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ORIGINAL PAPER

European Digital Sovereignty: A Layered Approach

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Abstract

The paper uses a stack model to come to an estimation of the EU's digital capacities on the global stage. Digital capacities are hard to measure and involve a wide variety of technologies ranging from semiconductors and network infrastructure to artificial intelligence and Internet of Things-devices. By adopting Benjamin Bratton's speculative work on the stack as the contemporary organizing principle of sovereignty, this paper presents a layered approach to digital technology and then assesses the EU's capacities across those layers. It aims to provide a framework to discern connections across different digital technologies and reason about required policies to achieve the EU's goal of digital sovereignty.

Keywords Technology stack · Digital technology · Geopolitics · Digital Sovereignty · Strategic Autonomy

1 Introduction

In order to describe the position of the European Union on the world stage, the former Belgian Minister of Foreign Affairs Eyskens famously said that it is "an economic giant, a political dwarf and a military worm." That still seems like an adequate description, although the war in Ukraine is leading to changes that cannot yet be foreseen. In this paper, we will also look at the EU's position on the global stage, but what we will address here is the question: What kind of entity is it in the digital domain? Is it closer to a giant like it is in the economic sphere or closer to the worm it is in the military domain? At first sight, arguments for both perspectives can be set up plausibly. On the one hand, the EU has a huge technology sector, and its internet coverage is among the broadest and fastest in the world. On the other hand, however, we can point to the complete absence of EU firms in the ranks of Big Tech. How to weigh such disparate observations?

We can look at some global rankings of digitalization. In terms of digital competitiveness in 2021, a ranking compiled by the IMD World Competitiveness Center, several

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European countries rank in the top: Sweden (3), Denmark (4), and the Netherlands (7) are in the global top ten. In Cisco's Global Digital Readiness Index, Western European countries are in the most advanced category. In 2016, the World Bank created a Digital Adoption Index that paints a similar picture. Next to these, there are different innovation indices or rankings for specific digital technologies like the Oxford AI Readiness Index. The European Union also introduced the International Digital Economy and Society Index (I-DESI) that looks at five dimensions of digitalization. Its focus is on digital capacities and it shows EU countries performing well on connectivity and skills and less well on digital public services (European Commission, International Digital Economy and Society Index, 2020). The focus on capacities however, does not bring to light dependencies on the services of foreign businesses. Recently, the Konrad Adenauer Stiftung developed an interesting index for Global Digital Dependence Structure that we will come back to later.

The problem with all of these indices is that they look at different aspects of the digital domain and it is unclear how these relate to each other or how to construct a coherent picture from them of the position of a country or a bloc like the EU.

These data thus do not paint a clear and unambiguous picture. This of course has to do with the complexity and diversity of the digital domain. It involves chips and semiconductors, telecommunication networks, social media platforms, e-commerce companies, cloud computing, and supercomputing facilities and much more. How to bring all these aspects together?

A country's economy is also extremely complex and diverse. There however, we have come to certain metrics that simplify economic activity. There, the use of general domestic product (GDP) serves well as a metric for all kinds of practical purposes and it gives us a method to make comparisons. At the same time, there is also a lot of criticism of this metric itself and also of the way in which it simplifies and obscures important aspects of economic activity, leading scholars to introduce alternative measures of economic complexity for instance (Balland et al., 2022).

At the moment, there seems to be nothing similar for the digital domain. What all the different metrics and estimations make clear is that the digital domain consists of many diverse aspects. The difficulties with the metric of GDP also suggest that bringing all of these aspects of digitalization together in a single metric, might not be the best way forward. As a result, it seems sensible to alternatively try to develop a framework that maps that diversity in a coherent way. Can we discern some kind of organization within the vast and diverse world of digitalization?

Much more is at stake than just the development of another metric. Not only is digitalization identified as key to economic competitiveness, but its geopolitical relevance is also increasingly emphasized. In 2017, Vladimir Putin stated in a lecture that the country that leads in artificial intelligence will be the country that dominates the world. In China, the government speaks of "cyber sovereignty." Since 2015, the "Digital Silk Road" has been a component of the Belt and Road Initiative, President Xi Jinping's signature foreign policy effort. In India, politicians and opinion makers speak of a form of "digital colonialism" and they compare Big Tech firms to the British East India Company.

Also within the EU, the geopolitical relevance of digital technology is becoming increasingly clear. During the Trump administration, French and German politicians started talking about strategic autonomy. Since then, the term has been used extensively by policymakers in Brussels. There is much confusion about the meaning of the term and often people connect it with guarding European sovereignty. We can understand sovereignty as the goal of policy and autonomy as the means to that goal (Timmers, 2021). We will define strategic autonomy here as "the capabilities, capacities, and controls necessary to decide and act on one's long-term economic, societal, and democratic future" (Timmers, 2022).

Increasingly, digital technologies have become part of the focus on strategic autonomy and EU officials often speak of digital sovereignty. Charles Michel, President of the European Council, has said that digital sovereignty plays a pivotal role in the greater goal of strategic autonomy. A briefing of the European Parliamentary Research Service provides a definition of digital sovereignty that we will follow here: "Europe's ability to act independently in the digital world," which involves "both protective mechanisms and offensive tools to foster digital innovation" (EPRS, 2020).

Although the connection between digital technology and sovereignty is increasingly made across the globe, it is important to emphasize the great diversity in concepts and policies. In contrast with the EU's focus on digital sovereignty, Russian and Chinese concepts are used to propagate a model of national internet governance with strong government control and surveillance. The 2019 amendments informally called Russia's "sovereign internet law" mandates internet surveillance. Moreover, seemingly technical efforts by these countries to bring governance of the internet under UN bodies like the International Telecommunications Union (ITU) mask their intentions of controlling the internet (Rühlig, 2020).

Another point that has to be made about the growing connection between digitalization and sovereignty is that although grand concepts like dominance and colonialism are used, often little is said about how this actually works in practice. Perhaps it is too early to tell and we will come back to this issue later. For our purposes here, an interesting hint is provided by the literature on weaponized interdependence. Farrell and Newman have shown how the networked character of digital technology with its hubs and spokes provides governments with ways to pressure other countries. In particular they focus on the use of the SWIFT communication system and the telecommunications infrastructure of the internet. They discern a panopticon effect and a chokepoint effect through which other countries can be monitored and pressured respectively (Farrell & Newman, 2019). In a paper written for the thinktank CSIS, Hillman describes the ways in which infrastructure provides ways to influence other countries in different parts of the process from financing to design, construction, ownership, and operation. He also emphasizes the ability to gather information as well as to deny access as ways to impact the ability to act of other countries (Hillman, 2019).

In other words, it is clear that digitalization is not just about competitiveness, but also effects sovereignty in several ways, which drives the EU's goal of digital sovereignty insert reference Ringhof, Torreblance here (Ringhof & Torreblance, 2022). In order to understand how that goal can be achieved, we need a way to organize our thinking about the digital sphere to estimate what needs to be done in order to achieve some form of digital sovereignty. The EU is engaging in a range of policies to strengthen its digital capacities. These include the Chips Act and an integrated AI Strategy as well as all kinds of regulation like the proposed AI Act, the DMA, the

DSA, and the earlier GDPR. How do such policies contribute to the broad goal of digital sovereignty? Are there aspects of the digital domain missing? How do these policies fit together?

