Joint Communication to the European Parliament and the Council, The EU's Cybersecurity Strategy for the Digital Decade, 16.12.2020, JOIN/2020/18 final.
- JOIN (2022), European Commission, Joint Communication to the European Parliament and the Council, EU Policy on Cyber Defence, 10.11.2022, JOIN/2022/49 final.
- JOIN (2023), European Commission, Joint Communication to the European Parliament and the Council, European Union Space Strategy for Security and Defence, 10.3.2023, JOIN/2023/9 final.
- Opinion of the European Economic and Social Committee (2023), Opinion of the European Economic and Social Committee on Digital Sovereignty: a crucial

- pillar for EU's digitalisation and growth (own-initiative opinion), OJ C 75, 28.2.2023, p. 8–12.
- Proposal for a Council Implementing Decision (Germany), Proposal for a Council Implementing Decision on the approval of the assessment of the recovery and resilience plan for Germany, COM/2021/341 final.
- Proposal for a Council Implementing Decision (France), Proposal for a Council Implementing Decision amending Implementing Decision (EU) (ST 10162 2021 INIT; ST 10162 2021 ADD 1) of 6 July 2021 on the approval of the assessment of the recovery and resilience plan for France, COM/2023/374 final.
- Proposal for a Regulation of the European Parliament and of the Council laying down measures to strengthen solidarity and capacities in the Union to detect, prepare for and respond to cybersecurity threats and incidents, COM/2023/209 final.
- Regulation (EU) 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013, OJ L 170, 12.5.2021, p. 1–68.
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- SWD (2023a), Commission Staff Working Document, Implementation of the Digital Decade objectives and the Digital Rights and Principles Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Report on the state of the Digital Decade 2023, 27.9.2023, SWD/2023/570 final.
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Declarations

Ethical Approval No ethics approval was required for the research conducted.

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