Above, we mentioned an index that researchers from the Konrad Adenauer Stiftung recently published that fits in with the concern for digital sovereignty. This index measures the extent to which countries are dependent on foreign actors for the three areas of hardware, software, and intellectual property. This index goes a long way toward creating a single index that measures how sovereign countries are in the digital domain and we will come to several similar conclusions as this important new analysis (Mayer & Lu, 2022). Our approach differs in two important ways. First of all, the index measures dependence, whereas our focus here is on capacities. Although these often overlap, a country might be dependent on foreign actors for elements of technology, because of the strongly globalized economy, while still having leading companies in that technology ecosystem. Our interest in capacities will emphasize those technology leaders and will thus paint a more orderly picture of the technology landscape. Secondly, as we will see now, our approach here also aims to present something of an architecture of the digital world.

In this article, I want to propose the “stack” as a model to bring structure to the digital world. The model is a way to come to a coherent estimation of the EU’s digital position and a tool to think about the EU’s policies to strengthen its digital sovereignty.

In the world of digital technologies, it is common to speak of technology stacks. These are combinations of technologies that together provide a product or service. It thus can refer to the different technologies that together create a certain software solution, but also a product like a mobile phone can be described in this way. Specific about stacks is their vertical and layered character. For a mobile phone to operate, engineers will for instance distinguish the chip layer, the network layer, the software layer, application layer, and the interface layer. These are stacked on top of each other to make the device work.

In a provocative and speculative work of political theory, Benjamin Bratton has argued that stacks are more than just a way to produce digital products. He argues that it represents the “model for the design of political geography tuned to this era of planetary-scale computation” (Bratton, 2016). Computation has the nature of a global stack consisting of different layers. In other words, not just products or digital services, but digital technology in general has the nature of a stack.

Furthermore, what it relevant about Bratton’s work is that he connects this view on digital technology with geopolitics and the issue of sovereignty. Indeed, the full title of the book is *The Stack: On Software and Sovereignty*. For this analysis, he builds on the work of the twentieth century German political thinker Carl Schmitt who spoke of “the nomos of the earth.” Nomos was the ancient Greek word for “the first measure of all subsequent measures” (Bratton, 25). With nomos, Schmitt refers to the principle behind and underlying all forms of legal, social and economic order. It is constituted by appropriation, distribution, and production. A nomos opens up a space, mental representations of it and this way lays the basis for all forms of order. Land-appropriation is for Schmitt the “archetype of a constitutive legal process,” it opens up legal space as such. Schmitt points out how the German words for place (*Ort*), orientation (*Ortung*), and order (*Ordnung*) and etymologically connected (Han, 2019).

According to Schmitt, a fundamental change in the nomos of the earth occurred with Columbus and the era of discovery. It opened up new lands and seas that entered collective consciousness, altered the space of human existence and also brought with it new power relations (Schmitt, 2011). Specifically, he describes this as a spatial revolution focused on the maritime domain. Although skeptical of the non-terrestrial nature of that domain and the concomitant difficulty to establish order on the seas, he traces how England reoriented itself as a maritime power and that way became globally dominant. Whereas land powers focused on control of territory, maritime power is about access, trade routes and chokepoints. Schmitt quotes Sir Walter Raleigh: "Who controls the sea, controls the trade of the world, and who controls the trade of the world, holds all treasures of the world, indeed the world itself" (Schmitt, 2008). Schmitt traces the breakdown of the European-led world order through the American Monroe Doctrine and the emergence of what he calls separate large spaces (*Grossraum*). At the end of his work *Land und Meer*, where he contrasts terrestrial and maritime order, he speculates on a new nomos of the earth, an emerging spatial revolution. Referring to airplanes and the radio, he first points to the element of air, but the combustion engine leads him to identify fire as the new element organizing human activity (Schmitt, 2008).

The interesting question for us here is what digital technology implies for the idea of the nomos of the earth. The philosopher Byung Chul-Han has suggested that based on Schmitt's work we can discern "digital land-appropriation, a digital reclamation of land" (Han, 2019). The above-mentioned link between digital technology and sovereignty also provides hints for such a perspective. Already in 1988, Shen Weiguang, a Chinese official in the field of information warfare stated: "Countries with advanced networking technology rely on networks to expand their 'information territory' to many other countries and threaten the latter's 'information sovereignty'" (Hillman, 2021). We also saw how the digital system SWIFT is a chokepoint through which the USA can block other countries from global trade. In a variation of Sir Walter Raleigh we might say: Who controls digital technology, controls the trade of the world, and who controls the trade of the world, holds all treasures of the world, indeed the world itself.

If this is the case, the question then arises what the nature is of the spatial revolution caused by digital technology. According to Benjamin Bratton, the stack represents the new nomos of the earth. It also opens up new spaces, transforms human existence, its representation, and the global order. Bratton explains the stack by contrasting it with the global order since the Peace of Westphalia (1648), the treaty that codified the modern sovereign state system. The order of Westphalia was horizontal. It divided the world into adjacent areas on a map. Strict borders decided the sovereignty of states and guaranteed their independence. Crucial about the stack is that it is organized vertically, as we have seen. This means that it puts pressure on the fundamental organizing principle of the modern era, the modern state. The new vertical spaces of underseas cables, cloud infrastructures and internet addresses are not placed horizontally, but bring a different architecture that undermines classical sovereignty. The new geopolitical faultlines in the world are about the power of large technology platforms and Bratton even speaks of the first "Sino-Google war."

Bratton is not the only author who identifies verticality as discerning feature of digital technology. In 2021, Abishur Prakash published *The World is Vertical: How Technology is remaking Globalization*. Prakash's concept of verticality not only deals with technology however, but also with economic principles that we will not discuss here. José van Dijck analyzes platforms by conceptualizing them as trees characterized by hierarchy and vertical integration (Van Dijck, 2020). In *The Fourth Revolution*, Luciano Floridi also uses a vertical spatial metaphor for digital technology. He argues that we live on the piano nobile, the central top floor of a Renaissance that is visible to others. Underneath that room, there are hidden chambers in which the servants work, in our case the digital servants (Floridi, 2016).

Benjamin Bratton's book is a creative work that draws on diverse sources. Here, we will follow his suggestion of discerning layers of the global stack. At the same time, we will not follow him in the identification of the specific layers. His more speculative philosophical approach discerns the following layers: Earth, cloud, city, address, interface, and user. Our interest here is in understanding the digital capacities of the EU, so the layers we will distinguish will be closer to more common industry distinctions and it will for instance not include the city or the user in the stack, as Bratton does. Table 1 lists the layers of the stack that we will discern here.

In the course of this paper, we will discuss the seven distinguished layers of the global digital stack. We will look at the major players within each layer and in particular describe the position of the European Union. It will become clear that that the capacities of the EU differ widely throughout the different layers. Whereas the EU is actually a relatively strong player in the chips and network layer, it is much weaker in the intelligence and applications layer and virtually non-existent in the cloud layer. Based on these different capacities across layers, different policy responses are required. In the final section, we will compare these capacities and required policy responses with the current EU policy and provide some recommendations for future policy. Also, we will argue that this layered Stack-model is a tool to bring more order and coherence in the different digital policies of the EU by developing a full-stack approach. Finally, we will make some comments on the implications for European sovereignty and identify three specifically European dilemmas in achieving digital sovereignty.

Before we start with discussing these different layers to discern the EU's capacities, two comments need to be made. First of all, the layers represent complex dynamics and supply-chains. In this brief space here, we can only paint an overall

Table 1 Layers of the global stack

The global digital technology stack
The resource layer
The chips layer
The network layer
The cloud layer
The intelligence layer
The applications layer
The connected device layer

picture of the dynamics on a certain layer, but for a more comprehensive account more research is needed.

Secondly, the distinction in different vertical layers is meant as an analytical tool that maps dynamics in the digital world. In digital products, they come together and specific capacities that we describe in one layer often overlap with those in others. Several American companies for instance are leading in the cloud layer, but the cloud services they provide often involve artificial intelligence, which is the next layer. It is however, still valuable to distinguish them as separate layers, because the dynamics of capacities for developing cloud services and artificial intelligence are quite different, as we will show.

2 The Resource Layer

The first layer is the most basic layer of the global digital stack and represents its natural building blocks. Benjamin Bratton refers to this as the Earth layer. We will here speak of the (natural) resource layer. Before any digital machine can operate, it needs specific materials in order to operate. Every technology requires specific natural resources. Coal drove the Industrial Revolution and oil was the crucial input of the era of mass production and the automobile. Similarly, digital technologies require specific resources. Apart from traditional energy, certain metals are especially important. The lightweight metal lithium is a critical input for the batteries of many electronic devices like mobile phones and laptops. Another important metal is cobalt, which is important as the cathode material used in lithium-ion batteries.

A very important class of metals that is crucial as resource for digital technology is the category of so-called rare earth metals. These are not called rare because they cannot be found in many places. Many are actually present throughout the earth's crust. They are called rare because their concentration in the earth is low, which means that their extraction is difficult and costly. There are many rare earth metals, but some of the most important ones are neodymium, europium, terbium and dysprosium.

What does the global landscape look like on the resource layer? A clear picture emerges of Chinese dominance. The two largest producers of lithium are Chile and Australia, but also Bolivia and Argentina are important producers. Notable however, is that the two largest lithium mining companies are Chinese, Jiangxi Ganfeng Lithium and Tianqi Lithium. With regard to cobalt, the Democratic Republic of Congo (DRC) has over 50% of the world's proven reserves and is also the largest producer of cobalt. China is a large investor in the mining sector of the DRC. Globally, Chinese companies control nearly half of all production of refined cobalt (Finish Institute of International Affair, 2021).

China is however most dominant when it comes to rare earth metals. In 2021, the country was responsible for 60% of global production of these resources, a figure that several years ago was as high as 95%. Former Chinese leader Deng Xiaoping once called rare earth metals "for China what oil is for Saudi Arabia." China's dominance in this market has led to responses from other countries, which has led to its decline in global market share. Moreover, the country has earlier shown its willingness to use its market power for geopolitical rivalry. During the trade dispute between China and Japan in 2010, the country blocked the export of certain metals like tungsten which immediately had repercussions for the Japanese and American electronics and se

curity industries. As a result of the dispute, investments in rare earth metal production around the world have gone up, especially in the USA, but China remains the dominant player.

Where does the EU stand in the resource layer of the stack? Although European countries like Poland and Germany have large reserves, their share in global production is small. Over the years, European countries have been phasing out their mining industries as a result of social and environmental concerns. This has currently left them dependent on foreign actors and this could lead to a clash between strategic concerns on the one hand and social and environmental concerns on the other (Pitron, 2020). The EU has developed certain policies for its dependence and for instance developed the European Raw Materials Alliance (ERMA). It monitors and develops strategies for the increasing number of critical rare earth metals. In 2020, the European Commission adopted a Critical Raw Materials Action Plan and subsequently developed a strategic partnership with Canada in this field (Finish Institute of International Affair, 2021).

3 The Chips Layer

Let us next consider the layer of chips or semiconductors. This layer involves very complex supply-chains and there is also a wide variety of types of chips from more generic to highly specialized. We will first look at some general industry trends.

The development of chips is a process that consists of chip design, the creation of semiconductor manufacturing inputs and semiconductor fabrication (Allison et al., 2021). The USA is still the leading country in the first two fields. It has however steadily been losing ground in the field of fabrication. Its share of global production declined from 37% in 1990 to 12% in 2021.

Whereas China in 1990 was responsible for only 1% of global semiconductor manufacturing, it currently surpasses the USA with a 15% share. The Semiconductor Industry Association projects that over the next decade, China will develop 40% of new global capacity and become the world's largest semiconductor manufacturer with 24% market share (Semiconductor Industry Association 2021). Moreover, while until recently mostly producing low-end chips, leading Chinese companies are now producing more advanced chips. Its flagship Semiconductor Manufacturing International Corporation (SMIC) ranks among the top 5 foundries in the world and rivals the American champion Intel. Huawei's subsidiary HiSilicon became the first Chinese company to reach the top ten list of semiconductor companies.

Next to the USA and China, other Asian countries are also important producers of chips. From 1990 to 2021, Japan's share declined slightly from 17 to 15%. The share of South Korea increased from 13 to 21%. Important to note here is Taiwan. Its company TSMC is an absolute world leader in the production of advanced chips.

These other Asian countries are crucial in USA strategy that seeks to build chips supply chains that cut out China by cooperating more with Japan, South Korea, and Taiwan (Business Standard, 2022). Apart from other geopolitical considerations on maritime access and history, the chips industry is also an important dimension of China's claim to the island nation. Former U.S. Deputy Secretary of Defense and co-chair of the National Security Commission on Artificial Intelligence Robert Work stated it succinctly: "We're 110 miles away from going from two generations ahead to maybe two generations behind." The distance of 110 mi refers to the Taiwan Strait. If China were to cross the strait and take control of Taiwan's semiconductor production, the country would in one stroke become a leader in parts of the technology that would leave the USA far behind.

Where does the EU stand on the chips layer? Its share has also declined rapidly over the decades. Whereas in 1990, it was responsible for 24% of global production, just behind the USA, it currently ranks 6th by producing 9%. The EU does have companies that are central to global production like the Dutch ASML that is a leader in the production of machines that produce chips.

As a result of this declining market share and the concerns over digital sovereignty, the European Commission unveiled the EU Chips Act in February 2022. Its goal is to reinforce the semiconductor ecosystem in the EU, ensuring the resilience of supply chains and reducing external dependencies. It has the specific target of doubling the EU share in production to 20% over the next decade. In order to do that the Act focuses on the strategic objectives of strengthening fundamental research, building production capacity, developing a framework to increase production, addressing shortages in skills and talent, and developing an in-depth understanding of global semiconductor supply chains.

It is still unclear whether the EU approach will succeed. An early success seems to be the announcement of a large factory of the American firm Intel that is to be built in Germany. What we can conclude about this layer of the digital stack is that the EU's share in the chips industry has been declining, but that it still is a considerable producer of chips. This is not a layer of the stack where the EU is absent from the world stage. As a result, it has strong capacities it can build on.

4 The Network Layer

We will next consider the network layer. This layer is about the infrastructure for the connectivity of digital technology. This infrastructure consists of different elements. First, it consists of telecommunications networks in the ground for cable and wireless networks. These are often rolled out in cities, regions or nation-wide telecommunications programs. Another important element of international connectivity consists of underseas internet cables. A final element of the connectivity infrastructure that we will consider is satellite technology.

Let us first look at telecommunications networks. The key issue in this part of the connectivity infrastructure is the rollout of the next generation of 5G networks that promise to increase internet speed a 100-fold, but also to improve the reliability of networks. The global geopolitical battle over this layer of the digital stack has gotten much attention with concerns over infrastructure laid by the Chinese company Huawei. Over the years, it has become a leading player in the development of telecommunications infrastructure around the world and also in many western countries. Under the Trump administration, concern increased over not only the economic effects, but particularly over the security issues of telecommunications infrastructure developed by this Chinese company. This involved the potential for surveillance but also of blocking communication in case of conflict. In May 2019, President Trump made an executive decision to blacklist Huawei (Hussein, 2019) and in speeches stated the explicit goal of "killing Huawei." The US policy did hurt the company's business and has led many European countries to also ban the company entirely or from the more advanced parts of their telecommunications networks. Globally however, it remains a strong company and most importantly, it does have cutting-edge technology.

The rollout of a new generation of network technology is very complex and historically it has been key in this field which countries were first to develop the technology and its standards. European firms for instance spearheaded the rollout of 3G networks. With 4G, US firms set the standards. With 5G, American pressure notwithstanding, it might still be Chinese firms. The country is currently by far the largest builders of the new generation of networks. In 2020, 87% of all global 5G networks were in China (Hillman, 2021). The USA and Europe are far behind. Whereas in 2020, China had 150 million 5G users, the USA had only 6 million. While the American companies Lucent and Motorola had a 25% market share in telecommunications in 2000, they now disappeared from the list of largest networks companies. No US company is in the top 5 of global companies in this field, whereas two are Chinese. In 20 years, Huawei's share has gone up from 0 to 28%, making it the global leader. The company also leads in 5G patent families granted by US and European patent offices (Allison et al., 2021).

The political decision to ban Huawei might thus slow its global reach somewhat, but Chinese companies remain at the forefront of building 5G-networks, which also gives the country an edge in developing the technology solutions that this new generation of network technology makes possible. The increase in speed and reliability from 3 to 4G made smartphone use, video streaming, and the first virtual-reality applications possible. 5G will probably also facilitate new sets of applications like smart cities, autonomous vehicles, precision medicine, fields that Chinese companies are well positioned for to lead in.

There is one trend in the industry that might tip the balance away from China: ORAN (Open Radio Access Network). With current network technology there is a high level of integration of infrastructure, which gives an advantage to companies that can provide all the required technology. ORAN is a new type of architecture that makes telecommunication infrastructure much more modular. This means different companies can more easily provide different parts of the infrastructure. The advantage of leading companies like Huawei that can provide entire infrastructures might thus be weakened. However, ORAN is still in its infancy and many experts believe it will not come soon enough for the rollout of 5G (Hillman, 2021).

Where does the EU stand in terms of telecommunications infrastructure? Its position is actually quite strong, which surprisingly is not often discussed in the debate over

5G. In the controversy surrounding Huawei for instance, the suggestion was often made that the USA wanted a ban to help American companies like Cisco (Benner, 2021). As we have seen however, the USA no longer has leading companies in this field. Huawei's two main competitors are the European firms Nokia and Ericsson, formerly large producers of mobile phones. Currently, Huawei does have a technology lead over these firms and its services are often cheaper. But these two European firms are still large players in the market and provide competitive services. As a result, one might expect more EU policy to strengthen the position of these firms. There is a fierce debate in the EU over protecting industry champions and some have even suggested that if these firms were German or French instead of Scandinavian, there would already have been more policy to support them (Benner, 2021). Whatever the causes, in the battle over sovereignty over the digital Stack, telecommunications technology is actually a field in which the EU is strongly positioned to build its own technology.

To connect regions globally, another element of network infrastructure are undersea (submarine) internet cables. These are important to consider because a finite number of cables are central to connect internet traffic of different parts of the world. Problems with these cables have already led to connectivity issues in 2008 and 2011 for instance and in geopolitical analysis, the cutting of such cables is considered as a serious threat. Moreover, countries that sit along crucial cables or that create new connections are in a position to forge alliances globally.

Among the top makers of undersea cables are companies from Japan like Fujitsu Limited and NEC Corporation and several US firms like Infinera Corporation, TE Subcom, and Xtera Corporation. Notable here is also the rise of Chinese players. In 1994, the first cable laid by a US firm connected China to the internet. Currently, the country is responsible for 15% of global submarine cable development. Chinese companies in this field are Huawei Marine Networks and S.B. Submarine Systems. What is notable about Chinese projects is that they are working on creating new links between continents, between Asia and Africa, between Asia and Latin America, and between Latin America and Africa. Often these projects are dismissed as commercially unviable, which underlies their geopolitical relevance as they are motivated by an interest to develop cable connections that bypass the United States (Hillman, 2021).

Where does Europe stand in this field? Two European firms are in the global top ten cable producers: The German company Norddeutsche Seekabelwerke and the French company Orange. European companies are thus active in the field and possess the required technology. Less clear is whether these businesses and the projects they develop are informed by a view on digital sovereignty.

The final aspect of connectivity infrastructure that we will consider here briefly is satellite infrastructure that provides addition connectivity especially for applications like navigation. In this field, the USA is the clear global leader. The most important new trend in this field is low Earth orbit (LEO) satellites that are cheaper and that fly at a lower altitude than traditional satellites. American firms like Space X, Boeing, and Northrop Grumman are leading the way in this new promising connectivity technology. At the same time, it is clear that China is increasing its share in the market by launching satellites for connectivity. Space is one of the focus points in the countries *Made in China 2025* strategy and features prominently in the last few Five-Year Plans. Moreover, during the Taiwan Straits crisis in the 1990s, China experienced that after the launch of its first rocket, the USA managed to stop its second and third rocket with the help of its satellite navigation capabilities, specifically its global positioning system (GPS). Since then, the country has been focused on becoming independent of GPS. In the case of military operations, countries that are dependent on GPS might be blinded by the USA, which has profound geopolitical implications.

European countries are less active in the field of putting up new satellites, although Airbus is also involved with producing LEO satellites. Moreover, the EU did create its own alternative to the American GPS, despite strong pressure from Washington. In 2016, the European Galileo system went live. China now also has its own satellite navigation system called BeiDou. Interestingly, this system was developed from cooperation with the European Galileo system (Grosse, 2014). Although the EU weakened its geopolitical dependence by developing its own satellite navigation system, it thus seems that strategic concerns in relation to China were neglected. China now exports BeiDou as part of its global digital silk road. In 2018, it opened a BeiDou center in Tunisia's capital Tunis. Apart from the USA, China, and the EU, it is relevant to mention that also Russia has built its own satellite navigation program called Glonass.

5 The Cloud Layer

Whereas the EU has a relatively strong position in the field of connectivity, particularly regarding telecommunications infrastructure, the situation is quite different in the next layer of the digital stack. This is what we can call the cloud layer and it is concerned with computation. Whereas computation used to happen at local servers and mainframes, a large part of global computation is nowadays done in the cloud. Specialized firms provide these services for companies and other organizations. Complex cloud services require a lot of computational infrastructure at vast data centers.

By far the largest players in the field of cloud computing are American firms. The global leader is Amazon with its Amazon Web Services (AWS). According to Statista, in 2021, Amazon had 33% of the global market. Second is Microsoft's Azure service with a 21% market share. Next, on a smaller scale is Google Cloud Platform with 10% market share. These three US firms thus hold almost two-third of the global market. The first non-US firm in the top list is China's Alibaba with about 6% market share, but this is mostly restricted to the Chinese market. Then other US companies like IBM and Salesforce follow. The Chinese company Tencent, the only other non-American firm in the list, has a 3% market share.

Apart from these large global players in many countries, there are national cloud services often provided by telecommunications companies like Deutsche Telecom and British Telecom. But on the global scale, there are no European firms. As a result, European businesses and governments are to a great extent dependent on the services of a few American firms.

Because of this dependency, the cloud layer exhibits the most dire condition when it comes to European digital sovereignty. The EU's response to this has been the Gaia-X project. It is a project that is still in evolution and its aim is not to create European alternative to the services of Amazon or Microsoft. Rather it is a project for a data sharing infrastructure with common European standards. It has specific components for data sharing in sectors like healthcare and finance (Tardieu, 2022). The Gaia-X infrastructure should make it possible for European companies to grow as providers of cloud services in the future. Gaia-X was spearheaded by Germany and France and was from its inception mired with controversy. There was criticism from other countries that the infrastructure favored French or German companies. Another point of criticism was that certain large US and Chinese firms were also allowed as participants in the Gaia-X project. In April 2021, the non-European companies Microsoft, Google, Amazon, Palantir, Huawei, and Alibaba became full members and since then there are concerns that the efforts of these companies in the group could jeopardize the creation of European businesses. Others have pointed to the fact that many European members like Orange and Thales have partnerships with large American cloud providers. A Microsoft spokesperson said that "Gaia-X is a project initiated by Europe for Europe but open to all" (Goujard & Cerulus, 2021). This brings us to the tension between industrial policy to strengthen European business and the EU's commitment to an open and free internal market. In the conclusion we will come back to this tension.

At the moment, it remains unclear how successful Gaia-X can become in challenging US dominance in the cloud layer in the future. Currently, there are no significant European players in this field. Regulation then seems to be the best avenue to shape the market for cloud services while they remain dominated by foreign businesses. We will also return to this point in the conclusion.

An interesting new development in the field is quantum computing. Whereas current computing relies on the two states of 0 and 1, quantum bits or "qubits," can be in several states, potentially increasing computing power by a great magnitude. It is a field of fundamental scientific research that still needs to be proven to be more effective than the current computing paradigm. Quantum research consists of fields like quantum sensing, quantum communication and quantum computing. The first two are on the cusp of proving their geopolitical significance. Quantum sensing provides the potential for detailed surveillance around the globe and quantum communication will be impossible to hack. The Chinese military has already set up a quantum communications satellite link and experts believe that in a few years, the Chinese military could go entirely "black" because of this (Kwon, 2020). What concerns us here in this layer of the digital stack is quantum computing. American companies like Google, IBM, and Microsoft are important parties investing in this technology. In China however, research institutes are making rapid strides. The research institute Harbin Engineering for instance is in the top five of filers of patents in quantum computing software. In 2018, China as a whole surpassed the USA and is currently responsible for more than half of the global quantum science patents (Allison, 2021). Europe also has leading institutions working on quantum computing like those at Delft University in the Netherlands.

Recently, a global conference on quantum computing was held in the USA that brought together mostly European countries. The idea was to create an alliance that from the outset develops quantum computing in line with democratic values. As such it excluded Chinese participation (Matthews, 2022).

6 The Intelligence Layer

Stacked on top of the computation layer is what can be called the intelligence layer. This involves the advanced artificial intelligence algorithms that operate on data that is stored in the cloud. It thus consists of algorithms and data and is less physical than the previous layers. At the same time, the intelligence layer is strongly connected with hardware from previous layers. Advanced deep learning algorithms for instance do not run on classical central processing units (CPU) chips, but require GPUs, graphic processing units. These were originally developed for the gaming industry and the American firm Nvidia is an important developer of such chips. Intel is also an important maker of chips for artificial intelligence. Moreover, there is a whole range of specialized chips like tensor processing units (TPUs) for advanced AI and large US technology companies like Microsoft and Google make these in-house. Moreover, the intelligence layer is strongly connected with the cloud layer, which is why the providers of cloud services like Amazon and Microsoft also provide AI services in combination with those cloud services.

Looking at the global landscape of the intelligence layer, two countries stand out: the USA and China. Indeed, AI researcher Kai-Fu Lee calls them the two “AI superpowers” in his recent book. Both have highly advanced capacities to develop algorithms and large data sets to train these algorithms on. According to Kai-Fu Lee however, China has an edge over the USA. His argument focuses on the availability of data to develop specific AI applications. According to Lee, AI has entered an application phase in which the emphasis will be less on fundamental science than on the availability of data for specific applications. China has an edge because of the size of the Chinese population and hence the high percentage of global data that is produced in the country. Moreover, due to less strict privacy regulation, much of this data is relatively easily accessible for AI developers. Whereas in other parts of the world medical records, data on public space, and biometric data are more heavily regulated, these data are explicitly mobilized to train artificial intelligence in China. In fields of AI like speech recognition and machine vision, China has leading companies like iFlyTek, SenseTime, and Hikvision. iFlyTek, a speech recognition company for instance has 700 million users, twice the amount of people that use Apple’s Siri. China’s large technology companies, Baidu, Alibaba, Tencent are integrated platforms that combine all kinds of data which also makes them leading in AI.

In terms of the fundamental science of algorithm development, China still lags the USA, but it is rapidly catching up. Chinese scientists and organizations are increasing their share in global citations and patents (Ding, 2018).

Jeffrey Ding also made an estimation of global AI capacities. In contrast with Lee, he argues that the USA has an edge over China. This is first of all based on the lead in fundamental science, but the largest advantage he discerns is the above-mentioned semiconductor hardware. China is still heavily reliant on advanced chips produced by American companies. This is also why the Trump administration in its trade war with China targeted the chip sales of companies like Intel to Chinese firms, as China cannot develop such chips yet. Ever since the trade war, China has doubled down on strengthening its own chips industry, a key industry in its new approach of “dual circulation” that aims to decrease Chinese dependence on foreign firms for its domestic economy, while simultaneously making Chinese firms more critical in the supply chains of other countries. However, the country still has a long way to go, which is why Ding believes the USA will keep the upper hand in the foreseeable future (Ding, 2018).

Where does the EU stand on the intelligence layer? In terms of fundamental science, it is world leading, on par with the USA and still ahead of China. In terms of specialized chips hardware, it is like China reliant on the USA, but there seems to be no reason for concern over access to that technology. The EU’s position in data is weaker than both China and the USA. This stems partly from more strict privacy regulation, but also because there are less comprehensive datasets and there is great diversity in datasets across the countries of the union. Furthermore, whereas both China and the USA have large companies that invest R&D into AI, the EU does not have such leading technology firms. There are specific European firms that have AI in the core of their operations like Spotify and Booking. But these are more specialized niche players and both are actually reliant on US capital. Europe has not developed large integrated Big Tech firms. The EU has developed a range of policies for AI, ranging from coordinating national AI strategies to the planned regulation of the AI Act. We will later come back to the role of regulation. The national and EU-wide AI strategies show increased momentum, but the scale of ambitions and investments remain far below those of the Chinese and American AI strategies.

7 The Applications Layer

Next in the digital stack is the services or applications layer. All the discussed layers are crucial to make the modern digital economy work. The previous layers are however removed from the sight of most consumers. The resources, chips, networks, and intelligence are not parts of digital technology that users deal with directly. This changes when we arrive at the applications layer. Here, all previous layers are combined and used to create specific digital services. This can involve diverse services like social media networks, chat apps, search engines, streaming services, navigation apps, ecommerce platforms, or healthcare applications. This layer thus concerns well-known applications and its leading companies are global household names.

It is clear that in this layer, American businesses, colloquially called “Big Tech,” are the dominant players. Google, Amazon, Microsoft, Apple, and Facebook in particular are leaders in different segments of the internet services economy and offer a wide range of different applications. Google for instance is dominant in search, Amazon in ecommerce, and Facebook in social networking. But at the same time a company like Google offers navigation, translation services, video streaming, and payments next to its search engine. Apart from these huge platforms, American companies are also powerful in more specific domains like Uber in ride-hailing services or Netflix in video streaming.

Behind American firms, but rapidly growing, are Chinese companies. They have less reach globally outside of China, but they are equally successful in providing all kinds of applications. More so than American businesses, big Chinese firms like Tencent, Alibaba, and Baidu provide entire ecosystems that integrate all kinds of services. Indeed, it has been argued that these firms operate in a more competitive landscape than in the west and thus are at least equally innovative (Lee, 2018). Moreover, there are certain Chinese applications that have over the last few years proven to be successful globally. Alibaba's ecommerce platform is an example of this, but also Bytedance, the owner of the popular app Tiktok that appeals to young citizens in Europe and the USA.

Where does the EU stand in this regard? On this layer the union has a very weak position. Certain niche businesses we mentioned above in the intelligence layer like Spotify and Booking, are European, but there are no integrated application platforms like those mentioned from the USA or China. This is often attributed to different factors like a lack of venture funding, less risk-taking behavior, a less innovative digital ecosystem and national barriers. Regarding funding for instance, it is notable that the Swedish company Spotify had to attract American venture capital and the Dutch firm Booking was acquired by the American company Priceline.

It is unclear whether Europe can build its own capacities on this application layer. The best way to currently get a grip on these prevalent foreign services seems to be through legislation. Several American firms have already received substantial fines from European courts. Moreover, legislation like the GDPR, DMA, and DSA target the practices of the companies in what we describe here as the applications layer. Later we will get back to these policies. Here, we can conclude that the EU has a very weak position in the applications layer.

8 Connected Device Layer

The last part of the Stack that we will discuss here adds a final layer to the just discussed application: a physical component or device. Not all digital products require such a physical component. Many services on smartphones or computers remain virtual, but an increasing number of services also operate in and on the physical environment. Examples are smart thermostats and refrigerators, connected lantern posts, cameras, bridges, machines, self-driving cars, drones, and autonomous weapons. This connection of the internet economy with the physical world stems from the trend of the growing "internet of things" (IoT). The number of internet of things devices is expected to almost triple from 9.7 billion in 2020 to 29 billion in 2030 (Statista, 2022a, b). Because this is an emerging development and large growth is expected over the coming decade, this layer of the stack is rapidly evolving. The outcome is unclear, but we can discern some patterns in the global landscape.

Also in this layer, American companies are strongly positioned. Tesla for instance is an advanced global player in developing self-driving cars. The company iRobot manufactures the smart vacuum cleaner Roomba, but also produces robots for military use. Boston Dynamics creates smart robots whose abilities are well advertised in online videos. Nest, a company acquired by Google, produces smart thermostats, Amazon sells Ring, a smart doorbell, and companies like Apple, Fitbit, and Garmin make all kinds of wearables. IBM provides services and products for smart cities.

China also is a very strong player in this layer, especially in the field of infrastructure. Sensors and chips have already been embedded throughout Chinese public space in efforts to develop smart cities, but also for surveillance of the population. The Chinese company DJI is the global leader in commercial drones and Hikvision provides smart cameras.

As mentioned, connected devices are very diverse and their number is rapidly increasing, so it is not clear whether there will be a small number of global leaders like in other layers of the stack. This is in particularly relevant for the future of Europe. Traditionally, European countries have been strong in making devices, machines and appliances that operate in the physical environment. Think of the German and French automotive industry and manufacturing companies like Siemens, Philips, and Alstom. The German industrial robot producer Kuka was bought by the Chinese company Midea Group in 2016, which triggered fears of the EU losing strategic knowhow in new technology. As these physical objects increasingly become part of the digital stack, the question is what type of companies will dominate that development. Perhaps the leaders of the digital economy can expand to the physical domain. Tesla's disruption of the automobile sector is an example of a Silicon Valley business entering a traditional manufacturing sector. In 2011, investor Marc Andriessen described this type of development by stating "software is eating the world." On the other hand, however, it is also possible that traditional manufacturing companies will succeed in digitalizing their business. In that case, the traditional strength of European economies could extend to the digital economy. In the automotive industry, traditional manufacturers are also active developing self-driving cars. In 2015 for instance, three German car makers, BMW, Audi, and Daimler, bought

Table 2 Leading countries and companies

The global digital technology stack	Leading countries with key companies
The resource layer	China (Jiangxi Ganfeng Lithium, China Minmetals Rare Earth)
The chips layer	China (SMIC, HiSilicon) USA (Intel), Japan, South Korea, Taiwan (TSMC), EU (ASML)
The network layer	China (Huawei), EU (Nokia, Ericsson, Airbus), USA (Space X, Boeing)
The cloud layer	USA (Amazon, Microsoft, Google)
The intelligence layer	USA (Google, Amazon, Facebook, Microsoft, Apple), China (Baidu, Alibaba, Tencent, iFlyTek, Hikvision, SenseTime)
The applications layer	USA (Google, Amazon, Facebook, Microsoft, Apple, Netflix, Uber), China (Baidu, Alibaba, Tencent, Bytedance)
The connected device layer	USA (Tesla, iRobot, Boston Dynamics, Google, Amazon, Apple), China (DJI, Hikvision), Europe (BMW, Siemens, Philips, Alstom)

Table 3 Selected relevant EU policies

The global digital technology stack	Selected relevant EU policies
The resource layer	ERMA
The chips layer	Chips Act
The network layer	COREnect
The cloud layer	Gaia-X, DMA, DSA
The intelligence layer	AI Act, AI strategy
The applications layer	GDPR, DMA, DSA
The connected device layer	Horizon Projects

Nokia's map-making business. Here, in this layer of the stack, the EU has great potential. In terms of policy, the European Commission supports IoT projects and other activities under Horizon Europe's: From Cloud to Edge to IoT, aimed at for instance boosting industrial collaboration through open platforms and standards.

The two tables below summarize some of the findings of our discussion of the layers of the digital stack. Table 2 lists the leading countries with several key companies on each layer. Table 3 lists the relevant EU policies on the different layers of the stack.

9 Conclusion: Policy for Digital Sovereignty

We started with the question of how to discern where the EU stands in terms of digitalization compared to other parts of the world. We noted how complex and diverse the digital landscape is. In this paper, we proposed a way to organize that complexity and get an understanding of the EU's position in the global digital landscape in a more granular way. Our suggestion has been to look at digitalization through the lens of a technology stack. That is a vertical architecture where different technology layers are stacked on top of each other. They often intertwine, but analytically they can be looked at separately and the different layers exhibit quite different patterns. By using the layers of the stack, we can distinguish parts of the global digital world in a coherent and logical way.

What are the implications of such an approach? First, we will draw four conclusions relating to EU digital policies. We will end with some general reflections and dilemmas relating to digital technology and European sovereignty.

Starting with policy, our approach first of all makes clear that there is no single metric for gauging the strength of a country or region in the field of digitalization. Focusing on any specific feature will necessarily leave out much of the digital world and narrow the scope of policymakers. If we want to determine the EU's position in the digital landscape, the stack offers a structured way to study it.

Secondly, we saw how the EU's position differs strongly across the stack. There are commentators who emphasize the digital strength of the EU, whereas many others paint a very bleak picture of its position. The truth is that it all depends on which layer of the stack we are looking at. In certain layers, the EU is positioned quite well. This is the case when we consider the network layer. The EU has proven capabilities in the field of telecommunications infrastructure, satellite technology and undersea internet cables. In other layers, the EU has a relatively good position, but its share in the global market has over the years been declining. This is the case with the resources, chips and the intelligence layer. The situation is different in the connected devices layer, which represents a relatively new and growing market, for which the EU could be quite well positioned. Finally, there are layers in which the EU performs particularly bad. This is the case with the cloud layer and the applications layer. Here, there are no European businesses in the list of largest global players. Depending on which layer you are considering, the position of the EU is quite different.

This brings us to a third implication. Depending on the EU's position, the policy response should be very different across the stack. In fields where European businesses in mature markets need to be strengthened, like the network layer, this requires an industrial policy focused on skills development, incentives to increase R&D and smart procurement policy. In fields where the EU has been losing ground over the years, like the chips, resources, and intelligence layer, those policies should be applied next to more targeted industrial policy that organizes and stimulates European business. We can think here of industry-wide collaboration for artificial intelligence labs, building consortia of European chipmakers and protecting the EU ecosystem from hostile takeovers. In the connected device layer, which is a relatively new and open market, policy should focus on a global level-playing field and stimulation of investments. Finally, in those fields where the EU is very weak, like the cloud and applications layer, a dual approach seems more adequate. On the one hand, more venturesome projects are merited. Those require strong EU-wide commitment and bundling of industrial capacities. At the same time, it is clear that the prospects of creating European global players in these fields are quite bad and only have a change of success if more joint effort and capital is mobilized. In the short and medium term, focusing on standards and regulation is the best way to at least shape and influence the behavior of leading foreign businesses. Table 4 below characterizes the EU's capacities across the stack and links those with the required policies.

Table 4 Capacities and required policies

The global digital technology stack	EU capacity	Required policies
The resource layer	Threat	Extensive and coordinated industrial policy
The chips layer	Threat	Extensive and coordinated industrial policy
The network layer	Strong	Focus on skill development, increased R&D, smart procurement
The cloud layer	Dire	Ambitious venture projects and strict regulation
The intelligence layer	Threat	Extensive and coordinated industrial policy
The applications layer	Dire	Ambitious venture projects and strict regulation
The connected device layer	Opportunity	Guarantee level-playing field and stimulate investments

With such a classification of layers of the stack, we can look at and compare the different policies for digitalization of the EU. In the layer where the EU is strongest, networks, there are relatively few policy initiatives. The EC's Horizon 2020 Research and Innovation Programme did invest in COREnect (European Core Technologies for future connectivity systems and components) consortium, aimed at developing a high-level roadmap for telecommunications infrastructure. Our analysis however, suggests that much more should be done to make sure this field does not go the way of the chips and intelligence layer, where the EU has steadily been losing ground. In both of those fields, there are more policy initiatives ranging from coordinating the AI-strategies of national governments to the EU Chips Act. The latter in particular seems to be moving ahead quickly with strong and clear ambitions for increasing the EU's share in the global market. In those layers where the situation is most dire, applications and cloud, more ambitious projects are required. The Gaia-X project seems to fit that bill for the cloud layer. As our analysis suggests however, it is one of the biggest challenges for European digital sovereignty and internal frictions over the program and the influence of non-European firms do not bode well for the future. Our analysis suggests much more serious effort is needed, as this is the Achilles heel of European digital sovereignty. In the short term however, regulating and standardizing a field where foreign businesses dominate seems to be the best route to influence the layers of cloud and applications.

A short elaboration on the role of standards and regulation is relevant here. There are of course many reasons for good standards and rules in the EU that have to do with normative issues of a legal and ethical nature. Think of privacy infringement, exclusion or unsafe products. Our focus in this paper is on the geopolitical position of the EU and it is with this lens that we consider standards and regulation.

Both are important ways to shape the technology layers of the stack and secondly, both are policy tools with which the EU can exert global influence. Regulation shapes the way the stack is built and the practices of the firms in the different layers. The GDPR for instance impacts the way data is collected, stored, and used in the cloud and the intelligence layer. The forthcoming AI Act specifically deals with applications of artificial intelligence and bans applications from the European market like social credit scores, something Chinese businesses in particular are developing. The DMA and DSA regulation will have a large effect on specifically the cloud and the applications layer, the two layers in which the EU's position is weakest.

With her acclaimed book *The Brussels Effect*, Anu Bradford has shown that if in a specific field five conditions are present (the EU is a large market, it has regulatory capacity, regulatory willingness and the products are inelastic and non-divisible), the EU has the ability to unilaterally regulate global markets de facto and de jure. Next to fields like anti-competition law and chemical regulation, Bradford shows how parts of the digital economy like data collection fulfill these five conditions. Regulation is thus a powerful tool at the EU's disposal. However, Bradford also shows that the EU at least until now has not used this tool to explicitly strengthen the position of European businesses. As such, regulation is most relevant to help make the digital technology stack more in line with European values and to ban certain foreign technologies that are in conflict with those values.

Standardization is also relevant in shaping the digital stack and also a powerful policy tool of the EU. Standardization impacts the stack by for instance specifying the technical requirements of telecommunications infrastructure, chips design, software, or applications like facial recognition. Standardization happens at the national, regional and global level. In many fields, global institutions like the International Organization for Standardization (ISO) and the International Telecommunication Union (ITU) set the standards for specific industries, but also less formal organizations like the Internet Engineering Task Force (IETF) and the Institute of Electrical and Electronic Engineers (IEEE).

What is notable here is that Europe has traditionally been strong in setting those global standards, because of a long process of harmonizing standards across the continent for railways, telecommunications, and industrial production that dates back to the nineteenth century (Kaiser & Schot, 2018). Setting standards is relevant from our perspective because countries that are successful at setting standards can give their own industry a first-mover advantage. Competitors face retooling costs and see their existing stock become obsolete while the standard-setters move ahead unimpeded (Immerwahr, 2020). Although the EU thus has a good position, it is notable that in the field of standards for digital technology an international geopolitical rivalry is taking place. China in particular has been successful at appointing officials to top positions at international standardization bodies (Smuha et al., 2021; Rühlig, 2020). Moreover, with its strategy *China Standards 2035*, China explicitly aims to be a global leader in setting standards for new technologies. Because of this "geopolitization" of standards, the EU should act to keep its traditional strength in the field.

Fourth and finally, our approach offers a mental map to organize the digital field and think about linkages across the different layers. In contrast with a traditional industry approach, this approach does not place sectors next to each other in different markets, but shows how the digital world has its own architecture, where the layers are connected with each other and interact. It can bring to light how certain actors are increasingly moving across the stack.

Both US and Chinese companies are increasingly making such vertical moves. Apple for instance makes connected devices (like Apple Watch), applications (the AppStore, iTunes), as well as its own chips. Google and Facebook have projects to build telecommunications networks. The large Chinese companies are even more pursuing a full-stack approach. Alibaba is leading in applications, but also provides cloud services and connected devices with its smart city-projects. Apart from making policy for the different layers separately, understanding the dynamics of such linkages can help European policymakers aiming to increase the strength of the union in the digital domain. The model provides a way to develop a more integrated approach to discuss the linkages between policies like the Chips Act, the DMA, and DSA regulation and the EU AI strategy and to think about further steps.

We end this paper with a general reflection on the connection between digital technology and European sovereignty and by pointing at three specifically "European dilemmas" that highlight balancing acts between concerns for sovereignty and values that are central to the European Union.

How important is digital technology to European sovereignty? To a great extent, this remains unclear. The EU policies are also very recent, and it is too early to tell how successful they are. Looking at the current war in Ukraine, it might seem that the relevance of digital technology to sovereignty has been overstated. The war is an example of the classical challenge to sovereignty by sheer military force, a domain in which the EU has been characterized as a worm. At the same time, also this war has distinctly digital dimensions. Disinformation, the blocking of foreign news websites, and the use of connected devices like drones are all relevant aspects of the Russian invasion of Ukraine. Furthermore, the fact that this invasion seems distinctly twentieth century does not mean that future conflicts will also be. The concerns we mentioned throughout this paper, like the use of telecommunications infrastructure for surveillance, the severing of internet cables, and the access to data in cloud services all show threats to sovereignty entailed by digital technology. This is supported by the importance attached to digital technology by politicians in China, Russia, India, as well as the EU. Moreover, we discussed Carl Schmitt's idea of the nomos of the earth and saw how digital technology also creates a new organization of space and that way can greatly impact global politics.

Our stack model is a way to analyze that new organization of space. It is not clear yet how the layers will evolve, whether different layers might be added in the future nor how the different layers will interact or whether they will be more integrated. We can however, already discern how the EU is positioned on the different layers and point to its largest strengths and weaknesses.

We end with three European dilemmas that all deal with how to balance concerns over sovereignty with values that are central to the EU.

The first deals with the high standards that Europe has with regard to the environment and the data of citizens. In the resource layer, we saw that Europe is highly dependent on China and mines throughout the developing world. Although many of these resources can also be found in Europe, the opening of new mines goes against the environmental and labor concerns of many European citizens. Not only does this situation strengthen the European dependence of foreign actors, but it actually has a worse effect on the environment, because European digital technology is sourced from mines that are developed with much lower standards. In the layers of the cloud and intelligence, we saw how high European standards with regard to privacy are an inhibiting factor in developing European businesses in those layers. Regulation like the GDPR and the data governance of Gaia-X put forth high European standards, but more attention should be paid to leveling the playing field between European and foreign businesses.

The second dilemma is connected with this and deals with regulation in general. It is often argued that strict regulation inhibits innovation. The laxer regulatory environment of the USA and China is thought to be more conducive of innovation. We can make several qualifications to this thesis. First of all, it is clear that to a certain extent regulation also stimulates innovation. The protection of private property and patent protection for instance have been very important stimulating innovation and investments in R&D. Furthermore, the EU itself argues that good regulation is actually good for innovation. Only products that are safe and in line with public values will eventually be trusted by consumers. Regarding the EU's high standards on ethical AI, the European Commission states: “Building on its reputation for safe and high-quality products, Europe’s ethical approach to ai strengthens citizens’ trust in the digital development and aims at building a competitive advantage for European ai companies.” (Wetenschappelijke Raad voor het Regeringsbeleid (WRR), 2021). The argument by the EU seems plausible with regards to products like automobiles and powerplants, but the question remains whether this also holds in the digital domain, where network effects and winner-takes-all effects might favor first movers over business that develop their products more prudently.

The final dilemma we came across deals with balancing the need to strengthen European business through industrial policy with its internal market policies guaranteeing an open and free market. Concerns about European sovereignty and geopolitical rivalry can clash with Europe’s commitment to free competition. In the domain of railways for instance, the governments of Germany and France were in favor of a merger between Siemens and Alstom to deal with the large Chinese competitor in the market. The European Commission, however, ruled that the merger would create too large a player on the European market. We also encountered this dilemma in the digital domain. In the cloud layer, we encountered it in the controversy surrounding the participation of American and Chinese businesses in the Gaia-X program. In the network layer, we encountered it in relation to strengthening the position of European telecommunication firms Nokia and Ericsson.

All three dilemmas require careful balancing of European values with concerns over sovereignty. The EU should focus on strengthening its digital sovereignty, but it must at the same time balance this with concerns for the values that underpin the union. That will require a complex balancing act. With our full-stack model, we hope to contribute to thinking about the EU’s position in the digital domain—which turns out to be a giant in some layers and a dwarf and a worm in others—and the implications this has for its digital policy.

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